PVCON 2024

PHOTOVOLTAIC CONFERENCE

4th International Conference on
Photovoltaic Science and Technologies

3-5 JULY 24

Middle East Technical University
Culture and Convention Center Ankara, Türkiye

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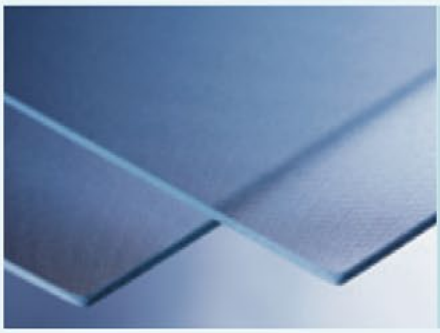
Product	Light Transmittance (D65) T_{D65}	PV Transmittance F_T, PV	Solar Transmittance (AM 1.5) T_{SOL}	SPF Class
Sandy 3.2 mm	91.8%	95.1%	91.2%	P1
Sandy 4 mm	91.9%	95%	91%	P1



Product	Light Transmittance (D65) T_{D65}	PV Transmittance F_T, PV	Solar Transmittance (AM 1.5) T_{SOL}	SPF Class
Prism 3.2 mm	91.8%	95.1%	91.2%	P1
Prism 4 mm	91.8%	95%	91.1%	P1

*Anti Reflective coating increases transmittance up to 2,5%, as a result Solar Transmittance up to 94% is reached for Anti Reflective coated products.

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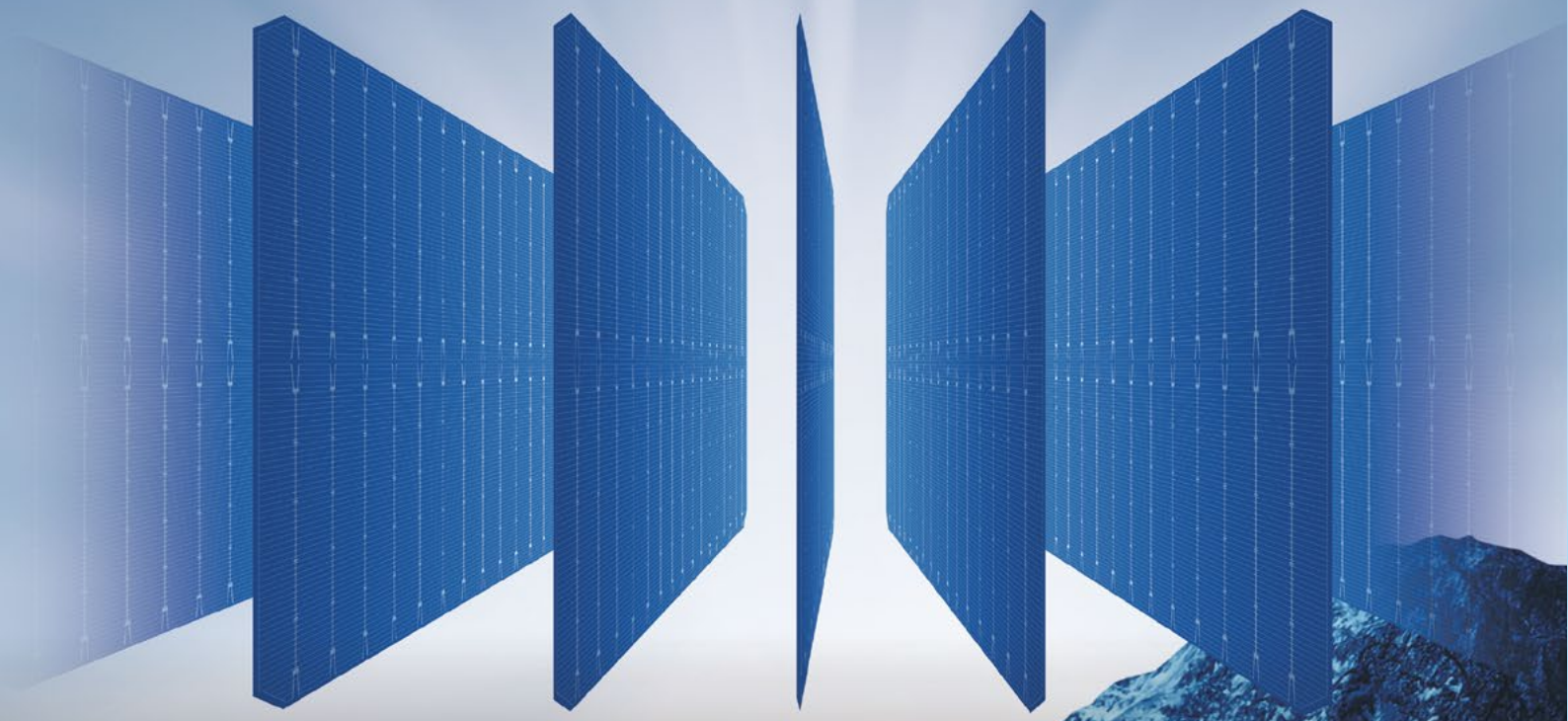

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Üretim Kapasitesi

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MEM Solar, MEM Grup şirketlerinin bir parçası olarak, Tier 1 standartlarında solar modül üretimi amacıyla 2023 yılında Kahramanmaraş, Türkiye'de kurulmuştur.

40 bin metrekare faaliyet alanında, 1 GW modül üretim kapasitesi ile faaliyetlerini sürdüren MEM Solar, dünyanın en büyük modül üreticileri ile yaptığı stratejik iş birlikleri ile dünya standartlarında güneş paneli üretimi yapmaktadır.

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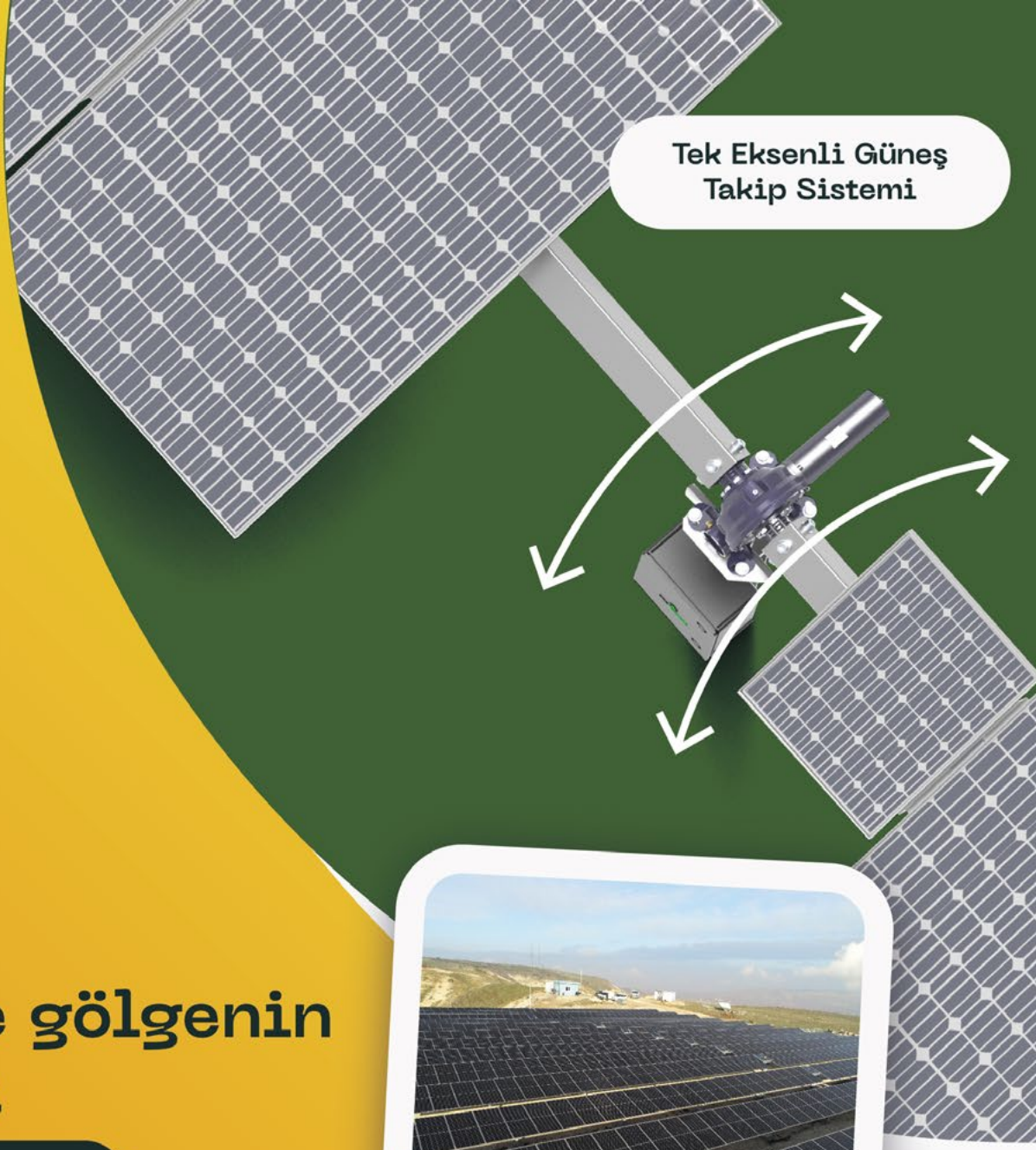

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SEVEN Sensor Solutions, a trademark of ArGesim Makina, is located in the Industrial Area of Corum in Türkiye. SEVEN specializes in producing, installing, and commissioning high-quality meteorological sensors for monitoring solar PV plants. Operating from a 1900 m² closed-area factory in the Corum Organized Industrial Zone, a team of young and dynamic engineers is dedicated to meeting the sensor needs of both Türkiye and countries around the world.

Research and development activities are conducted at the office in Corum Technopark. Through intensive R&D efforts, the intellectual property rights of innovative products are secured. As a subsidiary of Argesim Makina, which exports to over 100 countries, SEVEN is continually expanding its global reach.

Pioneering in Türkiye, SEVEN Sensor Solutions produces sensors for Weather Stations specifically designed for solar power plants. These Weather Stations are essential for calculating the performance ratio (PR) of PV plants and are compatible with dataloggers from many renowned inverter manufacturers.

Committed to nationalizing many more sensor technologies, SEVEN Sensor Solutions strives to close the gap in sensor technologies within Türkiye first and globally second. As the transition from an information society to a smart society progresses, the company is dedicated to innovating and leading the way.

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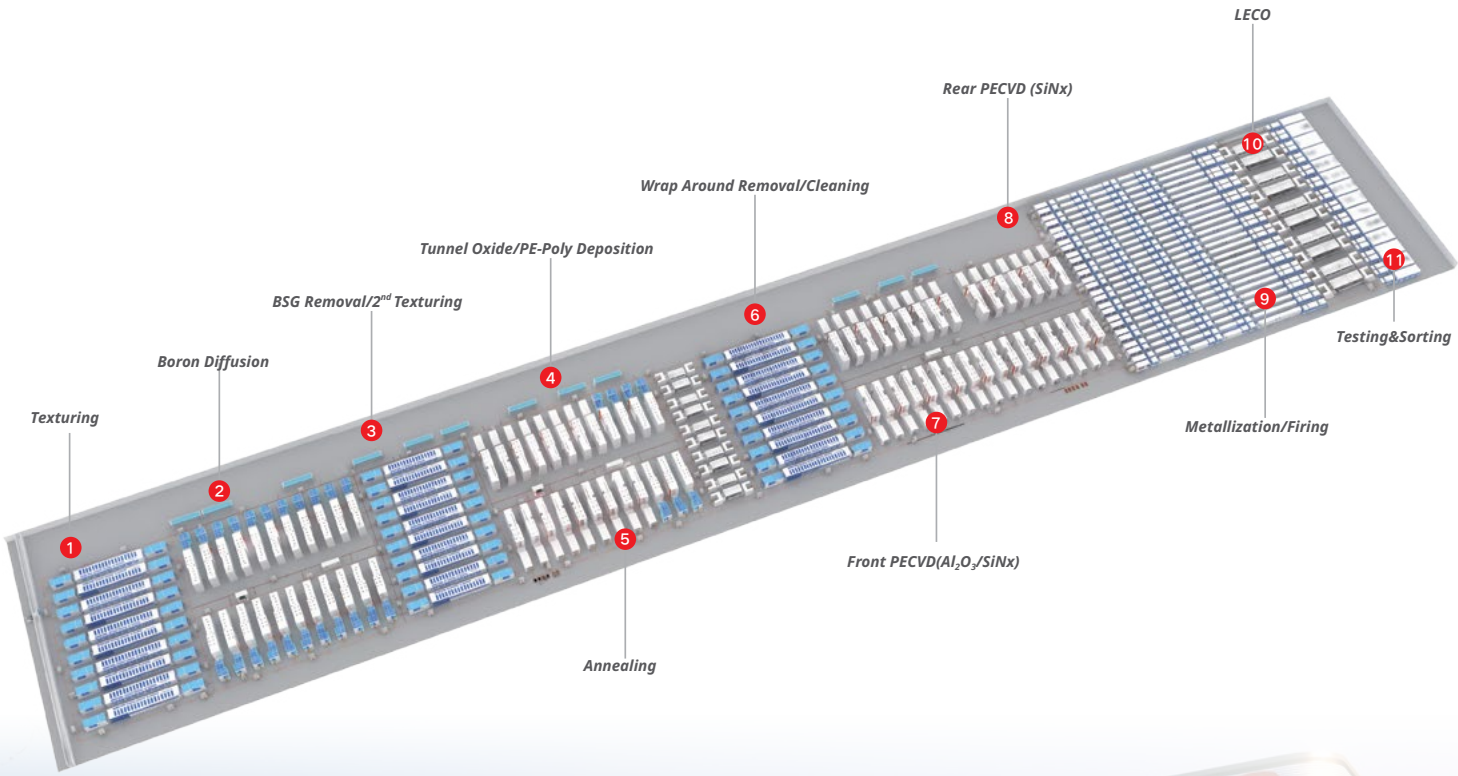

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Wuxi Songyu Technology Co., Ltd., established on December 20, 2017, is a leading manufacturer of photovoltaic and semiconductor process equipment. Its business covers the fields of photovoltaic cell manufacturing, semiconductor integrated circuits, IGBT, MEMS, and other new energy, new material, vacuum electronics, and magnetic material.Songyu is High-tech Enterprise in Jiangsu Province, Specialized Innovative Small and Medium-sized Enterprise in Jiangsu Province. It has passed ISO9001 quality management system certification and ISO14001 environmental management system certification, and is committed to building a well-known brand of high-end photovoltaic cell equipment.

Songyu currently has over 1200 employees, and its R&D team has rich work experience and practical execution ability. It has accumulated nearly 100 intellectual property rights. Among them, the key project of "research&development and industrialization of ALD atomic layer deposition equipment" has won the second prize in the final of the Growth Enterprise Group of the 2021 China Wuxi "the Taihu Lake Cup" International Elite Innovation and Entrepreneurship Competition.

Songyu's main PV product include atomic layer deposition equipment(ALD), high-temperature boron diffusion furnace, oxidation furnace, annealing furnace, LPCVD, PECVD and other equipment; Semiconductor core product include: vertical/horizontal diffusion furnace, oxidation furnaces, alloy furnace, annealing furnace, LPCVD, gas furnace, carbon nanotube synthesis furnace, and other vacuum thermal functional furnaces. At present, Songyu has established good cooperation with large photovoltaics new energy enterprises such as Jinko, Longi, CSI,Risen, DAS Solar,TW Solar,JA Solar,Solarspace,JTPV,Yingfa,DMEGC,Sany Silicon,Hoshine Silicon,Sunrev,etc.

PVCON 2024

PHOTOVOLTAIC CONFERENCE

Welcome to "PVCON 2024: 4th International Conference on Photovoltaic Science and Technologies", a synergy of academia and industry in the field of photovoltaics. As the Conference Chairs, it is our pleasure to extend a warm welcome to all participants, distinguished guests, and contributors.

Photovoltaics (PV) bears an essential significance in the global interest of sustainable energy solutions. As a continuous, free, and environmentally friendly source, progress in PV plays a key role in moderating climate change, decreasing reliance on fossil fuels, and developing a reliable and environmentally conscious energy landscape.

PVCON2024 provides participants with a unique opportunity to get involved in the latest advancements, emerging trends, and innovations within the solar energy sector. Engaging with experts, researchers, and industry leaders will give valuable insights into cutting-edge technologies, the latest breakthroughs in academic research, and market dynamics, empowering them to contribute meaningfully to the growth and maturation of the PV industry. Additionally, PVCON2024 serves as a dynamic platform for networking, collaboration, and knowledge exchange, encouraging a community-driven approach towards accelerating the global transition to sustainable energy systems providing an opportunity to benefit from a comprehensive understanding of the challenges and opportunities in the field of photovoltaics.

The scope of the conference extends beyond the traditional boundaries, embracing the importance of industry-academia collaborations. We recognize the pivotal role that such partnerships play in accelerating the practical application of groundbreaking research. As such, we have dedicated sessions to explore and foster collaborations that bridge the gap between theory and practice. PVCON2024 will explore the critical theme of knowledge exchange between university and industry. Enabling a smooth transfer of knowledge and expertise is crucial in this period of exceptional technological advancement. Our sessions aim to catalyze discussions on effective strategies and best practices in translating academic discoveries into real-world applications.

We extend our sincere appreciation to all academic researchers, industry professionals, students, and the organizing and scientific committee for their collaborative efforts in shaping this event. Your commitment to progressing the field of photovoltaics and driving innovation will contribute to the wide spread, dissemination and sharing of valuable research and expertise exchange via this conference.

Thank you for being part of PVCON2024. Your presence enriches and strengthens the dialogue and helps us to move towards a brighter and sustainable tomorrow all together.

Prof. Dr. Serap GÜNEŞ
Conference Chair
Researcher (ODTÜ-GÜNAM)
Faculty Member (Yildiz Technical University)

Prof. Dr. Raşit TURAN
Conference Co-chair
Chair of the Board (ODTÜ-GÜNAM)
Faculty Member (Middle East Technical Univ.)

Conference Program

Day 1 (July 3)

08.30	REGISTRATION	
	METU-CCC / Hall A	**METU-CCC / Hall B**
09.00	**OPENING SESSION** **CURRENT PANORAMA OF SOLAR ENERGY UTILIZATION IN THE WORLD AND TÜRKIYE & INNOVATIVE TRENDS IN PHOTOVOLTAIC CELL TECHNOLOGIE** (Session Chair: Serap GÜNES (ODTÜ-GÜNAM & Yildiz Technical University, Türkiye))	
09.00-09.10	**Welcome Speeches** Serap GÜNES (Chair) (Yildiz Technical University, Türkiye) Rasit TURAN (Co-chair) (METU & ODTÜ-GÜNAM, Türkiye)	
09.10-09.40	**Opening Speech** A. Bugrahan KARAVELİ (Chairman of the Executive Board and President of TENMAK, Türkiye) **The Role of Solar in Energy Transition of Türkiye**	
09.40-10.10	**Plenary Speaker** Michael GRAETZEL (EPFL, Switzerland) **Molecular Photovoltaics and The Stunning Rise of Perovskite Solar Cells**	
10.10-10.40	**Plenary Speaker** Rolf BRENDEL (ISFH, Germany) **Contact Selectivity Guiding the ISFH-Roadmap for Crystalline Si Photovoltaics**	
10.40-11-00	BREAK	
11.00	**SESSION - 2.1** **RECENT DEVELOPMENTS IN TOPCon CELL TECHNOLOGY** (Session Chair: Hisham NASSER (ODTÜ-GÜNAM, Türkiye))	**SESSION - 2.2** **SOCIOECONOMIC ASPECTS OF SOLAR ENERGY UTILIZATION AND APPLICATIONS - I** (Session Chairs: İpek GÜRSEL DINO (ODTÜ-GÜNAM & METU, Türkiye) Yelda ERDEN TOPAL (ODTÜ-GÜNAM & METU, Türkiye))
11.00-11.15	**Invited Speaker** Marc HOFMANN (Fraunhofer ISE, Germany) **TOPCon Solar Cell Technology: Status and Perspective at Fraunhofer ISE - I**	Elif Dilek YILMAZ (METU, Türkiye) **How Does License-Exempt Solar Excess Electricity Generation Affect Türkiye's Economic Growth?**
11.15-11.30	**Invited Speaker** Marc HOFMANN (Fraunhofer ISE, Germany) **TOPCon Solar Cell Technology: Status and Perspective at Fraunhofer ISE - II**	İbrahim TOKGÖZ (Marmara University, Türkiye) **Optimizing Photovoltaic Lifecycle Management: A Comparative Study of Business Models**
11.30-11.45	Berkay UYGUN (ODTÜ-GÜNAM, Türkiye) **Local p+ Poly-Si Passivating Contacts Realized by Direct FlexTrail Printing of Boron Ink and Selective Alkaline Etching for High Efficiency TOPCon Based Solar Cells**	Ömer Faruk TUNÇBİLEK (TENMAK / Clean Enerrgy Research Institute, Ankara, Türkiye) **Socioeconomic Aspects of Solar PV Applications: Example of Ankara Province Ayaş District**
11.45-12.00	Gökhan ALTINER (ODTÜ-GÜNAM, Türkiye) **Development Of Hydrogenated Aluminum-Doped Zinc Oxide Recombination Junction Enabling Superior Passivation Of Bottom Cell With Front TOPCon For Silicon/Perovskite Tandem Devices: Towards Indium-Free Recombination Junction**	Pınar DERIN GÜRE (METU, Türkiye) **Semi-Transparent Photovoltaic Windows in Türkiye: Exploring Stakeholder Perspectives on Opportunities and Barriers**
12.00-12.15	Damian Brunner (RENA Technologies, Germany) **Comprehensive Analysis and Process Optimization for Wet-Chemical Alkaline Edge Isolation for Industrial TOPCon Solar Cells**	Samed PEKDEMIR (Uludağ Elektrik Dağıtım, Türkiye) **Empowering PV-Integrated Energy Communities through Digitalization: Insights from the Masterpiece Project**
12.15-12.30	Eni MUKA (ODTÜ-GÜNAM, Türkiye) **Simulation of TOPerc Bottom Structures for Perovskite/Silicon Tandem Solar Cells using QUOKKA3**	Mehrdad Hajian ZEIDY (Eastern Mediterranean University, Turkish Republic of Northern Cyprus) **Evaluation of the Quality Components of the Urban Environment and their Influence on Citizen's Satisfaction by Use of Photovoltaic Systems for the Location of Gazimağusa / North Cyprus**
12.30-12.45		Besim Can ZIRH (METU, Türkiye) **A Case Study in Turkey (Akhisar): Opportunities and Constraints in the Transition to Solar Energy Transition**

Day 1 (July 3)

12.45-14-00	LUNCH BREAK	
	METU-CCC / Hall A	**METU-CCC / Hall B**
14.00	**SESSION - 3.1** **RECENT DEVELOPMENTS IN HETEROJUNCTION CELL TECHNOLOGY** (Session Chair: Marc HOFMANN (Fraunhofer ISE, Germany))	**SESSION - 3.2** **"SOLARHUB" SPECIAL SESSION:** **SHOWCASE OF FIVE ECOSYSTEMS** (Session Chair: Hande ERYILMAZ)
14.00-14.30	**Invited Speaker** Kaining DING (Forschungszentrum Jülich, Germany) **What is New in Silicon Heterojunction Solar Technology 2023/2024?**	
14.30-15.00	**Invited Speaker** Lang ZHOU (Nanchang University, PRC) **Potentials of HWCVD as a Lower Cost Alternative for HJT Cell Production**	
15.00-15.15	Büsra ALTINSOY (ODTÜ-GÜNAM, Türkiye) **Intrinsic Amorphous Silicon Bilayers for Surface Passivation in Silicon Heterojunction Solar Cells**	
15.15-15.30	Furkan GÜÇLÜER (Niğde Ömer Halisdemir University, Türkiye) **Investigating the Impact of MZO-IZO Bilayer Transparent Conductive Films on the Performance of c-Si Heterojunction Solar Cells**	
15.30 - 15.45	BREAK	
15.45	**SESSION - 4.1** **LARGE-SCALE PV MANUFACTURING** (Session Chairs: Raymond de MUNNIK (Enertics Pte. Ltd., Singapore), Kaining DING (Forschungszentrum Jülich, Germany))	**SESSION - 4.2** **SOCIOECONOMIC ASPECTS OF SOLAR ENERGY UTILIZATION AND APPLICATIONS - II** (Session Chairs: Erkan ERDİL (METU, Türkiye), Pınar DERIN GÜRE (ODTÜ-GÜNAM & METU, Türkiye))
15.45-16.00	**Invited Speaker** Vincent LAU (Jolywood, PRC) **Study on Efficiency Improvement Technology of Industrial Manufacturing for JolywoodTOPCon Solar Cell**	**Invited Speaker** Ramazan SARI (Technical University of Denmark, Denmark) **The Social Acceptability of New Technologies in Shaping Energy Policy - I**
16.00-16.15	**Invited Speaker** Jichun YE (Ningbo Institute of Material Technology and Engineering, PRC) **Recent Progress of TOPCon Solar Cell Technology in China**	**Invited Speaker** Ramazan SARI (Technical University of Denmark, Denmark) **The Social Acceptability of New Technologies in Shaping Energy Policy - II**
16.15-16.30	Xinrui AN (JTPV, PRC) **High Efficiency Cell Technology of JTPV**	Furkan TÜZÜN (Social Sciences University of Ankara, Türkiye) **Drivers and Challenges of Solar Photovoltaics Adoption by Turkish Manufacturers**
16.30-16.45	Dilara SUBASI (Fraunhofer ISE, Germany) **Improved Solar Cell Factory Design with increasing Equipment Throughput**	Esin YAZICI (METU, Türkiye) **Socio-economic Impact Assessment of Solar PV Technology in Türkiye**
16.45-17.00	Homer CHEN (S.C New Energy Technology Corporation, PRC) **Key Points of Advanced Turnkey High-Efficiency Mass Production Line of Different Solar Cells**	Tayfun HIZ (ODTÜ-GÜNAM, Türkiye) **Managing End-of-Life Photovoltaic Panels: A Comparative Analysis of National Policies and Regulations**
17.00-17.15	Josua STUCKELBERGER (LAPLACE Renewable Energy Technology Co. Ltd., PRC) **Advances in Turn-key Solutions for High-Efficiency TOPCon Cells**	Yelda ERDEN TOPAL (METU, Türkiye) **The Evolution of Turkish Solar Energy Research Network in Three Periods**
17.15-17.30	Yuelong HUANG (Wuxi Songyu Technology Co. Ltd., PRC) **High Efficiency Solar Cell Turnkey Line Solution**	Ezgi IPEK (Industrial Development Bank of Türkiye, Türkiye) **Unlocking Türkiye's Solar Potential: A Computable General Equilibrium Analysis**
17.30 - 19.30	WELCOME RECEPTION & POSTER OPENING SESSION	

Day 2 (July 4)

	METU-CCC / Hall A	METU-CCC / Hall B
08.45	**SESSION - 5.1** **EMERGING PHOTOVOLTAICS - I** (Session Chair: Figen VARLIOGLU YAYLALI (ODTÜ-GÜNAM & METU, Türkiye))	**SESSION - 5.2** **PV MODULE TECHNOLOGIES AND PERFORMANCE ANALYSIS - I** (Session Chair: Duygu KUZYAKA (ODTÜ-GÜNAM, Türkiye))
08.45-09.00	**Invited Speaker** Seçkin AKIN (Necmettin Erbakan University, Türkiye) **Breaking Barriers with Cutting-Edge Strategies: Advancing Efficiency and Stability in Perovskite Photovoltaics - I**	Aksel Kaan ÖZ (Fraunhofer ISE, Germany) **Pushing the Boundaries: Optimizing the Lamination Processes for Photovoltaic Modules in New Application Areas**
09.00-09.15	**Invited Speaker** Seçkin AKIN (Necmettin Erbakan University, Türkiye) **Breaking Barriers with Cutting-Edge Strategies: Advancing Efficiency and Stability in Perovskite Photovoltaics - II**	Refika BUDAKOGLU (Sisecam, Türkiye) **Environmentally Sustainable Methodologies for the Extraction of Ethylene Vinyl Acetate (EVA) from PV Panels Dismantled by Hot-Knife Technic**
09.15-09.30	**Invited Speaker** Henk BOLINK (University of Valencia, Spain) **Vacuum Deposited Perovskites For Single Junction And Tandem Solar Cells**	Meryem Ezgi KARAHALLI (ODTÜ-GÜNAM, Türkiye) **Analyzing the Changes in Electrically Conductive Adhesives During the Curing Process for Shingled Solar Cells**
09.30-09.45	Mustafa YASA (ODTÜ-GÜNAM, Türkiye) **Novel Patterning Approach for Large-Area Translucent Perovskite Solar Cells for Indoor Applications**	Abdulkerim GÖK (Gebze Technical University, Türkiye) **Toward Sustainable PV Systems: Evaluating Alternative Encapsulant Materials for Enhanced Reliability**
09.45-10.00	**BREAK**	
10.00	**SESSION - 6 (PART - I)** **SPECIAL SESSION: HORIZON EUROPE PROJECTS ON PEROVSKITE-BASED SINGLE, TANDEM AND TRIPLE JUNCTION PV** (Session Chairs: Selçuk YERCI (ODTÜ-GÜNAM & METU, Türkiye) Görkem GÜNBAS (ODTÜ-GÜNAM & METU, Türkiye))	
10.00-10.15	**Invited Speaker** Perrine CARROY (CEA-INES, France) **HE Project NEXUS: Overview of the Results Achieved during the 1st Period**	
10.15-10.30	**Invited Speaker** Hisham NASSER (ODTÜ-GÜNAM, Türkiye) **NEXUS Hybrid PERC/TOPCon Bottom Cell Enabling Ag-Free and In-Free Design for Perovskite-Si Tandem Solar Cells**	
10.30-10.45	**Invited Speaker** Jons BOLDING (SALD B.V., Netherlands) **Industrially Applicable Spatial Atomic Layer Deposition of Metal Oxides for Perovskite and Tandem Solar Cells**	
10.45-11.00	**Invited Speaker** Jonas SCHÖN (University of Freiburg, Germany) **Simulation-Based Structure Optimization of Monolithic Perovskite/Perovskite/Silicon Triple Junction Solar Cells**	
11.00-11.15	**Invited Speaker** Christian Wolff (EPFL, Switzerland) **Perovskite/Perovskite/Si Triple Junctions by Solution Processing**	
11.15-11.30	**Invited Speaker** Henk BOLINK (University of Valencia, Spain) **Perovskite solar cells with enhanced stability and applicability (VALHALLA)**	
11.30-11.45	**BREAK**	

Day 2 (July 4)

	METU-CCC / Hall A	METU-CCC / Hall B
11.45	**SESSION - 6 (PART - II)** **SPECIAL SESSION: HORIZON EUROPE PROJECTS ON PEROVSKITE-BASED SINGLE, TANDEM AND TRIPLE JUNCTION PV** (Session Chairs: Selçuk YERCI (ODTÜ-GÜNAM & METU, Türkiye) Görkem GÜNBAS (ODTÜ-GÜNAM & METU, Türkiye))	
11.45-12.15	**Q/A & Discussion** All the Invited Speakers & Session Participants	
12.15-13.15	**LUNCH BREAK**	
13.15	**SESSION - 7.1** **AGRIVOLTAICS AND METEOROLOGICAL MONITORING FOR PV SYSTEM DESIGN AND APPLICATIONS** (Session Chair: Emre DEMIREZEN (ODTÜ-GÜNAM & METU, Türkiye))	**SESSION - 7.2** **PV MODULE TECHNOLOGIES AND PERFORMANCE ANALYSIS - II & POWER ELECTRONICS FOR PV APPLICATIONS - I** (Session Chair: Aksel Kaan ÖZ (Fraunhofer ISE, Germany))
13.15-13.30	Bilge SENTÜRK (ODTÜ-GÜNAM, Türkiye) **The Impact of Photovoltaic Panels on the Environment and Yield Parameters in an Open Field Agrivoltaic System: A Case Study in Ayaş, Ankara**	Rıdvan ÇELIK (ODTÜ-GÜNAM, Türkiye) **Glare Effect Assessment for the Highway, Circular Road Junction, and Airport in the Mardin Region**
13.30-13.45	Ilhan Bora SERIN (Seven Sensor Solutions, Türkiye) **Meteorological Sensors Selection for PV Plants**	Zeynep CANTÜRK (ODTÜ-GÜNAM, Türkiye) **Comparison of Panel Glass Surface Texturing for Anti-reflective and Anti-soiling Properties by Three Methods: RIE, MACE and LIPSS**
13.45-14.00	Harun GÜMÜS (Ege University, Türkiye) **Multidimensional Assessment of Agrivoltaic System Potential in Turkey**	Batuhan Mert LAÇINKAYA (Robsys Robotic Systems, Türkiye) **Techniques and Trends in Photovoltaic Panel Cleaning for Sustainable Solar Energy**
14.00-14.15	Ömer YALÇIN (ODTÜ-GÜNAM, Türkiye) **Agrivoltaic System Design for Sugar Beets and Wheat in Central Anatolia**	Özgür Arda KÜÇÜKASLAN (ODTÜ-GÜNAM, Türkiye) **A Situational Awareness and Decision Support Tool for Power Systems with High rPV Penetration**
14.15-14.30	**BREAK**	
14.30	**SESSION - 8** **SPECIAL SESSION:** **PERC'ÜN VARISI KIM?** **(IF PERC IS DYING, WHO IS THE HEIR?)** **(in Turkish)** (Session Chair: Rasit TURAN (ODTÜ-GÜNAM & METU, Türkiye))	
14.30-14.45	**Invited Speaker** Tarık SARVAN (CW Enerji, Türkiye)	
14.45-15.00	**Invited Speaker** Halil DEMİRDAG (Smart Solar, Türkiye)	
15.00-15.15	**Invited Speaker** Dr. Fırat ES (MEM Solar, Türkiye)	
15.15-15.30	**Invited Speaker** Assoc. Prof. Dr. Selçuk YERCI (METU & ODTÜ-GÜNAM, Türkiye)	
15.30-15.45	**Q/A & Discussion** All the Invited Speakers & Session Participants	
15.45-16.00	**BREAK**	

Day 2 (July 4)

	METU-CCC / Hall A	METU-CCC / Hall B
16.00	**SESSION - 9** **SPECIAL SESSION:** **TARIMDA FOTOVOLTAIK SISTEM TASARIMI VE UYGULAMALARI** **(AGRIVOLTAIC SYSTEM DESIGN AND APPLICATIONS)** **(in Turkish)** (Session Chair: Bahadır TURHAN (Solar3GW, Türkiye))	
16.00-16.15	**Invited Speaker** Dr. Murat ERÖZ (EnerjiSA Üretim, Türkiye)	
16.15-16.30	**Invited Speaker** Yasir HERDEM (Gumbel Group, Türkiye)	
16.30-16.45	**Invited Speaker** Assoc. Prof. Dr. Talat ÖZDEN (ODTÜ-GÜNAM & Gümüshane University, Türkiye)	
16.30-16.45	**Invited Speaker** Dr. Ramona DAVOUDNEZHAD (Kalyon PV, Türkiye)	
16.45-17.00	**Q/A & Discussion** All the Invited Speakers & Session Participants	
19.30	**GALA DINNER**	

Day 3 (July 5)

	METU-CCC / Hall A	METU-CCC / Hall B
08.45	**SESSION - 10.1** **ADVANCED PRODUCTION METHODS FOR SILICON SOLAR CELLS** (Session Chair: Veysel ÜNSÜR (ODTÜ-GÜNAM & Necmettin Erbakan University, Türkiye))	**SESSION - 10.2 BUILDING-INTEGRATED PHOTOVOLTAIC TECHNIQUES AND APPLICATIONS** (Session Chairs: Bülent G. AKINOGLU (ODTÜ-GÜNAM & METU, Türkiye) Parisa SHARIF (ODTÜ-GÜNAM & Türkiye))
08.45-09.00		**Invited Speaker** Sascha SADEWASSER (INL - International Iberian Nanotechnology Laboratory, Portugal) **Micro-Structured Semi-Transparent Cu(In,Ga)Se2 Solar Cells - I**
09.00-09.15		**Invited Speaker** Sascha SADEWASSER (INL - International Iberian Nanotechnology Laboratory, Portugal) **Micro-Structured Semi-Transparent Cu(In,Ga)Se2 Solar Cells - II**
09.15-09.30	Hüseyin Utkucan KAYACI (Nanovatif Materials Technologies, Türkiye) **Water-Based Electrically Conductive Adhesive for PERC-Type Shingled Solar Cells**	Kerem Çagatay IÇLI (Sisecam, Türkiye) **Atmospheric and Online Deposition of Dichroic Filters on Flat Glass by a Pyrolytic Process for BIPV Applications**
09.30-09.45	Nabil KHELIFATI (CRTSE, Algeria) **Effect Of The Morphology Of Black Silicon Passivated By Alumina On The Performance Of Interdigitated Back Contact Solar Cells**	Giray KARTOPU (Northumbria University, UK) **Laser Patterned Thin Film Solar Cells for BIPV Applications**
09.45-10.00	Muhammad USMAN (National Centre for Physics, Pakistan) **Ion Implantation for High-Efficiency Solar Cells**	Parisa SHARIF (ODTÜ-GÜNAM, Türkiye) **Development of a Photonic Glass-Based Colored Photovoltaic Panel for BIPV Applications Utulizing Metal Oxide Nanoparticles**
10.00-10.15	Mustafa BÜYÜKGÜZEL (ODTÜ-GÜNAM, Türkiye) **Formation of Selective Emitter Through Double Diffusion Approach**	Ahadollah AZAMI (Cukurova University, Türkiye) **Building Shape Impact on BIPV Performance with Different PV Module Technologies**
10.15-10.30		Amirhossein KARIMIZADEH (Eastern Mediterranean University, Turkish Republic of Northern Cyprus) **A Cost-Benefit Analysis of Photovoltaic Building Facades: A Case Study in Northern Cyprus**
10.30-10.45	BREAK	
10.45	**SESSION - 11.1** **EMERGING PHOTOVOLTAICS - II** (Session Chairs: Seçkin AKIN (Necmettin Erbakan University, Türkiye), Mustafa YASA (ODTÜ-GÜNAM, Türkiye))	**SESSION - 11.2 PV-INTEGRATED HYBRID SYSTEM DESIGN AND TECHNOLOGIES & METEOROLOGY AND SOLAR ENERGY RESOURCE ASSESSMENT - I** (Session Chairs: Onur TAYLAN (ODTÜ-GÜNAM, Türkiye), André AUGUSTO (Dalarna University, Sweden))
10.45-11.00		**Invited Speaker** Canan KANDILLI (Uşak University, Türkiye) **Potential of the Photovoltaic Thermal Systems for Green Transformation in Industry and Zero Energy Building Applications - I**
11.00-11.15		**Invited Speaker** Canan KANDILLI (Uşak University, Türkiye) **Potential of the Photovoltaic Thermal Systems for Green Transformation in Industry and Zero Energy Building Applications - II**
11.15-11.30	Konstantin TSOI (ODTÜ-GÜNAM, Türkiye) **Bayesian Optimization with Experience for Fast Development of Monolithic Tandem Solar Cells: Simulation Case Study**	Nikolaos I. TSONGIDIS (CERTH, Greece) **Sustainable Conversion of Agri-food Waste using HTL Reactor Integrated with Concentrated Solar Energy, Thermal Energy Storage and Solar PV**
11.30-11.45	Zeynep GÖZÜKARA KARABAG (ODTÜ-GÜNAM, Türkiye) **Strong Impact of Substituent Position in PEAI-Founded Organic Cations to Enable the Efficient and Durable 3D/2D-Constructed Perovskite Solar Cells**	Emre ILTER (Yildiz Technical University, Türkiye) **Towards Large-Area Luminescent Solar Concentrators: CsPbBr3 Quantum Dot-Embedded Glass Nanocomposite Integration Strategies**
11.45-12.00	Enrique H. BALAGUERA (Universidad Rey Juan Carlos, Spain) **Stabilization Of Current-Voltage Curves In Perovskite Solar Cells**	Neslihan ÇOLAK GÜNES (Ege University, Türkiye) **Enhancing Heat Pump Efficiency through Integrated Photovoltaic Thermal Systems**
12.00-12.15	Sevdiye Basak TURGUT (Ege University, Türkiye) **Utilizing a Carbazole-Incorporated Regioisomeric Synthesis Strategy to Design Hole Transporting Materials for Perovskite Solar Cells**	Ilkim CANLI (ODTÜ-GÜNAM, Türkiye) **Rooftop Segmentation Approach with Unclassified Data for PV Potential Estimation**
12.15-12.30	Cihangir KAHVECI (Yildiz Technical University, Türkiye) **Investigation Performance and Stability Effect of Natural Antioxidants on the Perovskite Solar Cells**	Hasan TENLI (Sakarya University, Türkiye) **Maximizing Solar Energy Harvesting Efficiency: AI-Based Prediction for PV Panel Systems Positioning**

Day 3 (July 5)

	METU-CCC / Hall A	METU-CCC / Hall B
12.30-14.00	LUNCH BREAK	
14.00	**SESSION - 12.1** **EMERGING PHOTOVOLTAICS - III & POWER ELECTRONICS FOR PV APPLICATIONS - II** (Session Chairs: Gönül HIZALAN ÖZSOY (ODTÜ-GÜNAM, Türkiye), Aliekber KARABAG (ODTÜ-GÜNAM, Türkiye))	**SESSION - 12.2 PV-INTEGRATED HYBRID SYSTEM DESIGN AND TECHNOLOGIES & METEOROLOGY AND SOLAR ENERGY RESOURCE ASSESSMENT - II** (Session Chairs: Canan KANDILLI (Uşak University, Türkiye), Nikolaos I. TSONGIDIS (CERTH, Greece))
14.00-14.15	Bahri Eren UZUNER (ODTÜ-GÜNAM, Türkiye) **Wide Bandgap Perovskite Solar Module Geometry Optimization by Single-diode Modeling Leading >98% Geometrical Fill Factor >80% Fill Factor**	**Invited Speaker** André AUGUSTO (Dalarna University, Sweden) **Hybrid PV Solutions for Industrial and Household Heating Systems - I**
14.15-14.30	Asma BOUBAKRI (Cadi Ayyad University, Morocco) **Comparative Analysis of Properties of SnS Thin Film Deposited by Electrodeposition and Sol- Gel Spin Coating Techniques**	**Invited Speaker** André AUGUSTO (Dalarna University, Sweden) **Hybrid PV Solutions for Industrial and Household Heating Systems - II**
14.30-14.45	Mehmet Cem SAHINER (ODTÜ-GÜNAM, Türkiye) **Insights into the Recombination Dynamics of Perovskite Solar Cells via Voltage and Photon Flux Dependence of Impedance Response**	Robert BALOG (Texas A&M University, Qatar) **Nonplanar PV System Application on Water Tower**
14.45-15.00	Duygu AKIN KARA (Ege University, Türkiye) **Formulation and Characterization of New PEDOT:PSS Inks for Inkjet Printed Perovskite Solar Cells**	
15.00-15.15	Cansu EMIR (Atilim Univ., Türkiye) **Boosting Device Efficiency, Exploring Si Nanowire and SnS2 Thin Film Heterojunctions**	Ertugrul ÇUBUK (ODTÜ-GÜNAM, Türkiye) **Cooling Optimization for Concentrating Photovoltaics Modules: A Study of Convective and Radiative Cooling with a Focus on Plate Fin Applications**
15.15-15.30	Mrittika PAUL (Indian Institute of Technology, India) **Morphology Control of β-CsPbI3 Perovskite Phase in Air Ambient Condition**	Berathan YILDIRIM (Istanbul Energy, Türkiye) **Mobile Energy Applications in Mobile Offices**
15.30-15.45	M. Mustafa ÇODUR (ODTÜ-GÜNAM, Türkiye) **Optimizing Transparent Conductive Oxide Thickness for Perovskite Solar Cells Under Indoor Illumination**	Mahmut S. BÜKER (Necmettin Erbakan University & SOLIMPEKS Solar, Türkiye) **Investigation of the Effect of a New Absorber Plate Design on Hybrid PV/T Collector Performance**
15.45-16.00	Drici MANAL (Badji Mokhtar Annaba University, Algeria) **Comparison between P&O and Incremental Conductance MPPT Control Strategies for PV**	Ismail Mekkaoui ALAOUI (Cadi Ayyad University, Morocco) **Hybrid Water Pumping as A Complement to the Irrigation System in the Ziz Valley (East of Morocco)**
16.00	CLOSING REMARKS & END OF PVCon2024 (Small Foyer)	

Poster Presentations

Poster ID	Abstract ID	Advanced Characterization Techniques for Solar Cells and Modules	
P-001	6435	A Classification and Review of Photovoltaic Models	***Nabila Elbeheiry***
P-002	3592	Advanced Characterization of Poly-Si Thin Film Solar Cells Deposited by E-Beam Evaporation Using Machine Learning	***Şeymanur Selver***
P-003	1005	Application of Copper Iodide Inorganic Hole Transport Layer in Perovskite Solar Cells	***Azam Khorasani***
P-004	7424	Exploring the Catalytic Potential of Silver-Doped Zinc Oxide in Photocatalytic Degradation of Waste Dyes	***Mohammad Sutaif***
P-005	5209	Influence of Deposition Electrolyte Concentration on the Characterization of Molybdenum Sulfide Thin Film via Electrodeposition For Solar Cell Applications	***Iskandar Dzulkarnain***
Poster ID	**Abstract ID**	**Advanced Techniques in Crystalline Photovoltaic Solar Cells**	
P-006	7436	A Roadmap and Feasibility Study on GW-Scale PV Manufacturing in Türkiye	***Hande Karakan Cankul***
P-007	8043	Determination of the Passivation Effect of Organic Nonafluorobutane Sulfonic Acid on Crystalline Silicon	***Cem Maden***
P-008	5315	Developing stable and long life irradiance sensor	***Elşen Aydın***
P-009	6677	Effect of Deposition Temperature, Power Density, SiH4 Flow Rate and PH3 Doping Concentration on the Nanocrystal Growth in n-Type Amorphous Silicon Layer	***Milad Ghasemi***
P-010	2617	Effect of Hydrogen Content on Conductivity in Hydrogenated Indium Oxide as Transparent Conductive Oxides	***Ozan Aydın***
P-011	3727	Overview of mandatory and optional additives in wet chemical process steps in manufacturing for industrial TOPCon solar cells	***Damian Brunner***
P-012	8456	High Quality P-TOPcon with Ex-Situ Doping on Flat Silicon Surfaces for Bottom Cells in Tandem Solar Cells	***Yiğit Mert Kaplan***
P-013	7041	Investigation of Laser-Induced Lifetime and Implied Voc Deterioration on Passivated Flat and Textured Silicon Surfaces During the Laser Ablation Process	***Melisa Korkmaz Arslan***
Poster ID	**Abstract ID**	**Emerging Solar Cells: Innovations and Stability Enhancements**	
P-014	7292	2D Phosphorene Integration for Enhanced DSSC Performance and Outdoor Stability	***Meriem Lougdali***

P-015	6772	A Strategy for Improving Perovskite Film Characteristics through MACl Vapor Annealing	***Youngmin Kim***
P-016	3531	Angle-Independent Diffractive Optical Elements for Enhanced Solar Cell Efficiency: Fabrication via Stereolithography 3D Printing	***Parisa Naghinazhadahmadi***
P-017	9736	Co-Evaporation and Flash Evaporation Techniques Production Method Comparison for Semitransparent Lead Free MABil Perovskite Absorber	***Gokhan Yılmaz***
P-018	9713	Development Of Metal Oxides Using High-rate Atmospheric Pressure Spatial Atomic Layer Deposition For Highly Efficient And Stable Perovskite And Tandem Applications	***Jons Bolding***
P-019	6795	Diketopyrrolopyrrole (DPP)-based Polymeric Passivators: The Rising Star in Perovskite Solar Cells (PSCS) to Overcome Stability-Related Barriers	***Aliekber Karabağ***
P-020	7024	Effects of Fe-Doping On the Structural and Optical Properties of Lead-Free All-Inorganic Cs2AgInCl6 Double Perovskite Particles	***Aybüke Şenol***
P-021	3827	Enhancing Ambient Stability of Formamidinium-Cesium Lead Halide Perovskite Solar Cells Fabricated under Air Ambient Conditions	***Binita Boro***
P-022	1959	Enhancing Stability of Perovskite Solar Cells through RbI Passivation	***Amir Zarean Afshord***
P-023	4492	Glove Box-Free Deposition for Enhanced Performance of Planar CH3NH3PbI3 Solar Cells Using Sol-Gel Synthesized ZnO Nanoparticles	***Buse Koçak***
P-024	8405	Influence of Microalgae Addition on the Performance of Perovskite Solar Cells	***Tuğba Demirbay***
P-025	2778	Investigating Passivation Effects in Inverted Planar Perovskite Solar Cells via Thiol Treatment	***Nilay Ağaçkesen***
P-026	7259	Investigation Of Lead-Free Material For Perovskite Solar Cells As Absorber Layer Using Oghmanano And Taguchi Method	***Ahmad Muhajer Abdul Aziz***
P-027	1035	Maximizing the Photovoltaic Performance of Planar Perovskite Solar Cells with Indium-Chloride Toluene-Based Antisolvent Washing	***Şevval Öztürk***
P-028	1191	Mg-Doped ZnO Nanoparticles: Dual Application in Aqua Media Dye Photocatalysis and Dye-Sensitized Solar Cells	***Mohammad Sutaif***
P-029	9869	Optical, Structural and Morphological Properties of CdS Thin Films Produced by CBD Method	***Aykut Küçükbaş***
P-030	4334	Optimization of FTO/ZnS/MASnI3/CZTS Perovskite Solar Cells through Numerical Analysis Using SCAPS-1D	***Mohamed Amine Benatallah***
P-031	1212	PAN, LiClO4 and TEABF4-based Composite Polymer Electrolytes for Supercapacitors	***Damla Şahin***
P-032	6639	Performance Evaluation of Mxene-based Flexible Substrate for Perovskite Solar Cell Applications: A Comparative Study with ITO	***Gülşah Yılmaz***
P-033	9158	Performance of Mixed Cation Wide Bandgap Perovskite-based Solar Cells Under Different Indoor Light Sources	***Snehangshu Mishra***
P-034	3144	Perovskite Thin Film Production and Optimization Studies With Alkyl/Arylammonium Salts Containing Fluorinated And Non-Fluorinate Ligands	***Semra Koçyiğit***

P-035	3755	Power Generation from Perovskite Architectural Elements	***Elshan Asadi***
P-036	7312	Reliable and Comprehensive I–V Characteristic of Emerging PV Devices	***Hatice İlhan***
P-037	8803	Semitransparent Inorganic Halide Perovskite (CsBiX and CsSbX, (X=I, Cl, Br)) Absorber Layers Production by Flash Evaporation Technique	***Gökhan Yılmaz***
P-038	8545	Semitransparent Organic Photovoltaic (ST-OPV)	***Lamkaouane Hind***
P-039	2323	Solvent Engineering of Hole Transport Layer for Improved Efficiency and Stability in Perovskite Solar Cells	***Adem Mutlu***
P-040	1237	Synthesis of Novel Conjugated Structures and Their Use in Perovskite Solar Cells	***Selma Gülnaz Öztok***
P-041	2337	Synthesis of TiB2 and TiB2@Co Nanocomposite Structures Developed as Electrode Materials and Supercapacitor Applications	***Hatice Arici Kahyaoglu***
P-042	2697	Two-Step Sequential Vapor-Solution Hybrid Deposition of Uniform and Stable Perovskite Films Assisted by Slot-Die Coating Intended for Commercial Large-Area Photovoltaic Applications	***Ahmed Javed***
P-043	2063	Understanding the Mechanism of Organic Additive to Fabricate Stable Co-evaporated CsPbI3 Perovskite Solar Cells	***Sangwon Lee***
Poster ID	**Abstract ID**	**Innovative PV Module Technologies & Performance and Reliability Testing for PV Modules**	
P-044	3682	Advanced Solar Panel Design with Enhanced Color Conversion for Optimal Crop Yield and Quality	***Ümran Dilmaç***
P-045	5623	Assessment of a Pioneering Solar PV System Facilitating the Coexistence of Agricultural and Power Generation	***Chien-Chun Hsieh***
P-046	8370	Automatic Detection and Classification of Defects in PV Modules Using Electroluminescence Imaging: Artificial Intelligence Approaches	***Nurgül Polat***
P-047	1324	Characterization of Zinc-Indium-Tin Oxide Thin Films Deposited by Sputtering Technique	***Elif Peksu***
P-048	7656	Design and Simulation Studies of PERC and TOPCon Solar Panels	***Nil Bağrıaçık***
P-049	8153	Effects of Pollution on Solar Panels and Solution Suggestions	***Berat Yıldırım***
P-050	3992	Semi-transparent Cu(In,Ga)Se2 Solar Cells for Window Applications	***Nuno Rodrigues***
P-051	8979	The Effect of Rectifier Materials on Photovoltaic Devices	***İkram Orak***
P-052	1662	Water-Harvesting and Self-Cleaning Anti-Reflective Coating for Agri-PV Applications	***Sezen Öykü Kınacı***

P-053	4752	Optimizing Photovoltaic Module Efficiency with Photonic Crystal Multilayer Passive Cooling via Setfos Software	***Alihan Kumtepe***
P-054	1667	Blocking the PID: The Power of Chemically Tempered Glass	***Beyza Durusoy***
Poster ID	**Abstract ID**	**Novel Absorber Materials and Transport Layers in Solar Cells**	
P-055	5776	Compositional Analysis of the Carbon-Rich Fine-Grain Layer in Solution-Processed CZTSSe Films	***Ahmed Javed***
P-056	1879	Drastic Influence of Substituent Position on Orientation of 2D Layers Enables Efficient and Stable 3D/2D Perovskite Solar Cells	***Figen Varlıoğlu Yaylalı***
P-057	1553	Exploring the Potential of MgZnO Thin Films as a Sustainable Alternative to CdS Buffer Layer in CZTSSe Solar Cell	***Prabeesh Punathil***
P-058	9585	Fabrication of Semi-transparent Third Generation CZTS Solar Cells Via ZnO Nanorods Synthesized on Graphene Layers	***Elif Peksu***
P-059	7155	High Potential of Solution-Processed TiOx as Electron-Selective Passivating Contact for Silicon Solar Cell	***Naser Beyraghi***
Poster ID	**Abstract ID**	**Power Electronics for PV Systems & Socioeconomic Aspects of Solar PV Applications & PV-integrated Hybrid Energy Systems**	
P-060	3028	Control of MPPT Boost Converter for a 5-KW Hybrid Inverter	***Muharrem Baran***
P-062	5339	Insights to Citizen-Participatory Volunteerism and SDG 7: Energy, Volunteering and Non-Governmental Organizations in Türkiye	***Kaan Samet Çil***
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P-058	Fabrication of Semi-transparent Third Generation CZTS Solar Cells Via ZnO Nanorods Synthesized on Graphene Layers
	Elif Peksu, Çiğdem Yener, C. Gökhan Ünlü, Hakan Karaağaç
P-059	High Potential of Solution-Processed TiOx as Electron-Selective Passivating Contact for Silicon Solar Cell
	Naser Beyraghi, Selcuk Yerci
P-060	Control Of MPPT BoostConverter For A 5-KW Hybrid Inverter
	Muharrem Baran, Erhan Demirok, Enis Dokurlar, Yunus Çay, Ozan Keysan
P-061	Insights To Citizen-Participatory Volunteerism And SDG 7: Energy, Volunteering And Non-Governmental Organizations In Türkiye
	Kaan Samet Çil, Yelda Erden Topal
P-062	Investigating Hybrid Energy Systems Integrated With Photovoltaics
	Hanieh Sadat Jameie, HARUN Sevinç
P-063	Optimizing Machine Learning Models for Photovoltaic Arc Fault Detection
	Sawsan Shukri, Robert S. Balog
P-064	Socio-Economic Aspects Of Solar Energy: Social Acceptance And Economic Impacts
	Pehlül Okumuşoğlu

P-065	A Novel Framework towards Transitioning into Positive Energy Districts on Neighborhood Scale
	Ataberk Yılmaz, Eser Delice, Fatma Ece Gürsoy, Yasin Ataberk Demir, Cihat İlkbahar, Sena Nur Cabadağ, Onur Taylan, İpek Gürsel Dino
P-066	Cost-Effective Off-Grid PV Systems for Sana'a: A Techno-Economic Study
	Raimon Bawazir, Mohammad Sutaif
P-067	Optimizing Solar PV Site Selection: A Comprehensive Review
	R***aimon Bawazir, Mohammad Sutaif***
P-068	Optimum Bess Sizing And Utilization Using Rule-Based Control Approach For Buildings With Photovoltaics
	Nurhan Aydinalp, Murat Göl
P-069	Solar Power for a Sustainable Future: Assessing Solar Resource Availability and PV System Performance for Building Decarbonization in Turkey
	Ahadollah Azami
P-070	HYBRID K-MEANS AND PARTICLE SWARM OPTIMIZATION MODEL TO DETERMINE OPTIMUM PARCELS FOR AGRIVOLTAICS AND ELECTRIC TRACTORS
	Samed Pekdemir, Emin Keresteci

Pub No: PS-001

Molecular Photovoltaics and the Stunning Rise of Perovskite Solar Cells

Michael Graetzel [1]

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Abstract: Photovoltaic cells using molecular dyes, semiconductor quantum dots or perovskite pigments as light harvesters have emerged as credible contenders to conventional devices. Dye sensitized solar cells (DSCs) use a three-dimensional nanostructured junction for photovoltaic electricity production and reach currently a power conversion efficiency (PCE) of over 15 % and 30 % in full sunlight and ambient daylight respectively. They possess unique practical advantages in particular bifacial light harvesting, highly effective electricity production from ambient light, ease of manufacturing, flexibility and transparency, and aesthetic appeal, which have fostered industrial production and commercial applications. They served as a launch pad for perovskite solar cells (PSCs) which are presently being intensively investigated as the most promising future PV technology. The PCE of solution processed laboratory cells having currently reached 26.1%. Present research focusses on their scale up to as well as ascertaining their long-term operational stability. My lecture will cover our most recent findings in these revolutionary photovoltaic domains and well as the realization of a production plant for perovskite modules in Adana, by the Turkish company Günes Perovskite Solar Cells.

Pub No: PS-002

Contact Selectivity Guiding the ISFH-Roadmap for Crystalline Si Photovoltaics

Rolf Brendel [1]

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Abstract: The high quality of today's Si wafers makes the contacts the decisive element for the processing cost, the reliability and the efficiency of Si solar cells. The contacts have to be selective. This means they shall have a small resistance for the transport of majority carriers and a large resistance against the transport and subsequent recombination of minority carriers. We define contact selectivity quantitatively. In a simplifying model it is possible to analytically express the optimal area fraction of either contact, the optimal cell efficiency and the optimal light concentration analytically as a function of the contacts' selectivities. With these theoretical results screening of various contact combinations is an easy task. We find that combinations of n-type polycrystalline Si on oxide (POLO) junctions in combination with screen-printed Al contacts are an attractive compromise for achieving high efficiencies with cost effective processes that are proven in today's PERC+ production lines. The presentation discusses the current ISFH roadmap that is based on POLO junctions in combination with Al screen-printed contacts. Among various experimental achievements along this roadmap we highlight achieving 24.2% efficiency with a two sides-contacted, p-type, CZ-grown, Ga-doped, M2-sized, screen-printed Si solar cell that uses half the amount of Ag than other next-generation solar cells. We also report progress on fully avoiding Ag in future PV module fabrication.

Pub No: IS-001

Breaking Barriers with Cutting-Edge Strategies: Advancing Efficiency and Stability in Perovskite Photovoltaics

Seçkin Akın [1]

[1]Laboratory of Advanced Materials & Photovoltaics (LAMPs), Prof. Necmettin Erbakan University, Konya, Türkiye

Abstract: Perovskite photovoltaics have emerged as a transformative technology in the field of solar energy, offering unprecedented efficiency potential and ease of fabrication. However, challenges such as limited stability and scalability have hindered their mass production. In this presentation, we explore innovative strategies that are breaking barriers and advancing perovskite photovoltaics towards commercial viability. The talk begins by addressing the crucial aspect of efficiency enhancement. We demonstrate cutting-edge techniques and materials that enhance light harvesting, facilitate charge transport, and optimize interface engineering within perovskite solar cells. These advancements lead to substantial increases in power conversion efficiency, pushing the boundaries of achievable results in this technology. By combining cutting-edge strategies with a focus on efficiency, stability, scalability, and cost-effectiveness, this presentation provides a comprehensive overview of the current state and future prospects of perovskite photovoltaics. (Acknowledgment: This work was supported by the Scientific and Technological Research Council of Turkey (TUBITAK) BIDEB 2247-A Grant No 120C126 and ARDEB 1001 Grant No 119F185)

Pub No: IS-002

Potential of the Photovoltaic Thermal Systems for Green Transformation in Industry and Zero Energy Building Applications

Canan Kandilli [1]

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Abstract: While photovoltaic (PV) solar cells convert only the part corresponding to their spectral response range into electricity, depending on the properties of the material, a significant part of the solar radiation causes a heat load on the solar cell. Photovoltaic thermal systems (PVT), they are used to remove this excessive heat load and evaluate it as thermal energy. With PVT systems, both electrical and thermal energy can be obtained from a single module, and the negative effect of temperature increase on electrical conversion efficiency can be minimized. Within the scope of energy efficiency in industry and buildings, two important processes have been experienced in recent years: Green Transformation in Industry and Zero Energy Buildings. While solar energy takes the lead in achieving sustainability goals, utilizing high capacities of solar thermal energy along with electricity will reduce dependence on fossil fuels. PVT systems have a significant potential in supplying thermal energy in industrial applications. In addition, in a structure where heating-cooling-electricity expenses will be supported by PVT systems, it will be easier to achieve the zero energy target.

Pub No: IS-003

What Is New in Silicon Heterojunction Solar Technology 2023/2024?

Kaining Ding [1]

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Abstract: Silicon heterojunction (SHJ) solar technology has emerged as a frontrunner in the pursuit of efficient and cost-effective photovoltaic solutions. The years 2023/2024 have witnessed significant strides in this domain, marked by the continuous integration of advanced concepts into mass production. This contribution at PVCON2024 in Ankara, Turkey, aims to provide a comprehensive overview of the latest advancements in SHJ technology, focusing on key updates from the industry and outlining future trajectories. Additionally, this contribution will report on the industrial and scientific works presented at the 6th International Silicon Heterojunction Solar Cell Workshop, which took place in 2023 in China. This provides a good overview of the state-of-the-art research in SHJ solar technology. Most of the current activities aim to increase efficiency, reduce costs, and improve reliability. It is observable that the strongest push for this technology now comes from the industry, including both cell and module producers and equipment turnkey solution providers. Furthermore, this contribution will also examine the geographical situation of SHJ manufacturing, investigating the current players in various regions of the world. While the SHJ industry was expanding in China, reaching a production capacity of around 50GW by the end of 2023, some plans have been announced in the EU, the US, etc. It seems that SHJ is the primary technology to be chosen outside China.

Pub No: IS-004

Vacuum Deposited Perovskites for Single Junction and Tandem Solar Cells

Henk Bolink [1]

[1]University of Valencia, Spain

Abstract: In this study, Prof. Dr. Bolink presents recent progress on vacuum-deposited perovskites using low and high vacuum processes and their integration in single junction and tandem solar cells.

Pub No: IS-005

The Social Acceptability of New Technologies in Shaping Energy Policy

Ramazan Sarı [1]

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Abstract: Sustainability assessment has recently become an important issue for policymakers and decision-makers, driven by the necessity to balance environmental, economic, and social policies. Consequently, understanding social factors in general, and social acceptance in particular, is crucial for the successful implementation of renewable technologies, the development of efficient energy and environmental policies, and a smooth energy transition. We focus on the social acceptance of agroPV, nature-based solutions, and energy-from-urban-waste projects to help pave the way for smoother implementation of these technologies and policies.

Pub No: IS-006

Micro-Structured Semi-Transparent CU(IN,GA)SE2 Solar Cells

Sascha Sadewasser [1]

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Abstract: Semi-transparent solar cells have attracted strong interest in the photovoltaic industry as they allow the integration of photovoltaics in buildings, e.g. as windows. The current state of the art uses either tiled Si wafers, separated by transparent gaps, or thin-film solar cells with strongly reduced thickness allowing light transmission of longer wavelength light. Both approaches lead to an unsatisfactory user experience, either by a partially obstructed view or red colored lighting. Here, we present an alternative approach consisting of micro-patterning Cu(In,Ga)Se2 (CIGSe) solar cells in micro-stripes with fully transparent gaps in-between, leading to a superior user experience. To demonstrate the concept, we developed a top-down micro-structuring approach, where an opaque CIGSe solar cell is spatially segmented into micro-sized line-shaped solar cells. Varying the lines' width and spacing, the window's average visual transparency (AVT) is controlled. We use photo-lithography to define the pattern of micro-lines on top of a complete CIGSe solar cell stack. An aqueous bromine solution is then used to etch the developed solar cell areas, while the photoresist protects the solar cell lines. The bromine solution etches the complete CIGSe stack without damaging the photoresist. This process leads to an over-etch of the window layer of ~30 µm, making it challenging to fabricate lines narrower than 200 µm. After the bromine etching, a second etch with sodium hypochlorite removes the exposed molybdenum, thereby making the areas in between the solar cell lines fully transparent. To ensure proper current collection, we preformed simulations to design a metallic front contact grid that minimizes shadowing and ohmic losses in the transparent conducting oxide (TCO) layer. Narrow tapered aluminum electrical contacts were evaporated on top of the full length of the line solar cells, with a width between 30 µm and 1 µm. The process led to a non-disturbing color neutral semi-transparent CIGSe solar cell with a total area efficiency of 7.6 % and an AVT of 45 %.

Keywords: Cu(In,Ga)Se2, semi-transparent photovoltaics, building-integrated photovoltaics, BIPV

Pub No: IS-007

Topcon Solar Cell Technology: Status and Perspective at Fraunhofer ISE

Marc Hofmann [1]

[1]Fraunhofer ISE, Germany

Abstract: TOPCon solar cells are becoming increasingly important in industrial production. We will take a look at some snapshots of TOPCon technology at Fraunhofer ISE and discuss options for future technology paths.

Pub No: IS-008

Potentials of HWCVD as a Lower Cost Alternative for HJT Cell Production

Lang Zhou [1]

[1]Nanchang University, PRC

Abstract: Hot wire chemical vapour deposition (HWCVD), also known as CAT-CVD, was used for growth of the intrinsic and doped a-Si:H layers in HJT cell production before 2018, in both Sanyo/ Panosonic and CIE. The average efficiency of the cell products reached a superior level of 23.7% in 2017. However, the mainframe development of the HJT cell production has chosen PECVD as the tool for the growth of the a-Si:H layers, and the technological development in the recent years has been focused on the PECVD route. Currently, the PECVD-based HJT cell products have reached a a cell efficiency level of 25.5%, while HWCVD has been left behind due to much less development efforts. The major reason for the present talk is that high cost of PECVD has now become a severe barrier for further development of HJT cells in PV industry, while the HWCVD offers an opportunity for lowering the cost significantly. Our efforts for optimization of design and processing of HWCVD-based HJT cells, indicating its potential to catch-up the development of PECVD route, along with other group's relevant work, are reported. Other advantages of HWCVD apart from lower cost, as an alternative to PECVD in future HJT cell production, are also summarized and presented.

Pub No: IS-009

Simulation-Based Structure Optimization of Monolithic Perovskite/Perovskite/Silicon Triple Junction Solar Cells

Jonas Schön [1]

[1]University of Freiburg, Freiburg, Germany

Abstract: Perovskite-based triple-junction solar cells have the potential for highly efficient and cost-effective photovoltaic energy conversion [1]. However, the increased number of material layers and, thus increased complexity requires a target-oriented optimization of the structure and careful selection of materials. Simulations assist in identifying factors that contribute to efficiency loss, thereby guiding developers to improve specific layers. Current key challenges include achieving stable perovskite compositions with the right bandgap, as well as identifying hole and electron extraction layers with good passivation quality and suitable band alignment. We have developed a comprehensive opto-electrical model for the perovskite/perovskite/silicon structure using Sentaurus TCAD. The model has been validated through measurements on both triple-junction [2,3] and single-junction solar cells. Single-junction perovskite solar cells were fabricated and characterized to distinguish between optical and electrical losses in the two subcells. The talk will outline a developmental roadmap for monolithic perovskite/perovskite/silicon triple-junction cells and show the first technological steps. A first improvement involves adjusting the thicknesses of the perovskite layers to achieve current matching in the top subcells [3]. Furthermore, using perovskites with optimized bandgaps could significantly enhance the photocurrent density. We demonstrate that implementing a fully textured structure, a practical efficiency of 44.3% for this kind of triple-junction technology can be achieved. In line with the characterization of Perovskite/Silicon dual-junction solar cells [4], we have identified selectivity and recombination at the ETL/HTL interfaces in both perovskite cells as the primary sources of electrical losses.

Pub No: IS-010

Hybrid PV Solutions for Industrial and Household Heating Systems

Andre Augusto [1]

[1]Dalarna University, Sweden

Abstract: Heating represents close to 50% of global energy demand. In industry, over 70% of the final energy used is for heat. In the building sector, this number is closer to 80%. In industry, 90% of heat sources are fossil fuels, while in buildings it is closer to 60%. In this work, we discuss hybrid photovoltaic (PV) solutions to accelerate the decarbonization of industrial and household heating for temperature regimes below 150°C, which represent 30% of industrial heating needs and almost the entirety of household needs. Concerning industrial heating, we discuss a solar hybrid system from a techno-economic perspective to produce steam for the food and beverage industries, where we combine parabolic solar collectors with pressurized water thermal storage and PV with high-temperature sand storage, demonstrating economically competitive solar fractions as high as 90%. For household hybrid heating systems, we summarize our results on system performance assessment of PV, heat pump, and thermal storage hybrid systems, including the latest results on the optimization of a accelerated laboratory system test method to forecast annual energy performance.

Pub No: IS-011

Nexus Hybrid Perc/Topcon Bottom Cell Enabling Ag-Free and In-Free Design for Perovskite-Si Tandem Solar Cells

Hisham Nasser [1]

[1]GUNAM-METU, Ankara, Türkiye

Abstract:

Pub No: IS-012

Industrially Applicable Spatial Atomic Layer Deposition of Metal Oxides for Perovskite and Tandem Solar Cells

Jons Bolding [1]

[1]Sald B.V., Netherlands

Abstract: Spatial Atomic Layer Deposition (sALD) has been employed in high-volume manufacturing in the silicon solar cell industry since 2013, where it has been used for the surface passivation of PERC by thin films of Al2O3. Nowadays, sALD can be utilized in novel perovskite and tandem based solar cells for high-rate (web speed up to 1.5 m/s), large-area (upscalable to 1200 mm wide, also on R2R) deposition of inorganic metal oxides such as among others SnO2, Al2O3, AZO, NiO, and TiO2. In this work, we demonstrate how s-ALD can be used to deposit SnO2, Al2O3, and AZO at high throughput. SnO2 is a promising material for the electron transport layer as it acts as a buffer layer and protects the sensitive layers from generally harsh deposition conditions of the top TCO. Furthermore, recently, more attention is paid to passivating defects at the perovskite to boost the performance and Al2O3 shows great potential passivating surface defects by employing ultra-thin layers. But Al2O3 not only acts as a passivation layer, it is an excellent candidate to encapsulate flexible PV by acting as a barrier layer to undesired degradation mechanisms. And ultimately, AZO is investigated as recombination junction (RJ) to replace the commonly used In-based layers. We demonstrate that a thin layer of AZO improves the performance of the SHJ and TOPCon bottom cell, enabling the fabrication of efficient tandem devices. Spatial ALD matures the tandem technology by employing sustainable and abundant materials at a low cost and large scale, satisfying the demands of industry.

Pub No: IS-013

He Project Nexus: Overview of the Results Achieved During the 1st Period

Perrine Carroy [1]

[1]CEA-INES, France

Abstract: NEXUS aims to develop 2-terminal perovskite-Si tandem solar cells with power conversion efficiencies >33% (modules >30%) and stabilities comparable to state-of-the-art single junction Silicon PV modules. In addition, NEXUS will achieve these challenging targets using an eco-design approach: employing solvent-free perovskite deposition, reducing critical elements, demonstrating circularity and recyclability, showcasing simple manufacturing processes, with the overall goal of creating a viable economic pathway for the European commercialization of this sustainable technology. The presentation will highlight the results obtained during the first half of the project and provide an overview of the progress of the project towards its scientific, economic and socio-environmental objectives.

Pub No: IS-014

Perovskite/Perovskite/Si Triple Junctions by Solution Processing

Christian Wolff [1]

[1]EPFL, Switzerland

Abstract: Beyond tandem devices triple-junction solar cells offer the opportunity to increase the efficiency of solar cells to 50%. In reality, the best-performing triple-junction devices based on III-V and Si materials reached 36.1%, leaving only a small margin compared to the 33.9% for a tandem device based on perovskite and Si. The fast progress due to the ease of fabrication of perovskite solar cells is a strong advantage to explore the triple-junction concept with this technology. In this presentation I will present our recent progress in this regard and how we combine the three subcells to reach > 26% on laboratory scale devices.

Pub No: IS-015

Study on Efficiency Improvement Technology of Industrial Manufacturing for Jolywood-Topcon Solar Cell

Vincent Lau [1]

[1]Jolywood, PRC

Abstract: With the increasingly market demand for high-efficiency TOPCon solar cell, major manufacturers are encouraged to continuously improve cell mass production efficiency. Improving the contact resistance (ρc) between the metal electrode and the semiconductor and reducing the metal composite current density (J0,metal) is a key direction to improve the efficiency of silicon solar cells. As a high-density carrier of energy, LASER is favored for its advantages of normal temperature processing, high precision, controllable and changeable processing area. Therefore, this paper shows several efficiency improvement technologies for industrial mass production of TOP-Con based on laser equipment. Including the Laser Selective Emitter technology that has been put into mass production in Jolywood, it can improve the mass production efficiency of the solar cell by about 0.29%. And a new c-Si cell injection metallization technology successfully developed by Jolywood, namely “Jolywood Special Injected metallization technology (JSIM) - through a unique metallization process, the mass production efficiency of the solar cell can be improved by about 0.35% or more. Based on this technology, the power attenuation problem of TOPCon module after damp heat test is perfectly solved, and a solution is found for double-sided single glass.

Pub No: IS-016

Recent Progress of Topcon Solar Cell Technology in China

Jichun Ye [1]

[1]Ningbo Institute of Material Technology and Engineering, PRC

Abstract: Tunnel Oxide Passivated Contact(TOPCon)solar cells (SC) is replacing the PERC technology at an unprecedented speed, far exceeding any predictions of PV technology development. TOPCon SC started its mass production in 2022, and represented over 1/4 of the shipment in 2023, and is estimated to take ~70% of the market share in 2024. Although the current widely used TOPCon SC is a fundamental TOPCon SC only with the TOPCon structure on the rear-side, the warehouse efficiency has been significantly improved during the past year from 24.0-24.2% to 24.8-25.2% for now, mainly due to the improvement of the Si wafer quality, the front boron emitter with higher sheet resistance, the selective emitter, the laser-induced firing together with the modified silver paster, the improved passivation of TOPCon, and the reduced parasitic absorption in the rear-side poly-Si etc. In this presentation, the current status of TOPCon SCs will be reviewed and the future trends of technology will be analyzed. Also, the research activities on TOPCon SC at Ningbo Institute of Materials Technology and Engineering will be introduced.

Pub No: O-001

Local p+ Poly-Si Passivating Contacts Realized by Direct FlexTrail Printing of Boron Ink and Selective Alkaline Etching for High Efficiency TOPCon Based Solar Cells

Berkay Uygun [1], ***Sven Kluska*** [2], ***Jana Isabelle Polzin*** [2], ***Jörg Schube*** [2], ***Katrin Krieg*** [2], ***Mike Jahn*** [2], ***Raşit Turan*** [1], ***Hisham Nasser*** [1]

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Abstract: In this work we investigate the variables influencing the poly-Si etch back selectivity during KOH wet chemical etching and local p+ TOPCon production by direct printing boron ink on the intrinsic a-Si layer using FlexTrail [1], a mask-free approach, are presented in this work. By adjusting the printing process parameters, such as printing speed and set pressure, the width of the poly-Si can be varied over a wide range. When the proper preconditions are met before KOH etching, the fingers can be preserved. Our research has shown that the HF dipping time and subsequent annealing conditions are critical for achieving selectivity between locally doped and undoped poly-Si areas during KOH etching. The best conditions for obtaining selectivity during etching include a BSG layer (formed after high temperature annealing of boron ink) on top of the doped poly-Si and etching native oxide on the undoped poly-Si created after annealing entirely. In our investigation, we investigated these settings by varying the HF process time and the annealing temperatures. The ideal conditions were established when our samples underwent a brief HF dip (25 seconds) and high temperature annealing (950 °C) for 60 minutes prior to wet chemical etching. After 30 minutes of annealing at 925 °C, the samples with local p+ TOPCon lines had the lowest J0 total ~ 20 fA/cm2 and the highest iVOC values of 720 mV. In the near future, these local p+ poly-Si will be integrated into a high efficiency TOPCon solar cell, under metal contacts.

Etch Back Selectivty of Poly-Si

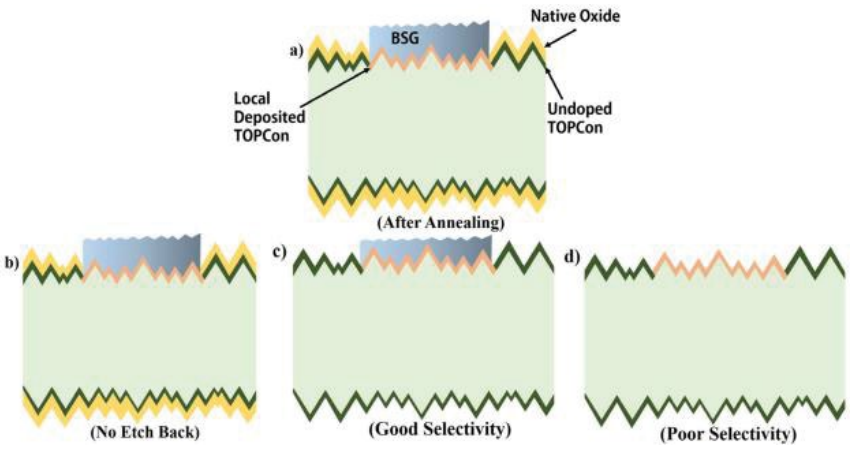

Fig. 1. a) Deposited local p+ TOPCon structure with BSG layer and native oxide after annealing. Prior conditions for b) no etching, c) good selectivity, and c) poor selectivity during KOH etching. No etching, good and poor selectivity can be achieved by KOH if no HF, short and long HF dip are applied, respectively.

PLI Image After Etch Back

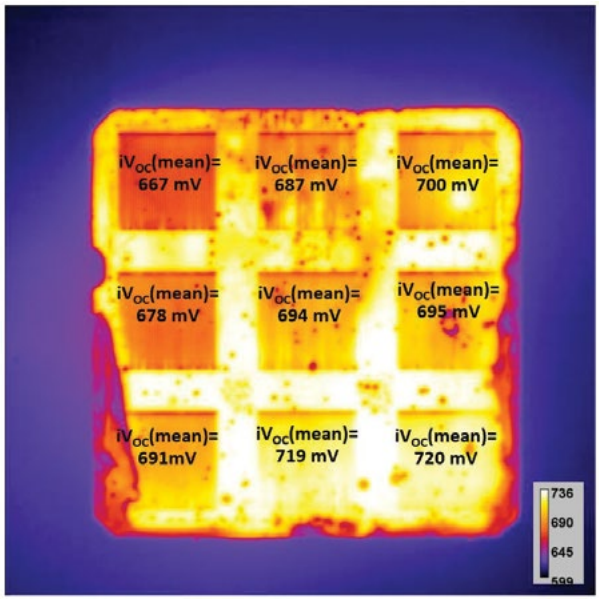

Fig. 2. iVOC images of textured M2 n-type wafers with local p+ TOPCon, which received 925 °C for 30 min annealing.

Keywords: Local TOPCon, Selective etching, TOPCon, Etch back of poly-Si, FlexTrail

Pub No: O-002

Development Of Hydrogenated Aluminum-Doped Zinc Oxide Recombination Junction Enabling Superior Passivation Of Bottom Cell With Front TOPCon For Silicon/Perovskite Tandem Devices: Towards Indium-Free Recombination Junction

Gökhan Altıner [1], ***Yiğit Mert Kaplan*** [1], ***Jons Bolding*** [2], ***Berkay Uygun*** [1], ***Floor Souren*** [2], ***Raşit Turan*** [1], ***Hisham Nasser*** [1]

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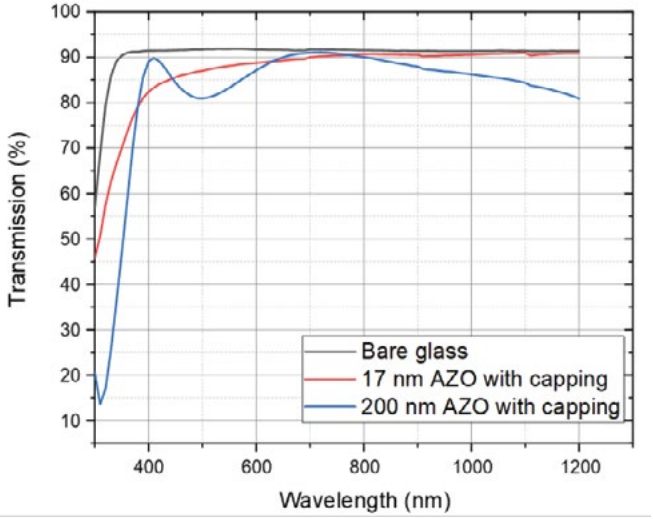
[2]SALD B.V., Zwaanstraat 1, 5651, CA, Eindhoven, the Netherlands

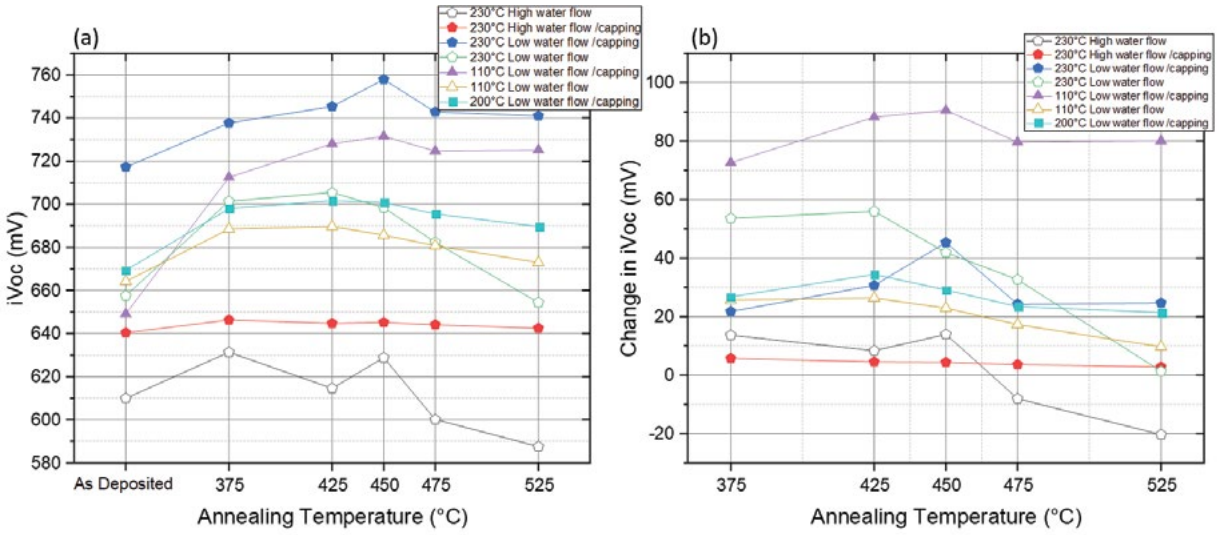
Abstract: This study demonstrates hydrogenated aluminum-doped zinc oxide (AZO:H) as a highly transparent and passivating indium-free recombination junction for perovskite/c-Si tandem devices, specifically on bottom cells with front TOPCon. AZO:H layers were deposited using a spatial atomic layer deposition (SALD) with different deposition parameters, with and without aluminum oxide (AlOx) capping layer on top. The transmission measurements on glass substrates for both 22 and 200 nm AZO:H resulted in more than 80% between 380-1200 nm wavelengths, while the thin AZO:H predominantly maintains a transmission level of around 90% (Figure1). The four-point probe measurements demonstrate the resistivity of AZO:H strongly depends on their thickness with thin AZO:H resulting in 660-800 mOhm-cm while the thick ones give remarkably low resistivities around 1-3 mOhm-cm. Different AZO:H recipes were also double-side deposited on symmetrical n-TOPCon/p-type c-Si/n-TOPcon structures and forming gas annealed for 5 minutes in different temperatures between 375-525°C to observe the hydrogenation effect of AZO:H(/AlOx) layers (Figure2). Samples with capping showed excellent passivation, peaking at 450°C, with impressive iVOC values reaching 758 mV, proving AZO:H/AlOx stacks as an excellent hydrogen source. While their uncapped counterparts improved the cells by up to 56 mV at 425°C, they resulted in lower iVOC values with worsened thermal stability due to hydrogen effusion from uncapped AZO:H during annealing [1]. Overall, AZO:H has great potential as a recombination junction connecting the bottom Si and top perovskite in tandem with remarkable transparency as well as an excellent hydrogenation source for the TOPCon layer on top of the Si bottom cell.

Figure1.



Transmission results for bare glass and different thicknesses of AZO with capping on the glass substrate.

Figure2.



(a) iVOC and (b) change in iVOC results for various AZO recipes with and without capping on symmetrical n-TOPCon samples on textured p-type czochralski c-Si wafers. (The thickness of tunnel oxide is 1.1 nm and poly-Si is 110 nm, the base resistivity of the bare wafer is 0.9 ohm-cm with a thickness of 170 µm)

Keywords: AZO, recombination junction, tandem, TOPCon

Pub No: O-003

Comprehensive Analysis and Process Optimization for Wet-Chemical Alkaline Edge Isolation for Industrial TOPCon Solar Cells

Tobias Dannenberg [1]

[1]RENA Technologies

Abstract: Tunnel Oxide Passivated Contacts (TOPCon) solar cells are on the way to becoming the next leading cell concept in industrial solar cell manufacturing. However, the efficiency gain in relation to state of the art PERC cells comes with higher expenses for additional processes in the manufacturing route. It is therefore of utmost importance to increase the profitability of the TOPCon cell architecture by reducing the capital and operational expenses as much as possible. Next to the development of high throughput and low footprint manufacturing machines the main lever for wet chemical processes is to reduce the consumption of costly chemi-cals whilst maintaining a high process quality.In this work, this goal is pursued with a focus on the wet-chemical edge isolation. This process is industrially predominantly performed in a combination of an inline process for single side glass removal followed by a batch process for rear side emitter removal (cluster process). This manuscript shows our approach to reduce the inline process duration without increasing the HF concentration. Furthermore, the rear surface morphology after the alkaline etching at different KOH concentrations with and without a new generation of polishing additive is characterized and the impact on implied open circuit voltages will be shown. In an analogous way we will investigate the influence of dissolved potassium silicate aiming for an increase of KOH-bath lifetime. Based on the findings we will present TOPCon cell results with efficiencies of about 24% as well as cost of ownership calculations for the most promising approaches.

Keywords: Industrial, TOPCon, wet-chemical process, Edge isolation

Pub No: O-004

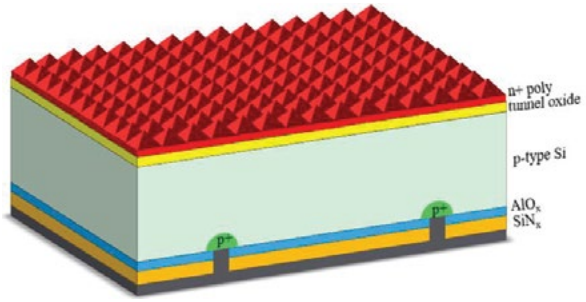
Simulation of TOPerc Bottom Structures for Perovskite/Silicon Tandem Solar Cells using QUOKKA3

Eni Muka [1], ***Raşit Turan*** [1], ***Hisham Nasser*** [1]

[1]ODTU-GUNAM Center for Solar Energy Research & Applications

Abstract: The study investigates the design of a p-type c-Si structure for the bottom cell of perovskite/silicon tandem solar cells, introducing a novel approach termed Tunnel Oxide Passivated Contacts and Passivated Emitter and Rear Contact (TOPerc). Using Quokka3 simulations with validated parameters, the research focuses on optimizing the rear side metallization design of TOPerc for enhanced performance. A two-step simulation process is employed to vary the rear side metal fraction, identifying an optimal value of 2.5% for achieving a balance between implied open-circuit voltage (Voc) and fill factor (FF). The study highlights the effectiveness of combining TOPCon and PERC technologies for the bottom cell in tandem structures, addressing challenges associated with conventional PERC-based bottom cells. By analyzing the impact of rear side metal configuration on Voc and FF, the research provides insights into the importance of optimizing parameters such as opening width, number of lines, and contact geometry. The findings emphasize the significance of rear side metal optimization for maximizing photovoltaic performance in TOPerc structures, offering a promising pathway to develop industrially feasible Ag-free Si bottom cell structure for efficient tandem solar cells.

TOPerc Schematic Structure



Keywords: TOPCon, PERC, metal fraction, bottom cell

Pub No: O-005

Intrinsic Amorphous Silicon Bilayers for Surface Passivation in Silicon Heterojunction Solar Cells

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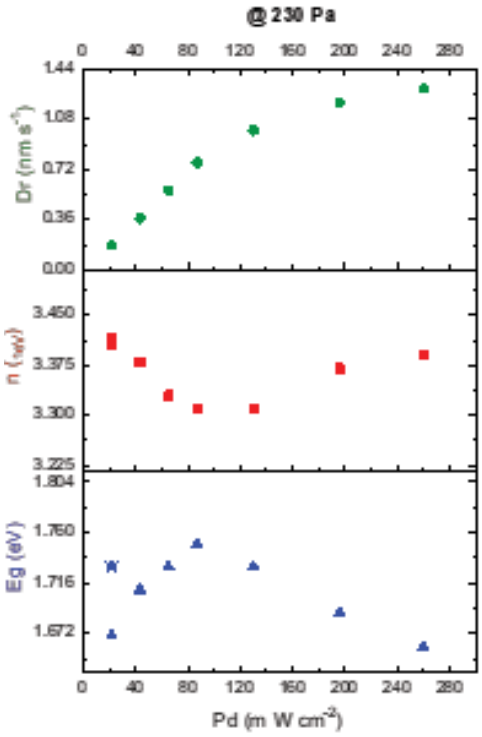
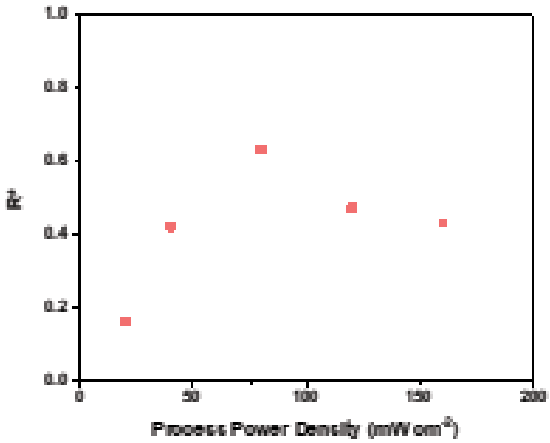
Abstract: The performance of Silicon Heterojunction Solar Cells is tied to specific properties of hydrogenated amorphous silicon (a-Si:H) thin layers as passivating contacts. This study provides insights into the structure and thickness optimization of intrinsic amorphous silicon (i-aSi:H) bilayers to increase passivation quality and ultimately enhance solar cell performance. The challenge lies in balancing porous films preventing epitaxial growth but having high defect density with the benefits of dense i-aSi:H films. The deposition parameters are systematically varied, optical properties and Si-H bond configuration of the resulting layers are characterized by using ellipsometry and ATR, respectively. Microstructure factors used for interpreting porosity of layers are calculated based on ATR results. “Bilayers” with a total thickness of 10 nm consisting of a porous interfacial layer and a dense capping layer are applied. The optimum thickness (2.2 - 4.4 nm) and microstructure factor (0.5) for the first layer are investigated to increase the passivation at the c-Si and i-aSi:H interface. Furthermore, the impact of post-hydrogen plasma treatment time on minority carrier lifetime is investigated. The results show that increasing post hydrogen plasma treatment time is more beneficial when the porous layer is thinner (Figure 4). The performance of heterojunction solar cells fabricated using bilayers will be investigated.

Figure 1



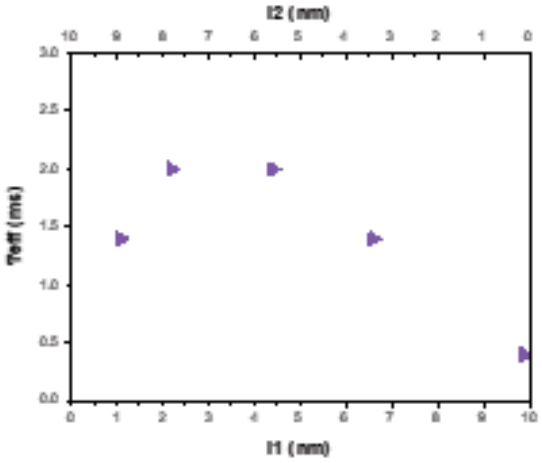
a) Deposition rate, b) refractive index (n1eV) and (c) optical bandgap (Eg, Tauc gap), of thin a-Si:H films (10 nm) as functions of the power density in PECVD process. Band gap and n1eV are also measured for the films deposited at 20 mW cm-2 and 80 mW cm-2 after post HPT process.

Figure 2



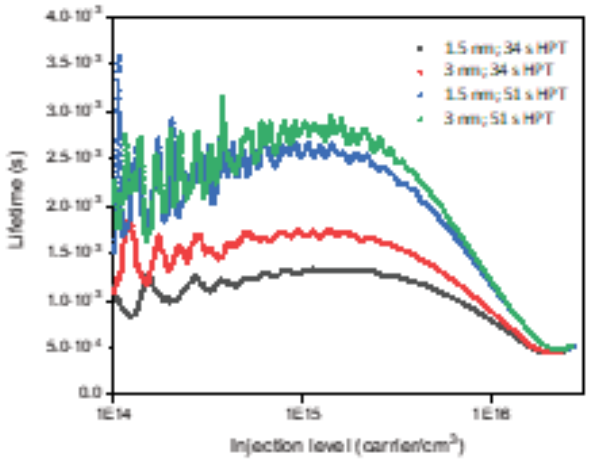
Microstructure factor (R*) of 25 nm a-Si:H films as functions of the power density in PECVD process. All the plots are the samples grown with SiH4:H2 1:4

Figure 3



Effect of the i1- to i2-layer thickness ratio on the effective lifetime of passivated wafers with i2/ i1/N/ i1/ i2 structures. The total thickness of the intrinsic bilayers is fixed at 10 nm.

Figure 4



QSSPC measurements for 10 nm bi-layers having different i1 thickness and treated with H2 plasma for 34s or 51s.

Keywords: bilayers, intrinsic amorphous silicon passivation, PECVD, Silicon Heterojunction

Pub No: O-006

Investigating the Impact of MZO-IZO Bilayer Transparent Conductive Films on the Performance of c-Si Heterojunction Solar Cells

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[3]Niğde Ömer Halisdemir University, Mechanical Engineering Department, Türkiye

Abstract: In this study, we utilized molybdenum-doped zinc oxide (MZO) and indium-doped zinc oxide (IZO), which are commonly used transparent conductive oxide (TCO) films, to investigate their performance in solar cells. Single-layer MZO, IZO, and bilayer MZO-IZO films were deposited at room temperature (RT) using radio frequency (RF) magnetron sputtering. The structural, optical, electrical, and morphological characteristics of the deposited TCO films were investigated. The thicknesses of single-layer MZO, IZO, and bilayer MZO-IZO films were determined to be 400 nm. Keeping this thickness constant, we varied the thicknesses of MZO and IZO films to obtain bilayer films with high optical transmittance (80% in the wavelength range of 400-1200 nm) and low sheet resistance (16.7 Ω/sq). The grain formation of TCO films was analyzed using XRD and AFM. We employed single-layer MZO, IZO, and bilayer MZO-IZO films as conductive oxide layers on the front surface of silicon heterojunction solar (SHJ) cells and thoroughly investigated their impact on the conversion efficiency of SHJ cells. The highest power conversion efficiency of 16.5% was achieved for SHJ solar cells fabricated using the bilayer MZO-IZO layer. These findings demonstrate the effective utilization of bilayer MZO-IZO films in solar cells.

Keywords: Transparent conductive oxide (TCO), molybdenum-doped zinc oxide (MZO), indium-doped zinc oxide (IZO), single-layer, bilayer, silicon heterojunction solar cell (SHJ)

Pub No: O-007

High Efficiency Cell Technology of JTPV

Xinrui An [1]

[1]JTPV

Abstract: As a Chinese professional solar cell manufacturer, JTPV released its latest n-type product MoNo1, featuring a range of advanced cell technologies including stack wafer depo technique, selective emitter (SE), metal-silicon contact optimization, super thin fingers and super-multi busbars (SMBB). Through optimization of surface and contact passivation as well as the use of finer front metal grid, an open circuit voltage (Voc) over 732mV is achieved. This high Voc, among other cell characteristics such as fill factor and conversion efficiency, can be well retained with a proprietary edge passivation treatment for half-cut cells, leading to power output up to 595W for a typical 144 half-cut module based on 182 square wafers.

Keywords: solar cell, contact passivation, selective emitter, n-type technology

Pub No: O-008

Improved Solar Cell Factory Design with increasing Equipment Throughput

Dilara Subasi [1], ***Peter Brailovsky*** [1], ***Baljeet Goraya*** [1], ***Jochen Rentsch*** [1], ***Sebastian Nold*** [1]

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Abstract: The throughput of PV cell manufacturing tools have increased by a factor of 2 to 4 times in recent years. This research provides recommendations for the planning of TOPCon (Tunnel Oxide Passivated Contact) PV cell factories with further increasing equipment throughputs in the future.PV equipment throughput and operational utilization are calculated with the deterministic techno-economic model SCost [3] and with a dynamic discrete event simulation performed with Tecnomatix Plant Simulation. Three scenarios were defined based on the technical equipment throughputs for: 1) reference case (R), 2) double of R (2R), and 3) quadruple of R (4R). Factory capacities are modelled from 1 to 5 GWp/a, in 1 GWp/a steps.The deterministic calculation reveals that a doubling (2R) or quadrupling (4R) of equipment throughputs result in significantly lower utilizations of a factory as for the reference case (R). As shown in Table 1, mean tools operational utilizations between 83% to 94% were obtained for R, while only 60% to 83% and 50% to 78% were achieved for 2R and 4R respectively. Therefore, factory capacities need to be tailored to avoid tools under-utilisation and throughputs losses associated to tools downtimes.With factory capacities of 1 GWp/a for 2R and 1 to 3 GWp/a for 4R, for some process steps only one tool would be required. In the event of a prolonged failure, this could result in zero net throughput. Discrete event simulations show net throughput losses can be avoided with work-in-process inventories and predictive identification of tool downtimes.

Tools operational utilizations per throughput scenarios and factory capacities.

Factory Capacity	Operational Utilization %								
	Minimum per process			Mean			Maximum per process		
	R	2R	4R	R	2R	4R	R	2R	4R
1GWp/a	86.1	51.7	25.8	93.9	60	49.5	97.4	76.2	76.2
2GWp/a	86.1	51.7	51.7	93.9	70.5	60	99.6	99.2	88
3GWp/a	86.1	72.4	54.3	93.9	82.7	78.4	99.6	99.8	99.8
4GWp/a	86.1	72.4	54.3	93.9	82.7	78.4	99.6	99.8	99.8
5GWp/a	68.9	86	64.6	82.9	89.4	82.1	99.6	95.2	95.2

Keywords: Photovoltaics, Solar cells, Factory planning, TOPCon, Techno-economic assessment

Pub No: O-009

Key points of advanced turnkey high-efficiency mass production line of different solar cells

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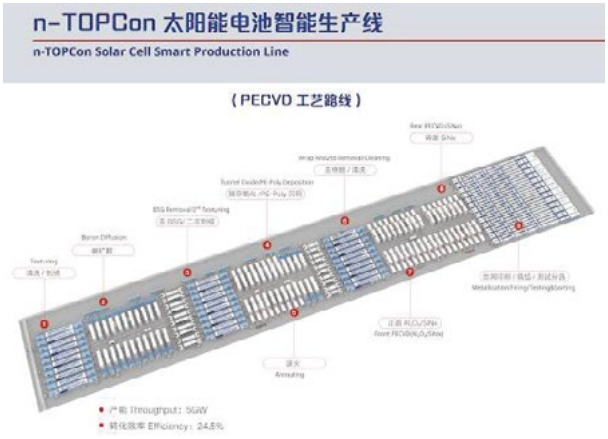
[1]S.C New Energy Technology Corporation

Abstract: Shenzhen SC has been deeply involved in solar photovoltaic equipment for 20 years and has provided over 200 international solar cell manufacturers with a total of over 700GW of various equipment, successfully exporting to 18 countries. In addition to being the largest provider of wet process equipment, it is also a leader in tube type coating equipment. With the successful shipment of roll-to-roll coating equipment, we provide various physical and chemical coating processes on production platforms such as slot type, tube type, plate type, and roll-to-roll. At the same time, we have also taken the lead in wafer cleaning equipment in integrated circuits and achieved fruitful results in silicon carbide straight furnace tube equipment. The most valuable solution we provide is the turnkey smart mass production solution for the entire factory. Those production linea include the main trend TOPCon, and HJT, Perovskite (PSC) solar cells. This article presents the comparison of individual equipment, the key points of how to combine various equipment to form a mass production line, and a summary explanation of the construction methods for various solar cells. Shenzhen SC provides one-stop services to meet customer customization requirements and provides the best engineering services.

Figure 1



Turnkey Solution provided by Shenzhen S.C

Keywords: Wet process, PVD, CVD, Roll-to-roll, TOPCon, HJT, PSC

Pub No: O-010

Advances in Turn-key solutions for high-efficiency TOPCon cells

Josua Stuckelberger [1], ***Kamel Ounadjela*** [1], ***Jia Liu*** [1], ***Fan Wei*** [1], ***Liang Xiao*** [1], ***Yao Zhang*** [1], ***Zhang Wu*** [1]

[1]LAPLACE Renewable Energy Technology Co., Ltd

Abstract: In the past four years, TOPCon cells have transitioned from record-breaking devices in research labs to a dominant technology for producing high-efficiency silicon solar cells at low costs, poised to capture over 60% of the market share in the next decade. Laplace, an equipment supplier, played a pivotal role in this transition from lab to manufacturing lines by introducing innovative and proprietary equipment for Boron diffusion and LPCVD for PolySi deposition, along with a reliable and cost-competitive process flow. Laplace-enabled manufacturing lines have achieved 15 world-record cell conversion efficiencies, including the current 26.89%. This contribution highlights recent advancements in Laplace TOPCon GW manufacturing lines and give an outlook on how to move towards 27% efficiencies and above. Several recent improvements have already taken place to primarily tighten the distribution of cell efficiency in manufacturing lines. For instance, the higher integrity of the tunnel oxide layer using LPCVD for the deposition of polySi layer has permitted to maintain high-efficiency cell performance in the manufacturing lines. Indeed, using LPCVD instead of PECVD for the polySi deposition has allowed a slight efficiency gain together with a higher overall performance of the cells. Moreover, measures like implementing a double-loading automation system for diffusion and polySi depositions (doubling throughput) and developing a proprietary nanocrystalline coating for quartz tubes, drastically improving their lifetime, have significantly reduced the cost of ownership (COO) for LPCVD deposition. Comparing LPCVD to PECVD for the PolySi layer enabled to decrease the COO by a factor of two.

Keywords: TOPCon, LPCVD, Poly Silicon, PECVD

Pub No: O-011

High Efficiency Solar Cell Turnkey Line Solution

Hongzhe Wang[1], ***Yuelong Huang***[1]

[1]Wuxi Songyu Technology CO., Ltd.

Abstract: This report mainly introduces Songyu's high efficiency solar cell turnkey line solution for the newest PVsolar cells process, high throughput and low material and media consumption, thus enabling to improve solar cells efficiency, to save energy and raw materials and to reduce manufacturing costs for highly efficient solar cells. The report will elaborate the most competitive TOPCon solar cell process at present time and the turnkey line solution. It also provides an overview of the turnkey line equipment and process solutions for perovskite solar cells, perovskite tandem solar cells, and TBC solar cells. Finally, the report also briefly introduces Wuxi Songyu Technology Co., Ltd. Songyu wish to contribute to the fast development of photovoltaics industry in Turkey.

Keywords: Perovskite Tandem cells, Solar cells turnkey line solution, TBC cells, Topcon cells, Topcon cells turnkey production line

Pub No: O-012

How Does License-Exempt Solar Excess Electricity Generation Affect Türkiye's Economic Growth?

Elif Dilek Yılmaz [1], ***Assoc. Professor Pınar Derin Güre*** [1]

[1]Middle East Technical University

Abstract: Türkiye, with ample sunlight, wind, and hydroelectric resources, is well-suited for developing renewable energy projects due to its geographic and climate characteristics. It aims to enhance its installed capacity by increasing the proportion of electricity generated from renewable sources. The unique model of license-exempt electricity generation, where most of the license-exempt generation falls on solar, primarily employed by solar power plants, presents investors with the opportunity to generate electricity for their self-consumption needs without obtaining a generation license and to sell excess electricity to the authorized supply company, subject to certain constraints. This study explores the relationship between license-exempt excess electricity generation and economic growth. Utilizing data from 81 cities in Türkiye from 2015 to2021, we employ the System GMM method to estimate the empirical model. The findings reveal a statistically significant positive impact of license-exempt excess electricity generation on economic growth.

Keywords: growth, solar, system GMM, license-exempt electricity generation

Pub No: O-013

Optimizing Photovoltaic Lifecycle Management: A Comparative Study of Business Models

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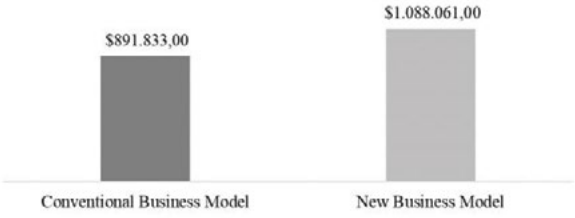
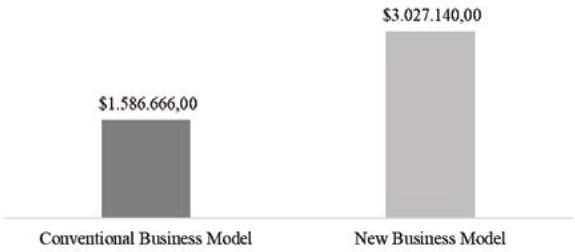
[1]Marmara University/Department of Mechanical Engineering
[2]Usak University/Department of Mechanical Engineering
[3]Marmara University/Department of Mechanical Engineering

Abstract: The escalating demand for solar energy necessitates effective lifecycle management of photovoltaic (PV) systems, particularly in the context of recycling and reuse. This study proposes an innovative business model that enhances the environmental and financial benefits of silicon-based solar panels. First, the current net present value (NPV) analysis yields the following comparison data: The NPV value for the conventional business model is $891,833, whereas the NPV value for the new business model is $1,088,061. Second, the new model projects a 45-year total income of $3,027,140 for a 1 MWE solar power plant, representing a 22% increase in profitability over the conventional model. Finally, following the financial analysis, the study assesses the environmental implications. The proposed model significantly reduces CO2 emissions, saving an additional 2.270 kg of CO2 per 550W PERC monocrystalline solar panel over its lifetime when compared to the conventional model. This corresponds to a 9% reduction in emissions, demonstrating the model's environmental benefits. The study's outcomes emphasize the potential of the solar panel recycling industry and contribute to discussions on sustainable energy production and responsible waste management practices. In conclusion, the research underscores the importance of adopting innovative business models in the solar energy sector to ensure sustainability and a reliable energy supply. It calls for collaborative efforts among investors, manufacturers, recyclers, and policymakers to implement these models effectively. The study also suggests that future research could explore the challenges of the new business model and its impact on other components of the solar power plant.

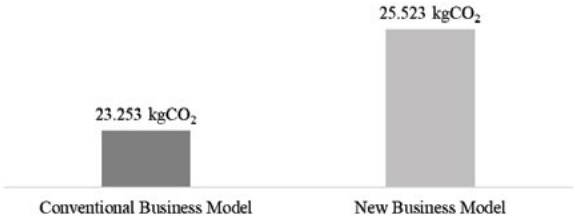
Net Present Value for 1 MW Solar Power Plant



Income from Electricity Sales for 1 MW Solar Power Plant



The Mitigated Carbon Emissions



Keywords: Recycling, Techno-Economic, LCA

Pub No: O-014

SOCIOECONOMIC ASPECTS OF SOLAR PV APPLICATIONS: EXAMPLE OF ANKARA PROVINCE AYAŞ DISTRICT

Ömer Faruk Tunçbilek [1], ***Emre Yıldırım*** [1]

[1]TENMAK/Clean Energy Research Institute, Ankara, Türkiye

Abstract: Renewable energy sources are comparatively less harmful in terms of environmental impact when compared to fossil fuels, and they are sustainable and clean energy sources. The efficient and effective utilization of these sources is crucial for ensuring a country's energy security. However, considering the effects of climate change and global warming on our planet in recent years, increasing the use of clean and renewable sources has become even more important.

In Turkey, the installation and proliferation of solar energy power plants have gained significant momentum, especially in the last decade. With the facilitation of regulations and increased incentives, investments in solar energy power plants have risen. As of March 2024, Turkey's installed electrical capacity is 107,799 MW, while the installed capacity of solar energy power plants is 12,636 MW [1]. According to Turkey's National Energy Plan, this momentum in solar energy is expected to continue to increase, with the solar energy installed capacity reaching 53,000 MW by 2035, in line with the net zero targets [2].

The environmental impact of solar energy power plants is considerably lower compared to fossil fuels or other renewable energy power plants. When considering the employment opportunities and social impacts it creates in the region, the social acceptance of solar energy power plants is quite high. However, if the socio-economic status of the region and environmental impacts are not taken into account during the installation and operation of these plants, social acceptance towards them can decrease [3].

This study aims to examine the societal acceptance of solar energy power plants among the residents living in the periphery of Ayaş district in Ankara Province and the factors influencing this acceptance. Evaluations will be conducted to increase societal acceptance towards these investments, and the socio-economic impacts of solar energy power plants as well as the environmental and social consequences they entail will be examined [4].

Keywords: Renewable Energy, Solar Energy, Environmental Effects, Social Acceptance

Pub No: O-015

Semi-Transparent Photovoltaic Windows in Türkiye: Exploring Stakeholder Perspectives on Opportunities and Barriers

Pınar Derin Güre [1], ***Bilge Şentürk*** [1], ***Güneş Kurtuluş*** [2]

[1]Middle East Technical University /Economics, ODTÜ-GÜNAM
[2]ODTÜ-GÜNAM

Abstract: As the world shifts towards sustainable energy, integrating renewable technologies into infrastructure is pivotal. Semi-transparent photovoltaic (STPV) windows generate solar energy while maintaining traditional window functions. This study explores the social dimensions of implementing STPV windows, focusing on opportunities, barriers, and social acceptance as perceived by key stakeholders in Türkiye. Using semi-structured interviews with a diverse group covering all quadruple helix, including community members, academicians, PV and window producers, civil engineers, architects, and policymakers from civil engineering and energy sectors, we uncover the perspectives on STPV adoption. This qualitative approach provides a rich understanding of the socio-cultural, economic, and environmental factors influencing the deployment of this technology.

Keywords: Semi-transparent photovoltaics, social acceptance, renewable energy, stakeholder perspectives, sustainable urban development, energy-efficient buildings, qualitative research

Pub No: O-016

EMPOWERING PV-INTEGRATED ENERGY COMMUNITIES THROUGH DIGITALIZATION: INSIGHTS FROM THE MASTERPIECE PROJECT

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[1]Uludağ Elektrik Dağıtım A.Ş.

Abstract: The transition towards sustainable energy systems demands innovative approaches that integrate renewable energy sources, particularly photovoltaic (PV) systems, within community contexts. This paper presents insights derived from the MASTERPIECE project, aimed at empowering energy communities through digitalization. Leveraging a multidisciplinary framework spanning from social sciences to marketing technology, MASTERPIECE introduces novel concepts, models, and methodologies to guide stakeholders in the creation and operation of energy communities, with a special emphasis on facilitating PV integration. Key elements include a digital ICT platform ecosystem, decision-making toolkits, and proactive engagement strategies to enhance the adoption and operation of PV systems within energy communities. Furthermore, the socioeconomic aspects of renewable energy applications such as addressing fuel poverty and promoting inclusivity within communities are emphasized. Through real-world pilots across diverse geographical including Turkey and regulatory landscapes, the project demonstrates the viability, scalability, and replicability of its solutions. This paper may offer valuable insights for policymakers, practitioners, and researchers seeking to advance community-based renewable energy initiatives, particularly in the context of energy communities and PV integration.

Keywords: Energy Community, Photovoltaic, Renewable Energy, Digitilization

Pub No: O-017

Evaluation of the Quality Components of the Urban Environment and their Influence on Citizen's Satisfaction by Use of Photovoltaic Systems for the Location of Gazimağusa/North Cyprus

MEHRDAD HAJIAN ZEIDY [1], ***Harun Sevinç*** [1],

MEHRDAD HAJIAN ZEIDY [2]

[1]Eastern Mediterranean University/Department of Architecture, Gazimağusa, North Cyprus
[2]University of Tehran/Department of Architecture, Tehran, Iran

Abstract: In times of environmental conflict, assessing the quality of the environment is crucial, as it impacts human satisfaction and well-being. Examining the building envelopes of buildings helps identify key elements influencing public perceptions. This article aims to evaluate the effectiveness of urban environment quality components and their influence on improving citizens' satisfaction through the installation of photovoltaic systems (PVs) on building rooftops. It clarifies and analyzes the concept of environmental quality, its affecting variables, and methods for assessing it in the urban landscape, providing a model to evaluate the urban environment quality of Gazimağusa / North Cyprus. In regards to practical objective, essence, and methodology, this study uses a descriptive survey methodology. To collect data, 300 questionnaires were randomly distributed among residents using Cochran's formula. Confirmatory factor analysis, variance testing, and one- and two-sample t-tests are the mainstays of the research approach. Citizen's satisfaction ratings of various aspects of the urban environment quality serve as a standard for assessing the quality of the urban environment in Gazimağusa / North Cyprus. The result shows that evaluating the quality of the urban environment is essential for the welfare and contentment of citizens. Cities may design surroundings that support use, pleasure, and health by looking at human cognition and enjoyment. Urban space quality can be improved by the use of photovoltaic systems (PVs), building exterior inspections, and assessment framework development. Future urban planning, decision-makers, and citizens working together can result in a more environmentally aware community.

Keywords: Urban Environment, Quality Components, Urban Space, Photovoltaic Systems, Citizen's Satisfaction

Pub No: O-018

A Case Study in Turkey (Akhisar): Opportunities and Constraints in the Transition to Solar Energy Transition.

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[1]Middle East Technical University, Sociology Department
[2]Bilkent University, Department of Political Science and Public Administration

Abstract: The global energy crisis and the intensifying effects of climate change have compelled various actors to seek alternative solutions. Solar energy is regarded as one of the most promising options in this regard. Conversely, the transition to solar energy use in various sectors (such as industry or domestic applications) necessitates an appreciation of the social context of energy consumption and the social impacts of the transition. The objective of this presentation is to discuss the findings of a social impact assessment study conducted as part of a wider research and development project. A panel research study was designed to gain insight into the perspectives and attitudes of various stakeholders regarding the transition to solar energy in the Akhisar district (Manisa province, Turkey). Akhisar is a sun-soaked district with extensive industrial (mainly olive-based) agricultural production and where local government plays a pivotal role in facilitating the widespread adoption of solar energy. The research involved the administration of semi-structured interviews with 22 key actors in the field of solar energy, conducted at two different points in time (October 2021 and December 2022). The research indicates that end-users have reservations regarding the decision-making process for various reasons. These include the instability of national policies, in addition to the infrastructural and architectural limitations, which create unevenness and render the transition process vulnerable to external constraints.

Keywords: solar energy, solar energy transition, social impact assessment, Akhisar, Türkiye.

Pub No: O-019

Drivers and Challenges of Solar Photovoltaics Adoption by Turkish Manufacturers

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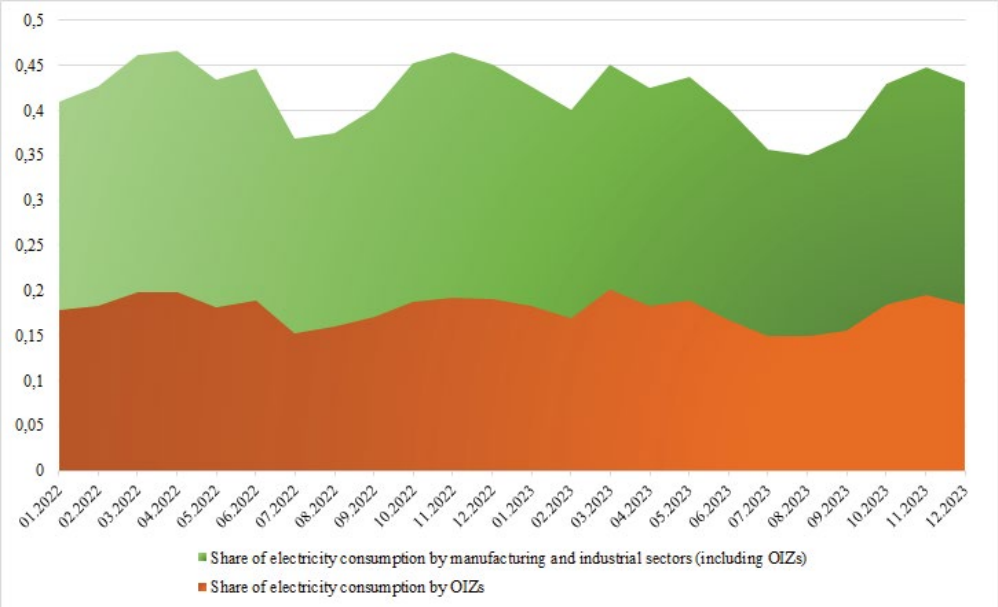
[2]Middle East Technical University

Abstract: In this research, we aimed to investigate the driving and challenging factors behind adoption of PV systems by manufacturing and industrial firms in Türkiye. To this end, we have conducted 17 semi-structured interviews with the managers of the Organized Industial Zones (OIZ) scattered around Türkiye. Due to their structurally mediating position between the government agencies and firms in PV applications, the OIZ managements were assumed to have accumulated the greatest and varying knowledge from both the government and firm perspectives. The main drivers behind adoption of PV systems revealed to be i) decreased payback period of investment due to high energy cost, ii) concerns over energy security, and iii) global climate change policies. The most challenging factors before PV adoption unfolded to be i) lack of infrastructural capacity, ii) architectural issues, iii) bureaucratic inertia, iv) panel market uncertainties, and v) lack of knowledge and dissemination of misinformation. Based on interviewee suggestions, we have provided policy advices that have potential to promote identified drivers and inhibit challenges. By addressesing the importance of industrial and manufacturing sectors' adoption of renewable energy in a developing country context, the present study fills a critical gap in literature caused by previous qualitative studies focusing primarily on households. To the best of our knowledge, no other research has investigated the manufacturing and industrial firms' perspective on renewable energy and, specifically, photovoltaics (PV) adoption in Türkiye.

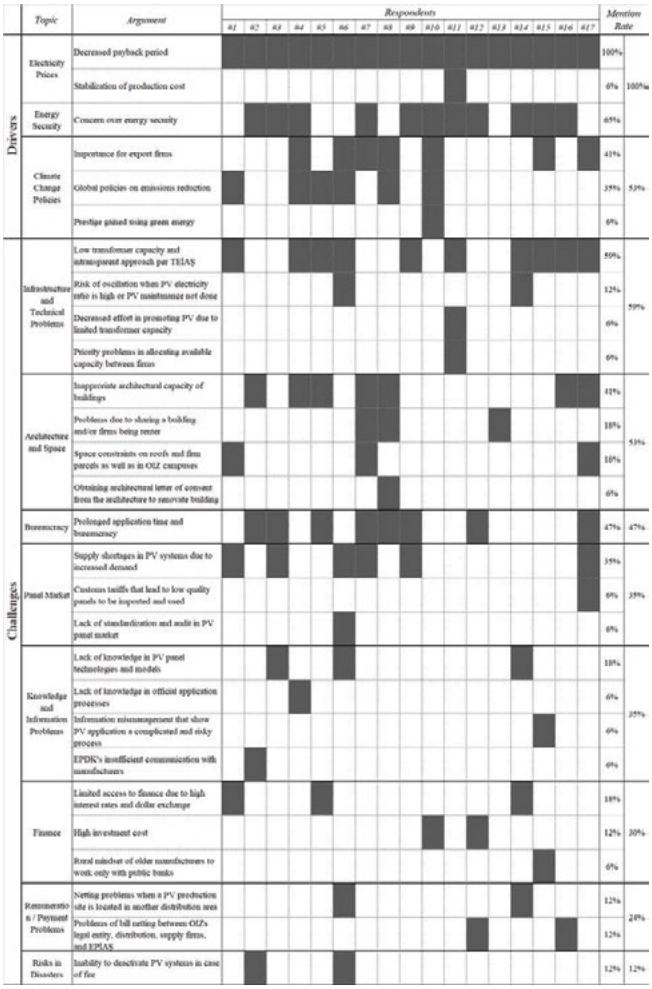
Sample Description

Interviewee						OIZ							
Interview #	Interviewee Role	Age	Gender	Education Level	Education Field	Region	Foundation Year	Operational Status	Area (ha.)	# of Lots in OIZ	Occupancy Rate	# of Firms	Elec. Dist. License
#1	OIZ Director	42	M	Bachelor	Labour Economy and Industrial Relations	Mediterranean	1973	Active	2227,4	566	99%	385	Yes
#2	OIZ Director	55	M	Masters	Electrical Engineering	Mediterranean	1976	Active	734,6	330	100%	331	Yes
#3	OIZ Director	57	M	Bachelor	Mechanical Engineering	Aegen	1975	Active	503	214	100%	136	Yes
#4	OIZ Director	51	M	Bachelor	Architecture	Southeastern Anatolia	1990	Active	921	384	96%	210	Yes
#5	OIZ Director *acc. by Deputy Director*	50	M	Bachelor	Geomatics Engineering	Marmara	2011	Active	753,4	244	56%	120	No
#6	OIZ Director *acc. by Energy Manager*	45	M	Bachelor	Mechanical Engineering	Southeastern Anatolia	1969	Active	4447	1465	100%	1132	Yes
#7	OIZ Director	50	M	Masters	Urban Systems and Transportation Management	Marmara	2002	Active	151	249	100%	768	No
#8	OIZ Director *acc. by Electrical Engineer*	44	M	Masters	Civil Engineering	Marmara	2000	Active	741,6	376	98%	974	Yes
#9	OIZ Director *acc. by Energy Op. Manager*	46	M	Bachelor	Mechanical Engineering	Central Anatolia	1976	Active	2199,3	1225	99%	1179	Yes
#10	OIZ Director	50	M	Bachelor	Geodesy and Photogrammetry	Marmara	1998	Active	847,96	528	63%	229	Yes
#11	OIZ Director	54	M	Bachelor	Electrical Engineering	Central Anatolia	1976	Active	2273	784	99%	790	Yes
#12	OIZ Director *acc. by Elec. Op. Manager*	43	M	Masters	Civil Engineering	Aegen	1999	Active	85,52	41	95%	38	Yes
#13	OIZ Director *acc. by Electrical Engineer*	51	M	Bachelor	Architecture	Mediterranean	1993	Active	756	230	99%	211	Yes
#14	OIZ Director	51	M	Bachelor	Business and Accounting	Marmara	2001	Active	234	286	100%	300	Yes
#15	OIZ Director	51	M	PhD	Elec. Engineering / Electronics & Communication Engineering	Marmara	2015	Building Phase	315	189	62.27%*	90*	No
#16	OIZ Director	54	M	Bachelor	Civil Engineering	Black Sea	1994	Active	161	98	100%	76	Yes
#17	Energy Consultant	47	M	PhD	Electrical Engineering / Solar Energy Technologies								

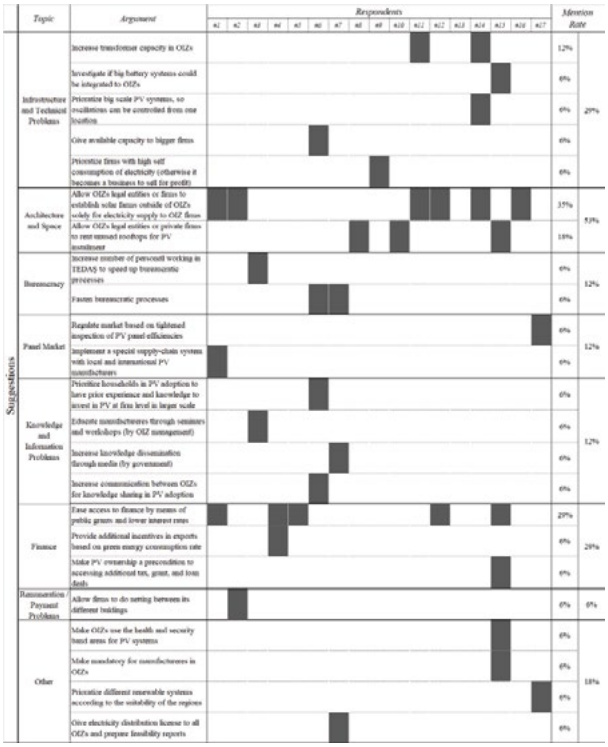
Share of Elec Cons by OIZ



Drivers and Challenges



Suggestions



Keywords: PV Adoption, Manufacturing Sector, Industrial Sector, Türkiye, Drivers and Challenges

Pub No: O-020

Socio-economic Impact Assessment of Solar PV Technology in Türkiye

Esin Yazıcı [1], ***Erkan Erdil*** [2], ***Pınar Derin Güre*** [2]

[1]Middle East Technical University, Science and Technology Policies Research Center, Ankara, Türkiye
[2]Middle East Technical University, Department of Economics, Ankara, Türkiye

Abstract: The increasing demand for energy around the world and the shortages experienced both regionally and globally, bring localized production of energy right to the center of our national agenda. Due to high inflation in Türkiye, the increase in energy prices impact pricing of all related commodities, causing a considerable burden to the livelihood of citizens. As local energy production becomes critical to mitigate import costs and ensure energy independence, projects/platforms like TFTP (Turkish Photovoltaic Technologies Platform), led by ODTU GUNAM, become of vital importance. One sub-project of TFTP, SOLARSOS, aims to asses the possible socio-economic impacts of this transition to solar energy utilization, through content analysis of in-depth interviews with 25 solar stakeholders contributing to this field through; work in this project, academia, private sector, public instiutions and NGOs. This research study aims to provide a thorough evaluation of interviews conducted within this context, using MaxQDA content analysis software, along with additional qualitative and quantitative inputs from solar energy literature constructing a current overview of global energy supply and how we can organize and diversify our sourcing abilities for a cleaner energy feed to ensure a sustainable development through social, cultural and economic improvements. The study also aims to include policy recommendations to ensure an efficacious integration of higher solar energy capactiy into the energy mix, while enchancing socio-economic impacts of this transition.

Keywords: Solar, Photovoltaic, Solar Energy Transition, Social Impact Assessment, Energy Policy

Pub No: O-021

Managing End-of-Life Photovoltaic Panels: A Comparative Analysis of National Policies and Regulations

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[2]Middle East Technical University (METU) - Department of International Relations

Abstract: This paper explores the challenges of photovoltaic (PV) waste management. PV panels are gaining popularity as they play a significant role in global energy transition from fossil fuels to renewable sources. However, when PV panels reach the end of their lifespan, proper waste management and disposal practices are crucial to minimize their environmental impacts and ensure the efficient use of resources. Therefore, defining rules and regulations for PV waste is a critical issue as panels reach their end-of-life (EOL). Such regulations are usually imposed by governments or local authorities. Therefore, this paper adopts a holistic theoretical approach to the topic by synthesizing the theories of circular economy, PV lifecycle management and policy analysis into a coherent perspective. The research methodology is as follows: For the countries that will potentially generate the highest amount of PV waste, as well as Türkiye, policy and regulation documents will be collected through their publicly available official documents. Secondary data published by international energy organizations and academic institutions will also be collected and analyzed. Using the comparative policy analysis, which is a commonly-used qualitative methodology, these documents will be compared in terms of the following criteria: logistics, subsidies and incentives, actors and responsibilities, waste management plans, collection and treatment targets, definition of recycling and recovery, and regulatory arrangements for PV panels. Such a comparative analysis of different countries' policy frameworks will help authorities to adopt actionable policy recommendations. Finally, our study will involve a SWOT analysis of Türkiye's potential national strategies for PV waste management.

Keywords: PV waste management, photovoltaic modules, renewable energy, recycling, policy, regulations, electronic waste, end-of-life PV panels

Pub No: O-022

THE EVOLUTION OF TURKISH SOLAR ENERGY RESEARCH NETWORK IN THREE PERIODS

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Abstract: This paper examines the research activities on solar energy in Türkiye and identifies the main actors and characteristics of the change in Turkish solar energy research network in three periods of pre-2000s, 2000-2009 and 2010-2019. The study presents the factors that have affected the network dynamics and research trends, and contributes to the literature by combining two different data sources of scientific publications and EU Projects. We used a panel dataset for the bibliometric analysis of Türkiye (TR)-addressed publications. The dataset was downloaded from Clarivate Analytics Web of Science (WoS) core collection using the solar energy-related part of the query developed by Armitage, Lorenz, and Mikki [1]. Our search on 8 June 2021 ended up with 3043 documents after data cleaning. For the pre-2000s period, the publications go back to the second half of the 1970s despite the fact that there was not a regular production of scientific publications till the 1990s. Information on all projects carried out since the beginning of Framework Programmes (1984) was downloaded from European Union Open Data Portal on 12 June 2021. By searching Turkey ("TR") in the organization address field and related keywords ("solar","pv", "photo") in the title, objective, and keyword fields, we found 122 projects on solar energy. After manual filtering for irrelevant projects, we identified 58 FP projects at least one TR-addressed organization included between 1996-2020. By combining these two dataset, we tentatively describe the research network dynamics in solar energy in Türkiye.

Keywords: Solar Energy, EU projects, bibliometric analysis, Turkiye, research network, collaboration

Pub No: O-023

Unlocking Türkiye's Solar Potential: A Computable General Equilibrium Analysis

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[2]TSKB

Abstract: Due to its geographical and climatic conditions, Türkiye has a high potential for solar photovoltaic (PV) energy. The crucial aspect of this potential is analyzing whether it can turn into domestically produced energy, as the energy supply is already highly dependent on imports, especially fossil fuels. This study aims to analyze the effects of increasing the share of solar PV in the Türkiye's electricity production mix, using two Computable General Equilibrium Models (CGE) for Türkiye, with different production structures. No other study for Türkiye uses CGE to focus on sole impacts of solar PV energy. An electricity sector detailed social accounting matrix (SAM) for Türkiye is constructed for 2021 for the model. It is the most detailed and recent SAM for Türkiye. For the scenario, it is assumed that the productivity of solar PV electricity production will increase due to the actions taken by TFTP. The environmental impacts of the shock are calculated based on the avoided carbon emissions. The results indicate that the output, domestic production, and exports of solar PV electricity increased, along with the other electricity sectors. Other affected sectors are the ones that are highly related to solar PV and have high energy intensity. Moreover, the macroeconomic effects of the shock coincide with the expected results. Also, high levels of carbon emission can be avoided if solar PV electricity replaces fossil fuels.

Keywords: Computable General Equilibrium Models, Social Accounting Matrix, Solar Photovoltaic Energy, Carbon Emissions, Türkiye

Pub No: O-024

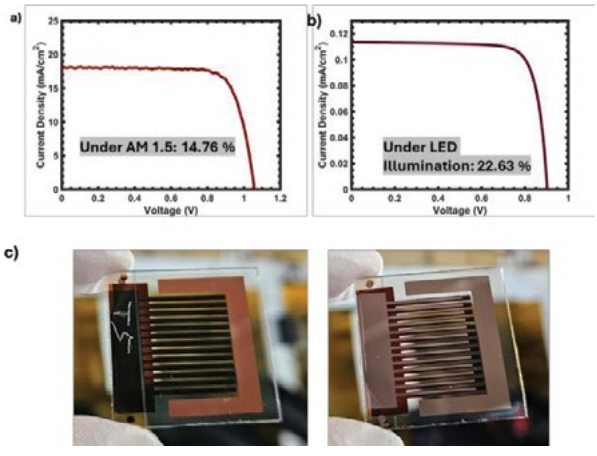
NOVEL PATTERNING APPROACH FOR LARGE-AREA TRANSLUCENT PEROVSKITE SOLAR CELLS FOR INDOOR APPLICATIONS

Mustafa Yaşa [1], ***Bahri Eren Uzuner*** [1], ***Görkem Günbaş*** [1], ***Selçuk Yerci*** [1]

[1]ODTÜ-GÜNAM-Center for Solar Energy Research and Applications
[2]Middle East Technical University

Abstract: Towards commercialization, the performance of perovskite solar cells (PSCs) under indoor illumination has been highly attractive due to their high power conversion efficiency (PCE), durability, low-cost production, and tunable band gaps. Translucent PSCs for indoor applications combine high-efficiency perovskites with aesthetic appeal, offering innovative architectural elements and facilitating the transition from opaque to transparent devices. Their band gap tunability allows for various applications in energy harvesting at suitable locations, leveraging the novel properties of perovskite materials, which are highly efficient at low-intensity light. In this study, perovskite materials were prepared using a sequential deposition process involving the masked evaporation of inorganic precursors followed by the spin-coating of organic precursors. Using the laser-free patterning method we fabricated translucent PSCs with 2.5 cm2 active area for light harvesting under both AM 1.5 and indoor illumination. The preliminary results showed a PCE of 14.76 % under AM 1.5, and a PCE of 22.63 % under indoor illumination (1000 lux, white LED). These findings highlight the potential of laser-free fabrication pathway for translucent PSCs.

Figure 1



Keywords: perovskite solar cells, band gap tuning, sequential deposition, large-area perovskites, translucent perovskites

Pub No: O-025

Pushing the Boundaries: Optimizing the Lamination Processes for Photovoltaic Modules in New Application Areas

Aksel Kaan Öz [1], ***Christine Wellens*** [1], ***Martin Heinrich*** [1], ***Holger Neuhaus*** [1]

[1]Fraunhofer ISE

Abstract: This paper presents a comprehensive study on the challenges of laminating photovoltaic (PV) modules for various applications. It discusses the optimization of the module design and the interconnection- and lamination processes for new cell types and additionally with regards to modules for special applications as VIPV, RIPV, etc. With the shift in solar cells from PERC to more effective Tandem cells, the manufacturing process of modules requires adaptation of process parameters [1]. Our study reveals that while PERC cells can be laminated at temperatures up to 180 °C in a short time process, tandem cells are more sensitive to high temperatures and therefore require low temperature lamination processes [2,3]. We have developed an in-house simulation tool that helps optimizing the process parameters by modeling the temperature- and crosslinkingprofile in the module during the lamination process. In contrast to standard modules, modules for new applications often have to fulfill additional requirements. This includes laminating the module on metal, dealing with 3D curved shapes, and mitigating sun reflectance of modules used as noise barriers on highways [4]. Sometimes, the bill of materials (BOM) also needs to be adjusted to meet all these requirements. In our study, we performed FEM simulations to simulate the themomechanical stress in solar modules for different applications in order to identifythe appropriate BOM for the modules. In conclusion, this study provides valuable insights into the considerations for designing modules for new applications and highlights the importance of optimizing the lamination process to enable the production of these modules.

Keywords: Lamination, Simulation, Module Design, FEM, VIPV, RIPV, Shingle Matrix Technology

Pub No: O-026

Environmentally Sustainable Methodologies for the Extraction of Ethyl Vinyl Acetate (EVA) from PV Panels Dismantled by Hot-Knife Technic

Refika Budakoğlu [1], ***Deniz Avcı Akın*** [1], ***İrem Olcay İrey*** [1], ***Ersin Gökçen*** [1], ***Güray Kasapoğlu*** [1], ***Duygu Yılmaz*** [2]

[1]T. Şişe ve Cam Fabrikaları A.Ş.
[2]Institute for Energy Technology

Abstract: The EU project 'Reintegration of photovoltaic panel waste back into manufacturing as high value' (RETRIEVE) aims to enhance the circularity and minimize the environmental impact of the Photovoltaic (PV) industry though the development and implementation of cost effective recycling technologies for the different components of silicon solar modules. As the beneficiary partner of the project, Şişecam aims to employ a close-loop recycling process for glass, thereby utilizing End-of-Life (EoL) PV panels as novel raw materials in PV panel production. In literature, there are many ways to separate EVA using mainly acidic chemicals and organic solvents, with the help of many secondary processes such as ultrasonic irradiation, thermal decomposition for the complete removal of EVA. In this study, we demonstrated the cleaning of EVA-adhered intact glass, which was dismantled from the PV module with the hot knife technique, using environmentally friendly chemical dissolution.

Keywords: Photovoltaic panel, Hot Knife Technic, Recycle, Sustainability

Pub No: O-027

Analyzing the Changesin Electrically Conductive Adhesives During the Curing Process for Shingled Solar Cells

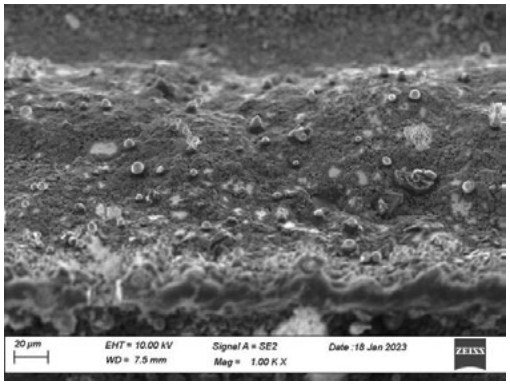
Meryem Ezgi Karahallı [1,2], ***Parisa Sharif*** [1], ***Cem Maden*** [1,2],

Melisa Korkmaz Arslan [1], ***Veysel Unsur*** [1,4], ***Talat Özden*** [1,3]

[1]ODTÜ-GÜNAM, 06800, Ankara, Türkiye
[2]METU, Micro and Nanotechnology Programme, Ankara, Türkiye
[3]Department of Electrical and Electronics Engineering, Gümüşhane University, Gümüşhane, Türkiye
[4]Department of Fundamental Sciences in Engineering, Necmettin Erbakan University, Konya, Türkiye

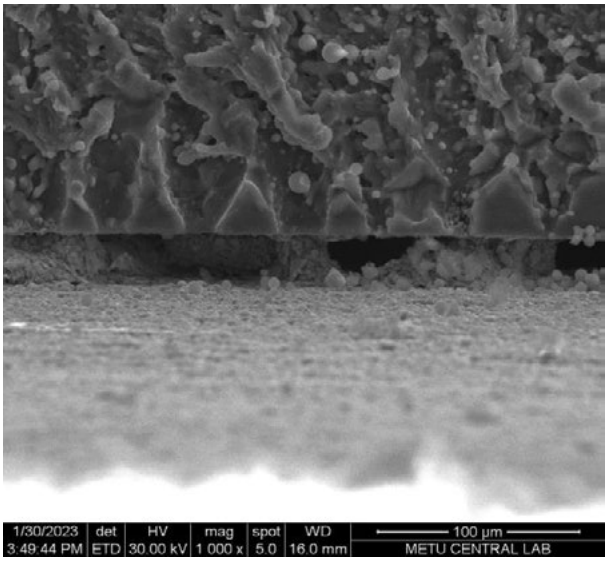
Abstract: Compared to conventional solar cells, the shingled array of solar cells has the advantages of a larger active area and lower current density. This method enhances module power while utilizing the same installed area, by reducing current density, which is a major factor in power loss. Initially, optimal cell parameters were determined through simulation, followed by the production of full-cell shingled arrays. Instead of conventional metal ribbon connections, shingled solar cells can be connected using electrically conductive adhesives (ECAs), enhancing active surface area for photo-current production and mainly defines the conductivity mechanism of ECAs, enabling high-power, high-efficiency modules to be developed, it is crucial to achieve the best efficiency by reducing the shading loss. Measurement of electrical resistivity changes during curing allowed assessment of the impact of component materials on the electrical characteristics of ECAs. Before curing, the ECAs with silver particles showed an electrical resistance of 4.0x10-3 Ohm-m. A curing period of over 300 seconds was required at lower temperatures to achieve a comparable efficiency improvement. This analysis are consistent and important regarding the cell efficiency of serially connected and separated cells made using the shingled array approach. In this study, we demonstrated how the efficiency changed for binary slices bonded with ECA, which has an area of around 94.8 cm2, and the influence of the curing temperature and time conditions on the characteristics of the ECA film and interconnected cell. This research also introduces an innovative method for extracting the ECA's resistance contribution to the connected cell.

ECA characterization via SEM and EL images



Surface morphologies of ECA films at Tcuring: 120 °C and tcuring:300s

ECA characterization via SEM and EL images



Surface morphologies of ECA films distribution on silicon cell

ECA characterization via SEM and EL images

EL image of shingled mini-module

Keywords: Shingled, ECA, Curing conditions, Busbar-less structure, Photovoltaic, Array

Pub No: O-028

Toward Sustainable PV Systems: Evaluating Alternative Encapsulant Materials for Enhanced Reliability

Abdulkerim Gok [1]

[1]Gebze Technical University

Abstract: During operation, photovoltaic (PV) modules encounter various environmental factors such as heat, humidity, ultraviolet radiation, and mechanical stresses. These conditions can lead to several degradation issues including delamination, discoloration of encapsulants, corrosion of cell metallization, and potential-induced degradation. Ethylene-vinyl acetate (EVA), though a leading encapsulant material, is particularly susceptible to humidity, breaking down to produce acetic acid, which significantly impacts the long-term performance of PV modules. Therefore, the selection of robust encapsulation materials is crucial for enhancing the durability and reliability of PV systems.This research explored the use of polyethylene copolymer-based encapsulants as alternatives to EVA. To reduce humidity ingress, double-glass construction with edge-seal was employed. One-cell mini-modules encapsulated with a crosslinking polyolefin elastomer, a non-crosslinking thermoplastic polyolefin, and an ionomer were tested under a damp heat protocol (85°C / 85% RH) for up to 5000 hours. The current-voltage characteristics indicated that these materials have strong potential to mitigate the negative effects of humidity on PV module performance. Considering the activation energies for power degradation under damp heat conditions, these enhanced modules could potentially achieve a service lifetime of 40 years even in severe conditions.From both economic and environmental viewpoints, extending the service lifetime of PV systems is expected to decrease the levelized cost of electricity and reduce greenhouse gas emissions, contributing to a more sustainable energy future.

Keywords: PV modules, encapsulant materials, lamination, durability and reliability, damp heat testing

Pub No: O-029

The Impact of Photovoltaic Panels on the Environment and Yield Parameters in an Open Field Agrivoltaic System: A Case Study in Ayaş, Ankara

Bilge Şentürk [1], ***Rıdvan Çelik*** [1], ***Güneş Kurtuluş*** [1], ***Talat Özden*** [1], ***Yelda Öylek*** [2], ***Zeynep Sevim Kanar*** [2]

[1]ODTU-GUNAM
[2]METU, Statistics

Abstract: Agrivoltaic systems are an innovative approach that combines energy and agricultural production by utilizing photovoltaic panels over agricultural areas, providing both economic and environmental benefits. This study aims to monitor and analyze critical parameters such as soil moisture, air temperature, Photosynthetically Active Radiation (PAR), energy and plant productivity in an agrivoltaic system installed in Ayaş, Ankara. Soil moisture and air temperature were regularly recorded using sensors, while PAR values were measured with a spectroradiometer. Both agricultural and electrical production values were monitored and documented. In the statistical analysis of the obtained data, correlation and regression analyses were used to examine the relationships between the parameters. The results were presented through comparative analyses to determine the effects of the agrivoltaic system on crops and energy productivity. The findings are crucial for developing models that predict and optimize the performance of agrivoltaic systems in future stages.

Keywords: Agrivoltaics, Soil Moisture, Air Temperature, PAR, Plant Productivity, Energy Production, Statistical Analysis

Pub No: O-030

METEROLOJICAL SENSORS SELECTION FOR PV PLANTS

İlhan Bora Serin [1]

[1]Seven Sensor Solutions

Abstract: Meteorological sensors play a crucial role in the efficient operation of photovoltaic (PV) plants. These sensors help in monitoring various environmental parameters that can affect the performance of the solar panels and the overall efficiency of the plant. Therefore, selecting the right meteorological sensors for a PV plant is essential to ensure optimal functioning of the PV plant and maximum energy production. There are several key parameters that meteorological sensors measure in a PV plant, including irradiance, module temperature, ambient temperature, soiling, wind speed/direction, snow, hail and humidity. These sensors provide data that can be used to optimize the performance of the plant and ensure that the plant is operating at its full potential. However, there is limited knowledge about how to utilize these sensors ina PV plant. It is normal the end-user may not specialize on this subject. But this is a common question even for EPC and consulting companies. What is the reason that wind direction sensor is required for a PV Plant? In this talk there will be answer for what is the function of each sensor in PV Plants. Also, attendees will have knowledge about recent development for photovoltaic based sensor technologies and types of PV based sensors. The goal of the talk is to provide attendees with the right tools and knowledge, to better positioned to make informed decisions when choosing sensors for PV systems, ultimately leading to improved energy yield, reduced downtime, and increased return on investment.

Figure 1

SEVEN Weather Station

Keywords: Meteorological Sensor, Monitoring of PV Plant

Pub No: O-031

Multidimensional Assessment of Agrivoltaic System Potential in Turkey

Harun Gümüş [1], ***Mete Çubukçu*** [1], ***Hasan Sarptaş*** [1]

[1]Ege University Solar Energy Institute

Abstract: Climate change and the need to increase food production due to a growing population are global challenges that require urgent solutions. The depletion of fossil fuel resources in the coming years and the greenhouse gases emitted as a result of the use of these resources to generate energy cause climate change. In this sense, it is critical to reduce carbon emissions by using renewable and clean energy sources such as solar energy. The concept of agrivoltaics proposes to use a piece of land both for solar energy production and for agricultural activities. Turkey has a significant agrivoltaic potential with vast agricultural lands and strong solar energy capacity. Turkey has 24 million hectares of arable agricultural land, which is approximately one third of its 78 million hectares. This study aims to assess the agrivoltaic potential of Turkey by using Geographic Information Systems (GIS). The study analyzes multi-layered datasets including solar radiation, soil characteristics, climatic conditions, and current agricultural use patterns. The results demonstrate the feasibility of agrivoltaic systems across Turkey, thus demonstrating the potential to both increase energy production and sustain agricultural production. In conclusion, this study shows that Turkey has significant potential for agrivoltaic systems. The research supports strategic planning for the deployment of agrivoltaic systems in various regions of the country and details the potential for large-scale implementation of these systems to increase the country's renewable energy capacity.

Research Method Applied for Determining APV Potential

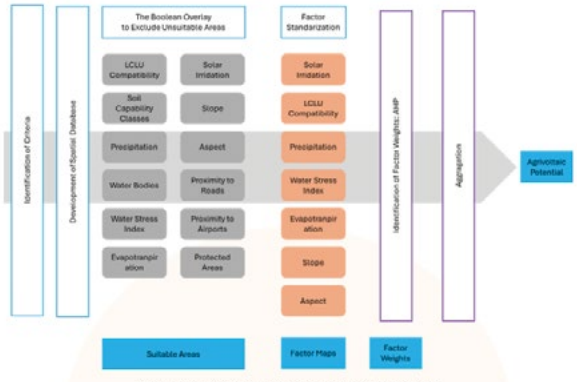


Figure 1. Research Method Applied for Determining APV Potential

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Keywords: Agrivoltaics, Solar Energy, Sustainable Agriculture, Geographic Information Systems (GIS), Energy-Food Nexus

Pub No: O-032

Agrivoltaic System Design for Sugar Beets and Wheat in Central Anatolia

Ömer Yalçın [1], ***Duygu Kuzyaka*** [1], ***Talat Özden*** [1], ***Dilara Güney*** [2], ***Talat Özden*** [3]

[1]Center for Solar Energy Research and Applications (ODTÜ-GÜNAM), Middle East Technical University
[2]Department of Architecture, Middle East Technical University
[3]Electrical and Electronics Engineering, Gümüşhane University

Abstract: The agricultural sector's reliance on energy-intensive practices contributes to significant environmental pressures, particularly through carbon emissions from fossil fuels. Agricultural Photovoltaic Systems (AgriPV) offer a promising solution by integrating solar panels into agricultural land, enabling dual-purpose use for energy generation and crop cultivation. AgriPV systems not only provide additional income streams for farmers but also mitigate energy costs and carbon footprints, thus fostering agricultural sustainability and energy transformation. In this study, we aimed to examine the potential effects and advantages of AgriPV in the agricultural sector by considering the light requirements of wheat and sugar beet crops, commonly grown in the Central Anatolia region. Our objective was to achieve optimal system design by taking into account the light needs of the plants, ensuring that they are neither exposed to excessive nor inadequate light. The obtained AgriPV designs can improve temperature control by providing suitable shading for plants and contribute to the efficient use of water, thereby enhancing the quality and quantity of agricultural products. Additionally, the creation of a microclimate by the plants can lead to a reduction in panel temperature, thereby contributing to the increased energy efficiency of solar panels. This research underscores the potential of AgriPV to address both energy and agricultural challenges, offering a sustainable solution that promotes environmental stewardship and economic prosperity in the agricultural sector.

Sample Agriculture Solar Power Plant design

Keywords: Agrivoltaics, PAR Analysis, Shading control, Renewable Energy, Sustainability

Pub No: O-033

Glare Effect Assessment for the Highway, Circular Road Junction, and Airport in the Mardin Region

Rıdvan ÇELİK [1], ***Duygu KUZYAKA*** [1], ***Talat ÖZDEN*** [1], ***Talat ÖZDEN*** [2]

[1]Center for Solar Energy Research and Applications (ODTÜ-GÜNAM), Middle East Technical University, Ankara 06800, Türkiye
[2]Electrical and Electronics Engineering, Gümüşhane University, Gümüşhane, 29100, Türkiye

Abstract: The increasing use of fossil fuels has led governments and authorities to redirect their focus towards renewable energy sources with solar energy being the most preferred option. Türkiye's geographical location ensures abundant sunny days, creating favorable conditions for the utilization of solar energy. However, installing solar power plants (SPPs) presents challenges like land requirements, limited energy production, and the need for approval from regulatory bodies. One of the primary analyses required for approval is glare and glint analysis. The fundamental difference between glare and glint lies in the duration of the risk they pose, where glint is instantaneous whereas glare persists for a longer period. Glare, affecting both drivers on highways and pilots landing and taking off at airports, can lead to accidents [1]. Mardin, with an annual sunshine duration of 3034 hours and a radiation value of 1589 KWh/m², possesses a higher solar energy potential concerning other regions. This may lead investors to choose Mardin as the location for SPP investments. In this study, the impact of a selected area for SPP installation near Mardin Airport on the historical Silk Road, drivers using the nearby four-way intersection, pilots using the air route, and the military zone near the airport as glare risk factors were investigated. The study also discussed various panel tilt angles, module glass types, and methods to mitigate glare from the SPP, along with the energy production potential, considering single-axis tracker, dual-axis tracker, and fixed system designs for the selected SPP site.

Keywords: Glint and Glare Analyses, Glare Parameters, Forge Solar, SPPs.

Pub No: O-034

Comparison of Panel Glass Surface Texturing for Anti-reflective and Anti-soiling Properties by Three Methods: RIE, MACE and LIPSS

Arian Goodarzi [1], ***Zeynep Cantürk*** [3], ***Mersiye Karakaş*** [2], ***Talat Özden*** [1], ***Alpan Bek*** [3]

[1]ODTÜ-GÜNAM, 06800 Ankara, Turkey
[2]Micro and Nanotechnology Program, ODTÜ, 06800 Ankara, Turkey
[3]Physics Department, ODTÜ, 06800 Ankara, Turkey

Abstract: The main two problems of PV panel glass are the reflection of the sunlight and soiling. To improved light management properties, micro- and nano-texturing of glass surface also has the potential to lend anti-soiling properties by minimizing contact area between dust and glass surface and exhibiting super-hydrophobic property. In this study, texturing of 2 mm soda-lime glass surface of flat PV panel by using three methods. The first method is the reactive ion etching (RIE) method at nanoscale to gain anti-reflective and anti-soiling properties. In this method, the size of 156 mm x 156 mm, 40 mm x 100 mm and 100 mm x 100 mm samples were used. After coating aluminum doped zinc oxide (AZO) the surface of sample RIE texturing was performed. The second method is metal assisted chemical etching (MACE) using an aqueous solution of HF as etchant and Ag and Al as catalysts. The samples of sizes were 20 mm x 20 mm. The third method is laser induced periodic surface structure (LIPSS) using 1030 nm wavelength femtosecond laser with maximum scan range of 300 mm x 300 mmm. Successful ordered and large area LIPSS on glass surface will be demonstrated for the first time in the world in this work. The resulting glass surface textures are characterized using dark-field optical and scanning electron microscopies. Optical properties are characterized using spectrally resolved optical transmission and haze measurements and the results are presented and compared. This work is supported by TÜBİTAK under grant nr 20AG002

Keywords: LIPPS, RIE, Glass surface ehtcing, MACE

Pub No: O-035

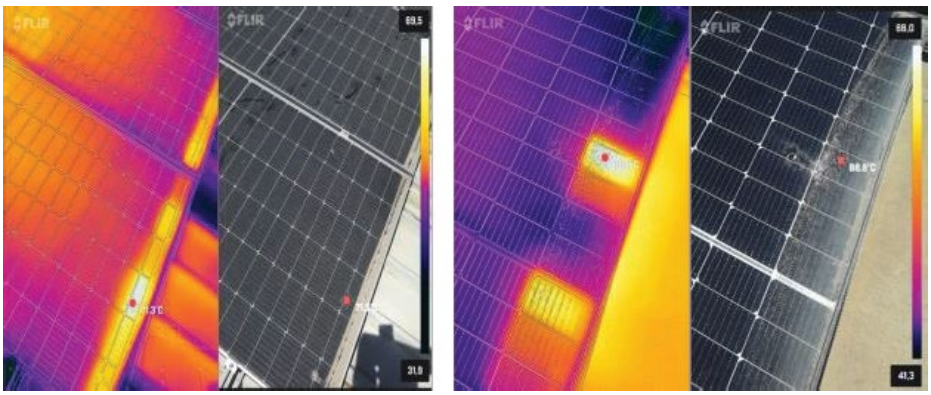
Techniques and Trends in Photovoltaic Panel Cleaning for Sustainable Solar Energy

Batuhan Mert LAÇİNKAYA [1]

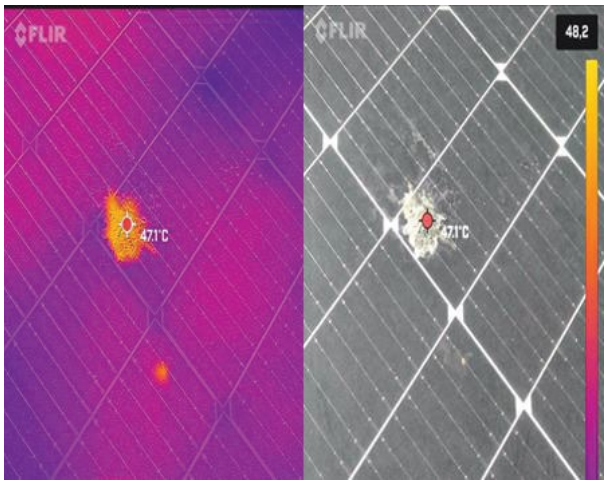
[1]ROBSYS ROBOTIC SYSTEMS

Abstract: Solar energy is gaining importance worldwide as a clean and sustainable energy source. Decreases in photovoltaic cell prices, increasing cell efficiencies, and countries' energy policies influence this trend. However, regular maintenance and cleaning are essential to enhance the sustainability of energy production and ensure the long-term use of photovoltaic panels. Dust and pollution significantly affect solar panel performance by covering their surfaces and impacting sunlight absorption, reflection, and heat transfer. Pollutants such as red soil, ash, sand, calcium carbonate, and silica can reduce panel efficiency[1]. Studies show that regular cleaning can increase solar panels' energy production efficiency by 11.1% [2].However, care is needed during cleaning. Using detergents or chemical products can leave marks on the panel's surface and cause corrosive effects on its substructure. Additionally, there is a high voltage risk during solar panel cleaning. Inappropriate brushes can scratch the panel's surface, reducing sunlight absorption. Scratches can cause efficiency losses of 5% to 10% [3]. Manual device use also requires caution, as tractors or other heavy equipment can increase the risk of panel cracking or breaking and alter the ground around the panels, creating system instability.In conclusion, regular cleaning of solar panels is crucial for increasing energy production efficiency. However, the cleaning process must be done carefully, with appropriate precautions to avoid decreased performance and damage. This study examines pollutant types, their effects on photovoltaic panels, and techniques and trends for cleaning these pollutants to promote sustainable solar energy.

The accumulation of dirt layers formed by rainwater at the edge of the solar panel



Thermal examination of shadowing caused by bird droppings



The effect of the solution on solar panels after cleaning with the solution

Cleaning methods used for photovoltaic panels installed on the ground

	Manuel Cihazlar: Motorlu ve basınçlı fırçalar	Düşük	Yüksek	Düşük	Yüksek	Personel ve güneş panelleri için risk oluşmaktadır.	
	Manuel Cihazlar: Traktör üzerine monte edilen fırça sistemleri	Orta	Yüksek	Orta	Orta	Personel ve güneş panelleri için risk oluşmaktadır.	
	Endüstriyel Sistemler: Tek eksende tamamda veya panel üzerinden kontrol edilen sistemler,	Orta	Orta	Orta	Orta	Operasyonel risklerden dolayı risk oluşmaktadır.	Proje Bazlı
	Robotik Sistemler: Paletli, tekerlekli ve çift hareketli sistemler	Orta	Düşük	Yüksek	Orta	Robotik sistemlerde yer alan güvenlik sistemleri ile düşük risk.	Çalışma Eğimine Uygun Olduğu Projeler
	Tam Otonom Robotik Sistemler: Operatör kontrolünün olmadığı tam otonom robotik sistemler	Yüksek	Düşük	Yüksek	Düşük	Operatör müdahalesinin minimumda veya olmadığı sistemler olduğundan risk.	Proje Bazlı

Keywords: Sustainability, Photovoltaic Panel Cleaning, Solar Energy, Pollution, Robotic Systems

Pub No: O-036

A Situational Awareness and Decision Support Tool for Power Systems with High rPV Penetration

Özgür Arda Küçükaslan [1], ***Murat Göl*** [2]

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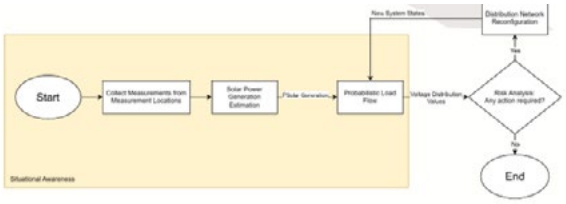
[2]Middle East Technical University

Abstract: With recent developments in photovoltaic panels and inverter technologies, behind-the-meter rooftop photovoltaic systems (rPV) have populated rapidly. However, the monitoring infrastructure for those rPV systems is neither economically nor computationally feasible since both the cost of this infrastructure and the amount of data will be immense. This causes major operational issues for the Distribution System Operator (DSO) due to the unobservability and uncertainty of the solar generation units. To solve such operational problems, a decision support system is proposed. The proposed system performs rPV generation estimation with a limited number of measurements based on [1] and [2]. Despite the limited number of measurements, strategically placing those measurements to improve measurement redundancy improves the accuracy under uncertainty. with multiple measurement usage, Probabilistic load flow analysis that considers stochastic characteristics of the solar generation provides input to situational awareness and distribution network reconfiguration algorithm that aims to solve possible technical problems of the distribution network without additional investment. The structure of the proposed system is given in Figure 1. The system aims to detect possible voltage regulation problems in distribution network buses and propose a feasible topology that regulates the voltages of every bus using only tie switches and shunt compensation elements in the system. By implementing such a system, the behind-the-meter rPV systems will be more efficient and easier to integrate into distribution networks. This will benefit the popularity of the behind-the-meter systems and the zero carbon and green energy goals.

Decision Support System



The structure of the proposed decision support system

Keywords: Rooftop Photovoltaic Systems, Decision Support, Situational Awareness, Distribution Systems Integration

Pub No: O-037

Water-Based Electrically Conductive Adhesive for PERC-Type Shingled Solar Cells

Hüseyin Utkucan Kayacı [1], ***Gürcan Utku Özdemir*** [3], ***Ezgi Karahallı*** [3], ***Ahmet Hamdi Aksoy*** [3], ***Doğa Doğanay*** [1], ***Şahin Coşkun*** [1], ***Talat Özden*** [3], ***Raşit Turan*** [3], ***Hüsnü Emrah Ünalan*** [1]

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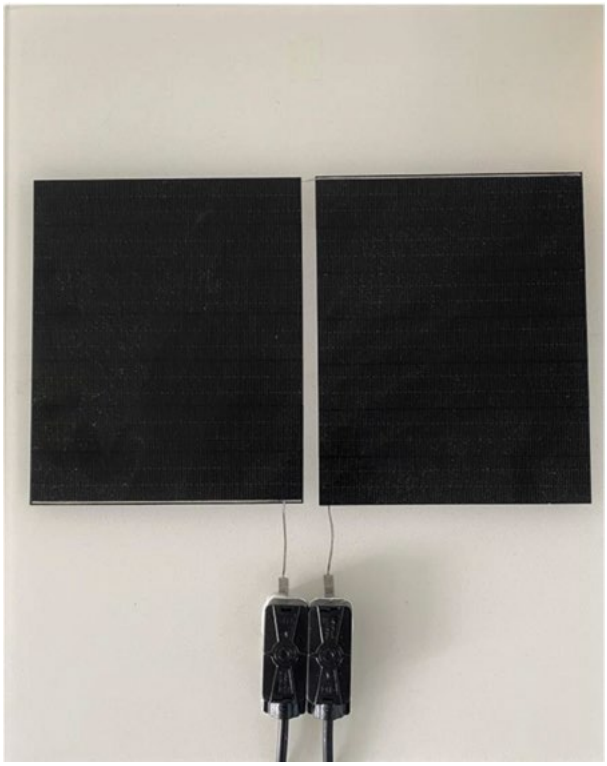
[4]Eskişehir Osmangazi University

Abstract: Electrically conductive adhesives (ECAs) play a pivotal role in PERC-type shingled solar cells, ensuring structural integrity, facilitating the seamless collection and transport of electrical current across various cell layers. However, traditional formulations often incorporate environmentally harmful chemicals like thinners and terpineol, presenting significant environmental challenges. Consequently, there is an urgent need to transition towards water-based formulations to reduce environmental impact and adhere to sustainable principles. Formulation necessitates a comprehensive understanding of the intricate interactions among ink constituents, their impact on particle packing within the adhesive matrix, and ultimately, their influence on cell performance. In response to this challenge, our study delves into the formulation of inks by strategically blending silver flakes with a carefully selected array of solvents, binders, and additives. Through meticulous experimentation, optimal particle packing within water-based adhesives is achieved, thereby yielding electrical performance comparable to that of commercial counterparts. Fabricated PERC-type shingled solar cells showed photovoltaic conversion efficiencies up to 20.5% with commercial ECAs and 19% with water-based ECA developed inhouse (Fig. 1), albeit printing challenges. Optimizing printing parameters is essential for unlocking the full potential of water-based formulations in achieving commercial product performance, underscoring the imperative for continued research and refinement in this critical area.

Figure 1



PERC type-shingled solar module fabricated with water-based electrically conductive adhesive.

Keywords: Electrically Conductive Adhesives, PERC-Type Shingled Solar Cells, Water-Based Formulations, Silver Flakes

Pub No: O-038

Effect Of The Morphology Of Black Silicon Passivated By Alumina On The Performance Of Interdigitated Back Contact Solar Cells

Nabil Khelifati [1], ***Ozan Aydın*** [2], ***Ozan Aydın*** [3], ***Bülent Arıkan*** [2], ***Ghania Fortas*** [1], ***Leila Harkat*** [1], ***Leila Harkat*** [4], ***Ville Vähänissi*** [5], ***Xiaolong Liu*** [5], ***Faouzi Kezzoula*** [1], ***Raşit Turan*** [2], ***Raşit Turan*** [3], ***Raşit Turan*** [6]

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Abstract: Black silicon (b-Si), is a material that has garnered significant interest due to its unique properties and advantages in various applications, especially in photovoltaics [1,2]. In this work, we investigated the effect of the morphology of b-Si passivated by Al2O3 on the performance of Interdigitated Back Contact (IBC) solar cells. The b-Si was prepared by Reactive Ion Etching technique on both surfaces of n-type Si wafers. Three similar series of b-Si with different morphologies were prepared and passivated by ALD Al2O3 of thicknesses 5, 10 and 15 nm for each series. The SEM imaging showed that the b-Si depth increases from 50 to 700 nm when the etching time varies from 1 min to 11 min. The weighted average reflectance measured in the range 350-1100 nm showed an important decrease that reache minimum values lower than 5% for the deepest b-Si. On the other hand, the passivation quality of b-Si evaluated through the maximum surface recombination velocity demonstrated, that the samples with lower reflectance, were the most difficult to passivate. The opposite and competitive effects of reflectance and passivation quality of b-Si were investigated by the simulation of IBC solar cell via Quokka software, using the experimental findings as parameters for the front side. The simulations showed that the impact of the low reflectance of deep b-Si was more dominant than that of the high passivation quality associated to the shallow b-Si. The low reflectance was found to be the underlying effect responsible of the IBC solar cell efficiency improvement.

Keywords: Black silicon, Surface passivation, Reflectance, IBC solar cell, Simulation

Pub No: O-039

Ion Implantation for High-Efficiency Solar Cells

Muhammad Usman [1]

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Abstract: Improving the efficiency of solar cells has always been crucial for driving down the cost of solar energy. In this contest, several manufacturing process improvements have been implemented, few of which ended up in industrial processes. Ion implantation, being one such method, is important in the semiconductor industry and is a powerful technique for introducing dopant atoms into a material. The process offers significant advantages over traditional diffusion methods for creating the p-n junctions, mainly due to precise control over incident energy (depth of dopants) and fluence (amount of dopants) of impinging ions, which are critical parameters for solar cell function. Ion implantation significantly enhances carrier concentration and uniformity, leading to reduced recombination losses. Phosphorus-implanted n-type silicon wafers show an increase in minority carrier lifetime and reduce sheet resistance, ensuing higher open-circuit voltages (Voc). Likewise, boron-implanted p-type wafers exhibit improved surface passivation and fill factors. A comparative analysis with diffused junction solar cells reveals a notable improvement in overall efficiency for cells processed with ion implantation. Moreover, it minimizes the thermal budget during the processing. Through this method, the manufacturing of advanced cell architectures, such as Passivated Emitter and Rear Contact (PERC) cells and Passivated Emitter Rear Totally Diffused (PERT), with enhanced light absorption and minimal recombination, has become easy to process. Furthermore, ion implantation can improve resistance to performance degradation mechanisms like potential induced degradation (PID).In this talk, we will explore the fundamentals of ion implantation and its versatile applications in silicon and other types of solar cells.

Keywords: Ion Implantation, Solar Cells, Doping, Efficiency, Silicon

Pub No: O-040

Formation of Selective Emitter Through Double Diffusion Approach

Mustafa Büyükgüzel [1], ***Melisa Korkmaz Arslan*** [1], ***Hasan Hüseyin Canar*** [1], ***İrem Nur Manaz*** [1], ***Furkan Çiçek*** [1], ***Yiğit Mert Kaplan*** [1], ***Simge Kaykıl*** [1], ***Murat Aynacıoğlu*** [1], ***Batuhan Taş*** [1], ***Shojaa Abusakha*** [3], ***Bülent Arıkan*** [1], ***Raşit Turan*** [1]

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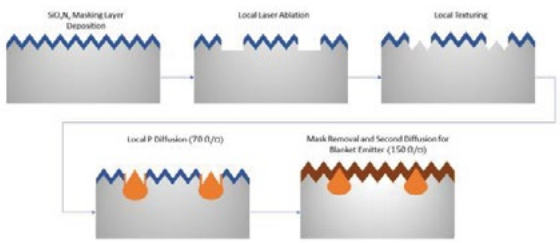
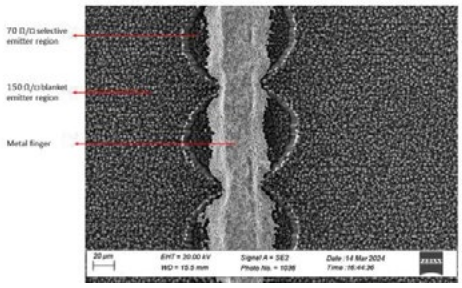
Abstract: Formation of Selective Emitter Through Double Diffusion ApproachSelective emitter structures are the next step in the production of high efficiency monocrystalline solar cells by reducing recombination in the emitter region. Traditional method of creating selective emitter regions involves laser doping underneath the metal fingers[1][2][3]. This research investigates an innovative Double Diffusion Selective Emitter (DDSE) method to enhance the performance of PERC solar cells. The experimental procedure involves several critical steps: After single side texturing, a SiOxNy mask is deposited on top of p type Cz wafers. The mask is locally ablated on the front side by a picosecond laser to create highly doped regions underneath the metal fingers. Ablated regions are locally textured again to remove the laser damage and the samples underwent a diffusion process to create a 60-70 Ω/□ selective emitter. After the first diffusion process, the masking layer is removed in HF solution and the samples underwent another diffusion process to create 150 Ω/□ blanket emitter. Finally, a SiO2/SiOxNy/SiNx layer stack is deposited on the front side for both passivation and anti-reflection coating and a Al2O3/SiOxNy/SiNx stack is deposited on the rear side for passivation. The DDSE technique is particularly designed to be compatible with advanced solar cell architectures and the application of the dual diffusion strategy is projected to demonstrate significant improvements in photovoltaic performance metrics. Further results will be presented at the conference.

Double Diffusion Process Flow



Process flow chart for the double diffusion approach

SEM



SEM image of the doubly diffused region

Keywords: Silicon, Solar cell, Selective Emitter, Diffusion, Picosecond laser

Pub No: O-041

Bayesian Optimization with Experience for Fast Development of Monolithic Tandem Solar Cells: Simulation Case Study

Konstantin Tsoi [1], ***Selçuk Yerci*** [2]

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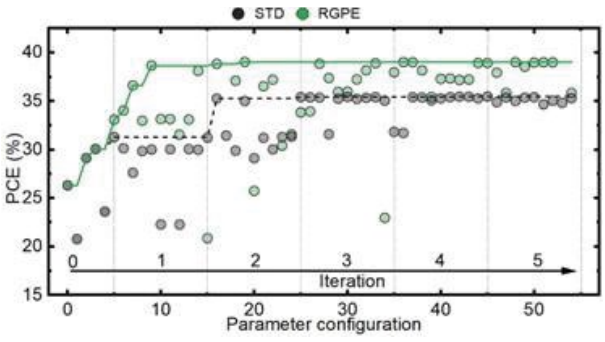
[2]Middle East Technical University/Department of Micro and Nanotechnology
[3]Middle East Technical University/Department of Electrical and Electronics Engineering

Abstract: Machine learning is gaining more attention in photovoltaic research and will be a vital tool in reaching record-high power conversion efficiencies (PCE) soon. One area where it is significantly beneficial is reducing the number of experiments needed to find the optimum combination of parameters in solar cell fabrication. Bayesian optimization (BO) provides routes for quickly identifying optimum parameters in problems with large parameter space. In this work, we demonstrate that the BO algorithm with experience built with rank-weighted Gaussian process ensemble (RGPE) [1] results in faster optimization of tandem solar cells, a technology rapidly gaining more interest due to its potential to deliver record-high performance. Namely, we set up a tandem solar cell in a simulation environment with seven input parameters (e.g., thickness of the top subcell, surface recombination velocity at the interface). As a result, a space of 5e7 possible parameter combinations is formed. Then, we apply RGPE method to obtain an optimum PCE, and demonstrate that it can be obtained after 2 batches/iterations (10 parameter combinations per batch) of experiments/simulations. Moreover, we demonstrate that RGPE method outperforms method without experience (STD) by yielding an increase of ~9%abs. (compared to only 2%abs.) in the 2nd iteration and requiring 5× less time to reach a target PCE of 38.5% across 20 different trials (shown in Figure). Results from this work help accelerate the development of tandem solar cells by removing the need for large numbers of experiments in identifying optimum deposition parameters of layers in the tandem solar cells.

Figure 1.



Exemplary optimization progress of tandem solar cell's PCE using BO methods in this work. Circles represent obtained PCE within a batch. Lines show the maximum obtained PCE.

Keywords: tandem solar cells, Bayesian optimization, machine learning

Pub No: O-042

Strong Impact of Substituent Position in PEAI-Founded Organic Cations to Enable the Efficient and Durable 3D/2D-Constructed Perovskite Solar Cells

Zeynep Gözükara Karabağ [1,2,3], ***Ali Ekber Karabağ*** [1,2,4], ***Ümmügülsüm Güneş*** [1,2,5], ***Xiao-Xin Gao*** [2], ***Olga A. Syzgantseva*** [6], ***Maria A. Syzgantseva*** [7], ***Figen Varlioglu Yaylali*** [1,2,4], ***Naoyuki Shibayama*** [8], ***Hiroyuki Kanda*** [2], ***Alwani Imanah Rafieh*** [2], ***Roland C. Turnell-Ritson*** [2], ***Paul J. Dyson*** [2], ***Selcuk Yerci*** [1,5,9], ***Mohammad Khaja Nazeeruddin*** [2], and ***Gorkem Gunbas*** [1,3,4,5]

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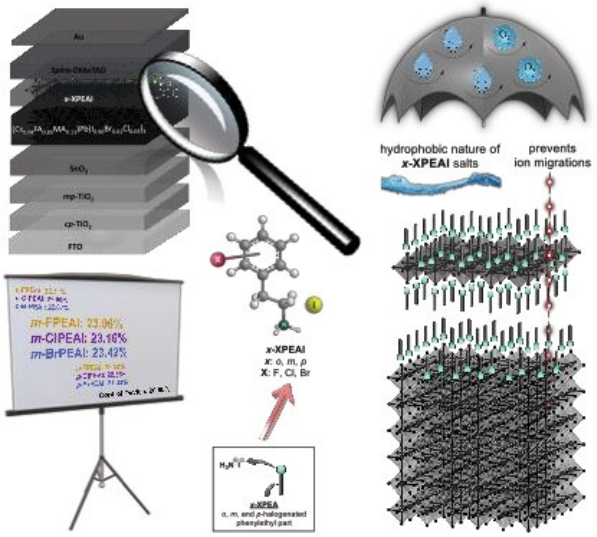
[5]Department of Micro and Nanotechnology, Middle East Technical University, Ankara, Türkiye [6]Department of Chemistry, Lomonosov Moscow State University, Moscow, Russia [7]Department of Physics, Mendeleev University of Chemical Technology, Moscow, Russia [8]Department of General Systems Studies, Graduate School of Arts and Sciences, The University of Tokyo, Tokyo, Japan [9]Department of Electrical and Electronics Engineering, Middle East Technical University, Ankara, Türkiye

Abstract: The passivation of perovskite solar cells (PSCs) is inevitable to improve their performance and stability. Integrating 2D-forming phenylethylammonium iodide (PEAI) salts for passivation is an emerging strategy due to their hydrophobic character and improved stability in PSCs, although various cations have been implemented. This study investigates the impact of 9 different large organic cations, particularly halogenated with fluorine (F), chlorine (Cl), and bromine (Br) as the substituents at -ortho (-o), -meta (-m), and -para (-p) positioned-PEAI salts (coded as x-XPEAI where x: o, m, p and **X: F, Cl, Br**) synthesized using a straightforward method on the passivation of 3D perovskite surfaces and their subsequent effects on device performance and stability. The formation of 2D layers on top of the 3D perovskite was confirmed using X-ray diffraction (XRD) and grazing-incidence wide-angle X-ray scattering (GIWAXS) analyses for all cations, regardless of the nature and position of the halogen. It revealed that m-substituted cations exhibited lower formation energies and higher interfacial dipoles, leading to enhanced device performance compared to their -ortho and -para counterparts. Among the halogenated PEA+ iodide salts tested, the device treated with **m-BrPEAI** exhibited the highest efficiency of 23.42%, with a high open-circuit voltage (VOC) of 1.13 V and fill factor (FF) of 81.2%. However, considering overall efficiency, stability, and reproducibility, the treatment with **m-ClPEAI** salt yielded the best performance. This comprehensive study contributes to understanding surface passivation in PSCs and offers insights for optimizing device performance through the rational design of large organic cations.

Systematic study of a series of halogenated phenylethylammonium iodide salts to elucidate the impact of substituent position on 2D perovskite passivation and device efficiency



Keywords: 3D/2D perovskite solar cells, substituent and position effects, stability, large organic cations

Pub No: O-043

STABILIZATION OF CURRENT-VOLTAGE CURVES IN PEROVSKITE SOLAR CELLS

Enrique H. Balaguera [1]

[1]Universidad Rey Juan Carlos

Abstract: Current-voltage measurements are a standard testing protocol to determine the efficiency of any solar cell. Nevertheless, this methodology is still applied with a certain uncertainty in perovskites due to the memory-based hysteresis phenomena observed during such electrical characterization. Herein, a theoretical model to analyze the current-voltage curves in perovskite solar cells by putting the transition between discrete photocurrent values under a magnifying glass. The approach consists of an "intelligent transient analysis" to accurately capture steady-state current-voltage responses, thus eliminating memory traces. From experimental measurements, we establish the shortest scan rate to obtain hysteresis-free stable power conversion efficiency of high-performance perovskite solar cells. By comparison between the current-voltage characteristics and the linearized version of the model analyzed from the perspective of Impedance Spectroscopy, we verify the evolution of hysteresis providing additional explanations to satisfy this complex anomalous behavior. Our analysis offers exceptional understanding of the ubiquitous current-voltage hysteresis, contributing to improve the estimation of the efficiency in perovskites.

Keywords: photovoltaic perovskites, electrical circuits, power conversion efficiency, anomalous hysteresis, transient responses, Impedance Spectroscopy

Pub No: O-044

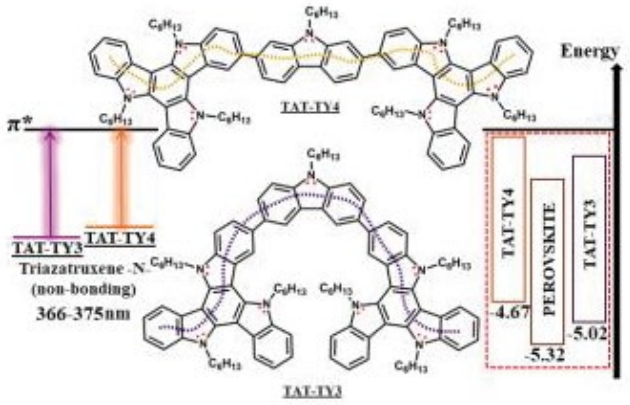
Utilizing a Carbazole-Incorporated Regioisomeric Synthesis Strategy to Design Hole Transporting Materials for Perovskite Solar Cells

Tamer Yeşil [1], ***Adem Mutlu*** [1], ***Sevdiye Başak Turgut*** [1], ***Burak Gültekin*** [1], ***Ceylan Zafer*** [1]

[1]Ege University

Abstract: Two new p-type molecules, namely TAT-TY3 and TAT-TY4, featuring triazatruxene end-caps and carbazole π-bridges, were synthesized. The photophysical and electrochemical properties of synthesized materials were comparatively investigated based on their 2,7- and 3,6-carbazole conjugation pathways. Optical characterizations revealed the impact of non-bonding electron delocalization of triazatruxene through carbazole moieties, resulting in a significant increase in absorption intensity corresponding to n-π* energy transitions and a red shift of triazatruxene moieties. Consequently, the optical band gaps of TAT-TY3 and TAT-TY4 were measured at 3.0 and 3.2 eV, respectively. Moreover, the molecules' first oxidation potentials exhibited a drastic difference due to the electrochemical behavior of 2,7- and 3,6-carbazole moieties. The highest occupied molecular orbital (HOMO) level for TAT-TY3 was measured to be -5.02 eV, while for TAT-TY4, it was measured as -4.67 eV. Hole-extraction properties were explored using steady-state and time-resolved photoluminescence spectroscopy, revealing enhanced charge transfer between the TAT-TY3/Perovskite interface due to the better alignment of HOMO energy levels. The photovoltaic performances of the hole-transporting materials (HTMs) were successfully characterized in triple-cation perovskite solar cells and efficiencies of up to 17.9%, 16.2%, and 9.8% were achieved for Spiro-OMeTAD, TAT-TY3, and TAT-TY4, respectively.

Graphical abstract



In this graphical abstract, the characterization of the differing photophysical and electrochemical properties depending on the variation in conjugation pathways is summarized.

Keywords: Hole Transporting Material, Regioisomers, Perovskite solar cell, Charge transfer, Energy transition

Pub No: O-045

Investigation Performance and Stability Effect of Natural Antioxidants on the Perovskite Solar Cells

Cihangir Kahveci [1], ***Hamed Moeini Alishah*** [1], ***Pınar Gökdemir Choi*** [1], ***Macide Canturk Rodop*** [1]

[1]Yildiz Technical University, Faculty of Arts and Science, Department of Physics

Abstract: Perovskite solar cells have emerged as a leading photovoltaic technology due to high light absorption coefficients, long carrier diffusion length, and the solution processability of metal halide perovskite materials. Currently, power conversion efficiencies (PCEs) have reached 25.5%, surpassing those of copper indium gallium selenide (CIGS) solar cells and competing closely with crystalline silicon solar cells. Additionally, the compa tibility of perovskites with large-area growth techniques has enabled the possibility of development of large-area perovskite solar modules[1].We fabricated inverted type (p-I-n) perovskite solar cells employing methylammonium lead iodide (MAPbI3) as perovskite using antisolvent washing and two step methods. We incorporated natural antioxidants found in plants, such as quercetin, glutathione, curcumin, and emodin, into the perovskite precursor and washing solutions to further improve the performance and stability of the devices. We observed that the efficiency and stability of perovskite solar cells were improved by the incorporation of antioxidants extracted from different plants, especially for the devices employing curcumin extracted from turmeric. All the devices were fabricated under ambient and high humidity conditions without use of a glovebox.Acknowledgement: This study was supported by Scientific and Technological Research Council of Turkey (TUBITAK) under the Grant Number 121F369. The authors thank to TUBITAK for their supports.Reference[1] Gao, P.; Gratzel, M.; Nazeeruddin, M. K. Organohalide Lead Perovskites for Photovoltaic Applications. Energy Environ. Sci. 2014, 7, 2448−2463.

Keywords: Perovskite Solar Cells, Antioxidant extracts

Pub No: O-046

Wide Bandgap Perovskite Solar Module Geometry Optimization by Single-diode Modeling Leading >98% Geometrical Fill Factor >80% Fill Factor

Bahri Eren Uzuner [1], ***Amir Zarean Afshord*** [2], ***Aranzazu Aguirre*** [6], ***Tom Aernouts*** [7], ***Görkem Günbaş*** [5], ***Yinghuan Kuang*** [6], ***Selçuk Yerci*** [3]

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Abstract: Perovskite thin-film solar cells have exhibited significant advancements in various aspects over the last decade, positioning them as the most promising candidate for the next-generation photovoltaic technology. Recently, significant efforts have been focused on the scale-up of perovskite solar cells towards enabling their commercialization. However, transitioning from individual small-area cells to large-area modules presents challenges, particularly in achieving a balance between electrical and geometric losses associated with the module structure. In this study, we performed electrical simulations based on measured electrical parameters to elucidate this balance and verified our model by fabricating both opaque and semi-transparent perovskite solar modules (PSMs). We showed that a P2 width of around 20-50 µm provides an optimized P2 contact resistance, resulting in high geometric fill factors (GFF) and fill factor (FF), simultaneously. We fabricated opaque wide bandgap (1.67 eV) PSMs with an aperture area of 4.2 cm2, reaching a GFF of 98.4%, an FF of 81.5%, and a PCE of 17.78%. To further demonstrate the scalability of this approach, 16 cm2 opaque modules, reaching a GFF of 97.0%, an FF of 80.1%, and a PCE of 17.58% were fabricated. We believe that the proposed optoelectronic simulation model, along with its validation through the fabrication of PSMs exhibiting both exceptionally high GFFs and FFs, effectively elucidates the optical-electrical trade-off in PSMs and thus offers valuable insights for the design of highly efficient PSMs.

Keywords: geometrical fill factor, laser scribing, perovskite solar modules, simulation, wide bandgap perovskites, single-diode model

Pub No: O-047

Comparative analysis of properties of SnS thin film deposited by electrodeposition and sol-gel spin coating techniques

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Abstract: This study presents a comparative investigation of the structural, optical, and electrical properties of SnS thin films elaborated by two distinct deposition techniques: electrodeposition and sol-gel spin coating. SnS thin films were deposited onto ITO-coated glass substrate using one-step potentiostatic electrodeposition and onto a glass substrate for spin-coating method. The precursors used for both techniques are tin chloride (SnCl2, 2H2O) and sodium thiosulfate (Na2S2O3, 3H2O) with triethanolamine additive (TEA) using the concentration ratio Sn:TEA= 1:1. The comparative analysis encompasses several key parameters including crystal structure, film's thickness, optical bandgap, and electrical properties. XRD patterns highlighted the deposition of pure orthorhombic SnS films with a preferred orientation variations depending on the deposition technique. Optical studies showed distinct absorption spectra and bandgap energy values of 1.39 eV and 1.60 eV for SnS films by electrodeposition and spin-coating, respectively. Moreover, profilometry revealed a wide discrepancy in film's thickness depending on the deposition technique. Electrical properties of the electrodeposited film were determined via capacitance-voltage measurements using Mott Schotteky (MS) method. The negative slope of the C-V plots confirms the p-type conductivity of the deposited SnS with a charge career density Na around 8.17 1018 cm-3 for electrodeposited films. While, for SnS deposited by spin-coating, Hall-Effect analysis revealed the deposition of N-type SnS film with Nd= 1.44 1018 cm-3. Consequently, this comparison provided valuable insights into the influence of deposition technique on the properties of SnS thin films, aiding in the optimization of fabrication processes for enhanced performance in photovoltaïc applications.

Keywords: Thin films, electrodeposition, sol-gel, Mott Schotteky (MS) method, charge career densit

Pub No: O-048

INSIGHTS INTO THE RECOMBINATION DYNAMICS OF PEROVSKITE SOLAR CELLS VIA VOLTAGE AND PHOTON FLUX DEPENDENCE OF IMPEDANCE RESPONSE

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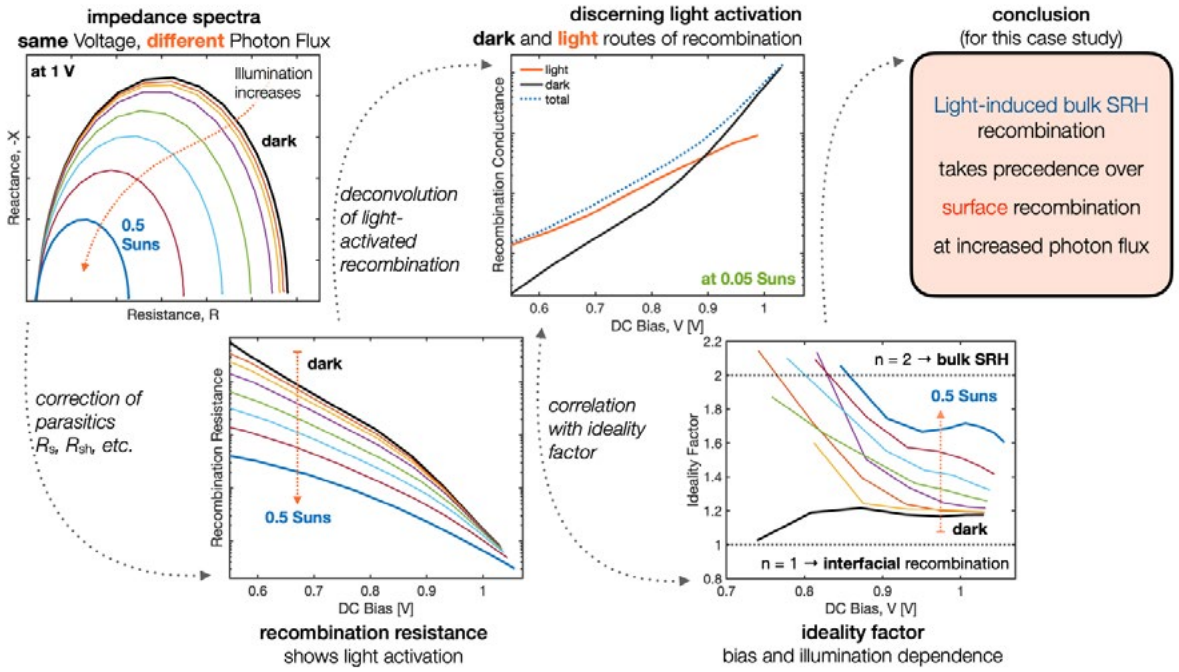
Abstract: Impedance spectroscopy is an indispensable characterization tool for elucidation of charge dynamics occurring at distinct timescales in perovskite optoelectronic devices. Although there are numerous measurement protocols, measuring a set of impedance spectra of a perovskite solar cell at the open-circuit conditions with varying photon flux intensities, followed by the analysis of fitting parameters against flux-bias pairs, is a common practice in the literature. However, this approach of working on the open-circuit voltage dependences can only provide a limited information by imposing a limit on the deconvolution of light-activated processes from the voltage-dependent ones. In this work, we show that the high-frequency impedance response of perovskite solar cells exhibits a strong light-activation effect [1] under a constant bias. Furthermore, we deconvolute the light-activated process from its dark counterpart by the subsequent analysis of the set of impedance spectra obtained in a rather comprehensive bias-photon flux space. We assigned the light-activated process to the amplification of single carrier-limited bulk SRH recombination pathway that is otherwise masked under low-light and/or high-bias conditions where, typically, the interfacial recombination dominates. We also corroborate our findings with the complementary analysis of ideality factor evolution with respect to both bias and illumination, obtained using high-frequency recombination resistance [2] that is inherently resistant to a possible ionic obstruction as a consequence of background ionic properties of perovskites. Our work here also demonstrates an empirical toolkit that can be used for diagnostic purposes regarding the recombination dynamics in perovskite optoelectronic devices.

Figure 1. An illustrative example of light-activation of high-frequency impedance response of perovskite solar cells



Keywords: perovskite, impedance spectroscopy, light-activation, ideality factor

Pub No: O-049

Formulation and characterization of new PEDOT:PSS inks for inkjet printed perovskite solar cells

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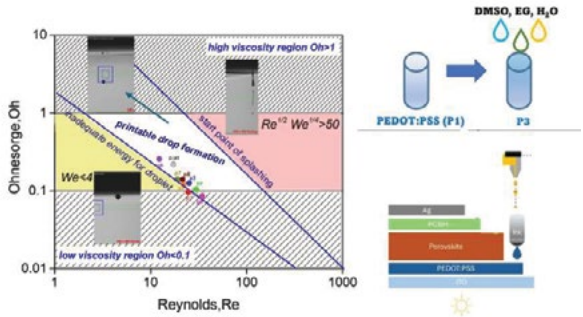
Abstract: In recent years, one of the areas that has seen significant advancements is undoubtedly inkjet technology, with a crucial parameter being the production of inks[1]. The successful inkjet printing of PEDOT:PSS, one of the most commonly used layers in planar perovskite solar cells, is still considered a major challenge [2]. The uniform deposition of the PEDOT:PSS layer is directly related to the inks used in printing and the inkjet printing parameters. Since additives used in the ink affect thin film morphology, conductivity, and optical transparency, and whether they remain within a printable range are of great importance. Here, we have prepared different PEDOT:PSS inks (P1-P8) using binary/ternary solvent systems with different ratios such as deionized water, DMSO, ethanol, and ethylene glycol. After performing detailed investigation of the inks, including viscosity, surface tension, and contact angle measurements, inkjet printing was carried out. Addition of commonly used solvents for improving conductivity and surface coverage were attempted, as well. Figure 1 shows the printability frame which gives information about drop formation and printing quality for inkjet printing. Developed PEDOT:PSS inks were printed via inkjet printer and used in devices with ITO/PEDOT:PSS/Perovskite/PCBM/Ag architecture. The addition of DMSO and the dilution of PEDOT:PSS itself was far better than the other candidates in terms of photovoltaic conversion efficiency. According to printability investigation, thin film characterizations and inkjet printed perovskite solar cell results, binary P3 ink demonstrated a big potential as a PEDOT:PSS ink for inkjet printed devices.

FIGURE 1



Developed inks (P1-P8) placement of Printability frame, inkjet printing inks design and device concept.

Keywords: PEDOT:PSS, INKJET PRINTING, INK FORMULATION, PEROVSKITE SOLAR CELL

Pub No: O-050

Boosting Device Efficiency, Exploring Si Nanowire and SnS2 Thin Film Heterojunctions

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[2]Graduate School of Natural and Applied Sciences, Gazi University, Ankara, Turkey
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Abstract: The study investigates the Si nanowire (SiNW) heterojunction structure with a two-dimensional SnS2 thin film, highlighting the advantages of using the metal-assisted etching (MAE) method to fabricate SiNW arrays due to its ability to control length and produce large areas of nanowires. The resulting SiNW exhibits significantly lower reflectivity compared to a planar Si substrate. By analyzing the diode characteristics of SnS2/SiNW and SnS2/Si planar heterojunctions through dark current measurements at temperature dependent, the study demonstrates that the three-dimensional interface between SiNW and the SnS2 thin film enhances diode performance, with different SiNW morphologies prepared by time-controlled methods affecting wire distances and consequently the diode performance. Transport mechanisms were examined, revealing that thermionic emission and thermally assisted tunneling dominate at low voltages (0.02–0.20 V), while space charge limited current (SCLC) dominates at higher voltages (0.20–0.40 V). The results indicate that the SiNW geometry significantly improves device efficiency by reducing defect densities caused by lattice mismatches at the junction. Temperature-dependent dark I–V measurements further confirmed these transport mechanisms, offering insights into the defective states at the interface. The SiNW structure significantly enhances the properties of heterojunction devices, highlighting its potential for advanced semiconductor applications.

Keywords: SnS2 thin film, Si Nanowire, metal-assisted etching (MAE) method, diode characteristics, Transport mechanisms, I–V measurements, semiconductor applications

Pub No: O-051

Morphology control of β-CsPbI3 perovskite phase in air ambient condition

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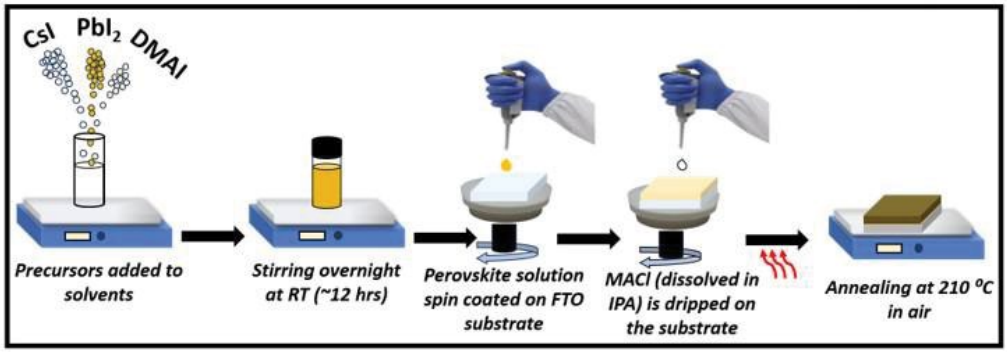
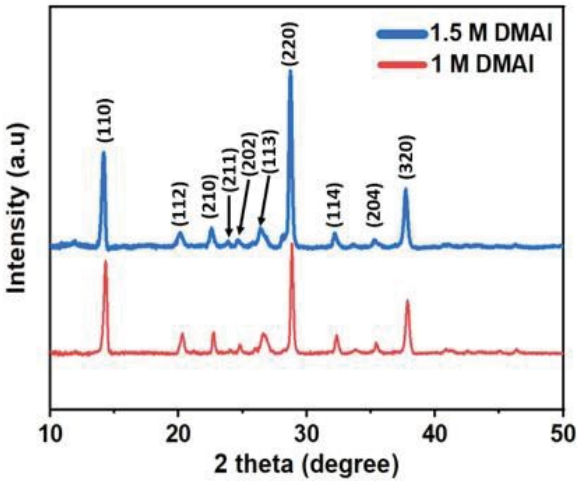
Abstract: Despite the high power conversion efficiency (PCE) of conventional organic-inorganic hybrid perovskite solar cells (PSCs), the poor thermal stability of the organic cations, such as MA+ and FA+ makes them highly susceptible to degradation. To solve this issue, all-inorganic perovskites devoid of any volatile components have garnered increasing attention.1 Among these perovskites, CsPbI3 holds a promising position owing to its suitable bandgap of ~1.7 eV for photovoltaic (PV) applications. This present study focuses on the fabrication, morphology control, and stabilization of the photoactive β-CsPbI3 phase by employing an N-Methyl-2-pyrrolidone (NMP) driven solvent engineering method.2 Figure 1 b shows the intense (110) peak at 14.2° using 1.5 M dimethylammonium iodide (DMAI) additive in the precursor solution, indicating a high crystallinity of the perovskite phase.3 To optimize the NMP concentration, precursor solutions with varying NMP quantities: 10 µL, 40 µL, and 100 µL were prepared by partially substituting DMSO in mixed triple solvent (i.e., DMSO, DMF, and NMP). Figure 1 c shows the poor morphology using just DMF and DMSO as the solvents, whereas, incorporating NMP improves the morphology (Figure 1 d). Increasing NMP content adversely affects the film morphology, whereas the optimized NMP concentration of 10 µL produced the best film features with better uniformity, surface coverage, and larger grains. It is well known that the perovskite film morphology has a crucial effect on tuning PSCs' device efficiency and stability. Thus, this study highlights promoting better efficiency of all-inorganic CsPbI3 PSCs in ambient air conditions by precursor solvent engineering.

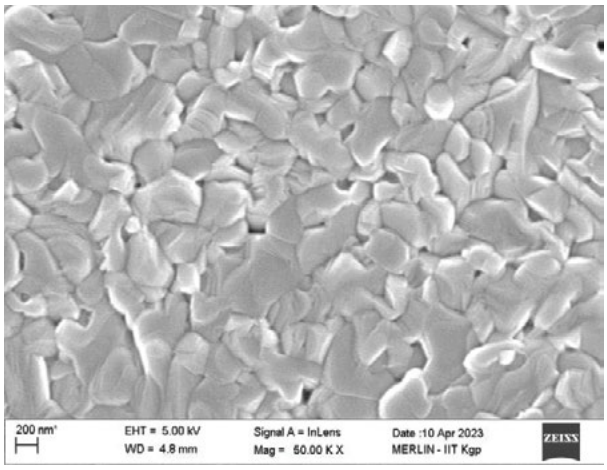
(a) Perovskite film fabrication process in ambient conditions



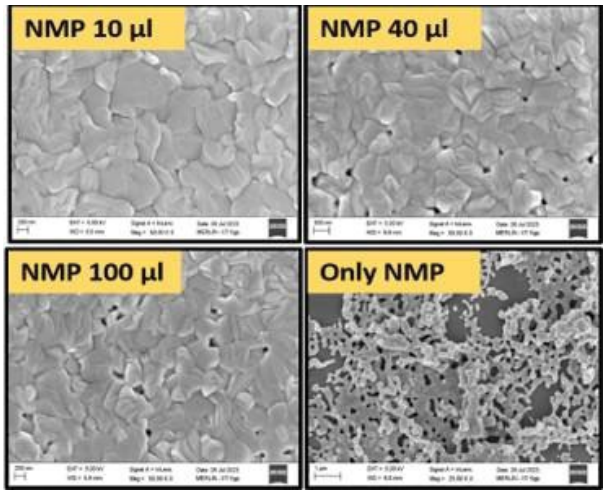
(b) XRD of as-prepared perovskite film.



(c) SEM images of as-prepared film with only DMF and DMSO solvents



(d) SEM images of as-prepared film with different NMP concentrations



Keywords: All-inorganic, β-CsPbI3, solvent engineering, air ambient

Pub No: O-052

Optimizing Transparent Conductive Oxide Thickness for Perovskite Solar Cells Under Indoor Illumination

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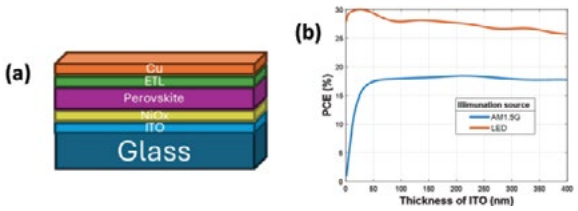
Abstract: Perovskite photovoltaic cells, with their customizable bandgap for indoor lighting, have the potential to meet this energy demand, enhancing the growth and utility of IoT devices in our digital transformation.Under indoor lighting, the amount of generated current decreases >100 fold when compared to AM1.5 illumination. At such low current values, the performance of a solar cell becomes less affected by the resistive losses, usually quantified in terms of series resistance. Since one of the dominant sources of series resistance is the sheet resistance of the transparent conductive oxide (TCO) under AM1.5 its thickness should be > 150 nm (in case of indium tin oxide, ITO) to minimize the resistive losses. However, under indoor illumination, it can be decreased as the performance is more tolerant to high series resistance. This behavior already has been analyzed in organic-based solar cells, however not been performed for perovskite-based solar cells. This study investigates the effect of reducing thickness of TCO in p-i-n perovskite solar cells, as depicted in Figure 1.a., under indoor illumination by performing optoelectrical analysis using Transfer Matrix Method (TMM) and a single diode model. Results demonstrate that performance of the solar cell remains unchanged for TCO thicknesses as low as a few couple of nm, while for AM1.5G illumination PCE approaches 0% as demonstrated in Figure 1.b. The results from this work provide a new guideline for designing the architecture of perovskite solar cells different from the ones used for standard operating conditions.

Figure 1. a. Structure of whole cell b. Comparison of the PCE of perovskite solar cells at various thicknesses of ITO under AM1.5G and indoor lighting conditions



Keywords: perovskite solar cells, indoor pv, indium tin oxide, transfer matrix method

Pub No: O-053

COMPARISON BETWEEN P&O AND INCREMENTAL CONDUCTANCE MPPT CONTROL STRATEGIES FOR PV

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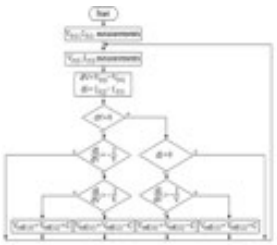
[3]Badji Mokhtar University of Annaba,LEA UBMA

Abstract: This research aims to compare between two most used strategies in maximum power point tracking system (MPPT) for photovoltaic (PV) system, Incremental Conductance (Inc. C.) and Perturb and Observe (P&O). PV module Current-Voltage (I-V) and Power-Voltage (P-V) characteristics are simulated under Matlab/Simulink environment. 5 parameters model of PV module is used. Inc. C. and P&O strategies performances are compared through their implementation ease, stability, maximum power point tracking speed and converter duty cycle, according solar radiation variations from 400W/m2 to 1000W/m2. From the simulation results, the Inc. C. method shows better performances and also has lower oscillations.

EXPLANATION OF THE MPPT BY THE P&O METHOD

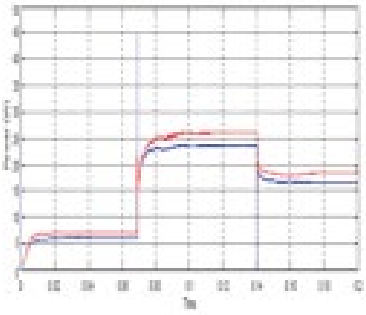
the P&O type of MPPT method, where the power evolution is analyzed after each voltage perturbation.

ORGANIGRAM OF THE INC. C. METHOD



It is based on annulation of power derivate with respect of voltage.Three cases are possible: a) dI/dV=−I/V: PV module operates at the MPP. So used duty cycle D must be maintained, b) dI/dV>−I/V: PV module operates at the MPP left. So used duty cycle D must be decreased, c) dI/dV<−I/V: PV module operates at the MPP right. So used duty cycle D must be increased

OUTPUT POWER SIMULATION RESULT P&O (BLUE) AND INC. C. (RED) MPPT GATHERED IN THE SAME GRAPH



The Incremental Conductance (Inc. C.) MPPT algorithm outperforms the Perturb and Observe (P&O) method in terms of power production, despite a slightly longer tracking time and reduced oscillations around the Maximum Power Point (MPP).

Keywords: incremental conductance, matlab simulink, MPPT, Photovoltaic module, perturb and Observe, solar irradiation

Pub No: O-054

Atmospheric and Online Deposition of Dichroic Filters on Flat Glass by a Pyrolytic Process for BIPV Applications

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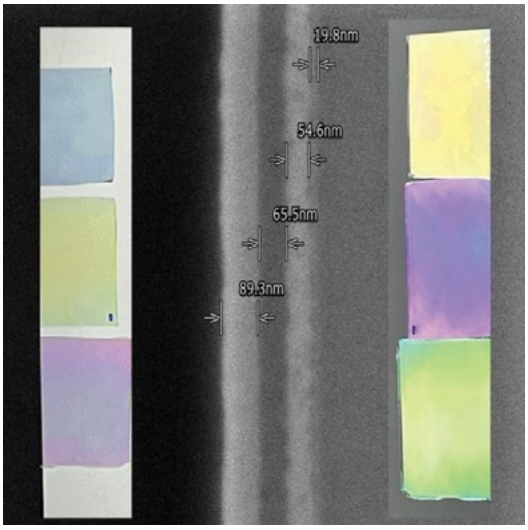
[1]Türkiye Şişe ve Cam Fabrikaları A.Ş.

Abstract: Building Integrated Photovoltaics (BIPV) have emerged as architectural elements in the past 20 years and the demand is steadily growing as climate change is a pressing global concern. Integration of photovoltaic devices into buildings is not only a technical issue, but also an aesthetic problem. Dichroic thin films deposited on flat glass as cover glass substrates, provide colorful and appealing visual appearance for the customers and spray pyrolysis provides a low capital cost alternative for the deposition of multilayer thin films. In this work, we investigate the low cost pyrolytic deposition of multilayer dielectric films comprising alternating stacks of TiO2 and Al2O3 to realize dichroic filters. Various colors including yellow, orange, green, violet, and blue were achieved at different viewing angles as observed visually and quantified by spectrophotometric studies. The coated glasses, effectively hide the modules underneath the cover glass. SEM and AFM results revealed that individual layers were uniformly deposited, additionally, film porosity can be adjusted by modification of the deposition precursor solutions, which allows us to tune the refractive index. We provide evidence that stoichiometric TiO2 and Al2O3 layers with crystalline structure could be successfully deposited based on XRD analyses. The transmittances are highly dependent on the color of the coated stack, and this has notable impact on the overall conversion efficiency of the solar module. This coating method paves the way for cost effective production of dichroic filters for building integrated photovoltaic applications.

Figure 1



SEM image of a three layer stack (glass/TiO2/Al2O3/TiO2) and different colors obtained by altering the thickness of the top layer.

Keywords: dichroism, optical thin films, building integrated photovoltaics, flat glass

Pub No: O-055

LASER PATTERNED THIN FILM SOLAR CELLS FOR BIPV APPLICATIONS

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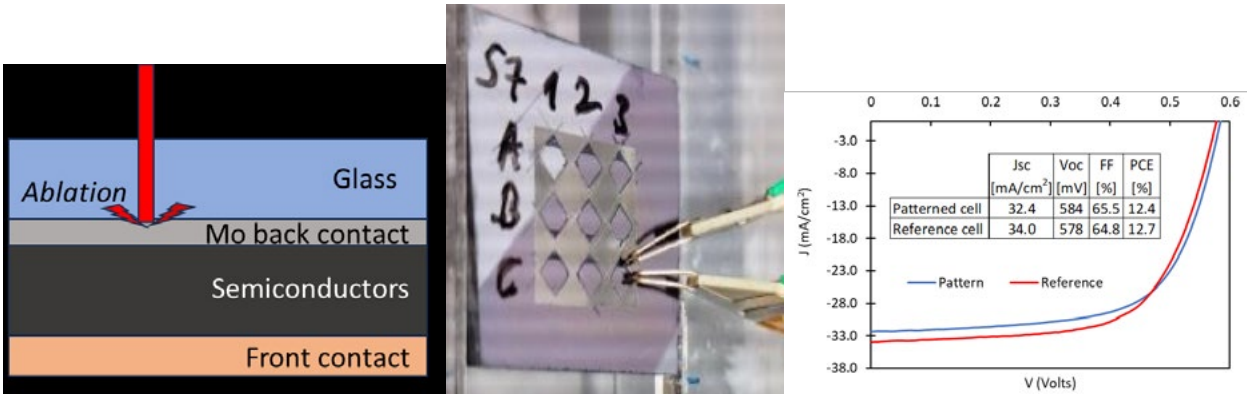
[1]Northumbria University

Abstract: This study reports on the patterning of CIGS thin film solar cells on molybdenum-coated soda-lime glass using laser ablation. The threshold energy for Mo ablation was determined to be 4.2 J/cm² using a 1064 nm nanosecond pulsed laser. Semiconductors and front contact layers, grown on the Mo back contact, can be removed alongside the Mo layer at energies slightly above this value and at high processing speeds (>10 cm/s). Challenges were encountered with patterning in an air medium, including the redeposition of the ablated vapor and the formation of edge defects within the heat-affected zone, causing electrical shorts. However, transferring the process to a pumped water medium effectively addressed these problems. An additional scribing step was developed to enhance edge isolation and realize high-performance devices. The conversion efficiency of patterned cells reached over 12%, while the reference non-patterned cells were 12-13% efficient. This study demonstrates the potential of patterned thin film PV devices for building integrated PV solutions such as semi-transparent glazing and balcony fences. Keywords : CIGS, pulsed-laser ablation, BIPV

Figure 1. (a) Device structure with patterning laser beam, (b) A patterned CIGS device under solar simulator JV test, and (c) Light JV curves of the best performing patterned and reference CIGS solar cells

Fig 1

a) b) c)



Keywords: CİGS, BIPV, pulsed laser patterning

Pub No: O-056

Development of a Photonic Glass-Based Colored Photovoltaic Panel for BIPV Applications Utulizing Metal Oxide Nanoparticles

Parisa Sharif [1], ***Talat Ozden*** [1], ***Eda Cevik*** [1], ***Sahin Coskun*** [3], ***Husnu Emrah Unalan*** [3], ***Alpan Bek*** [4]

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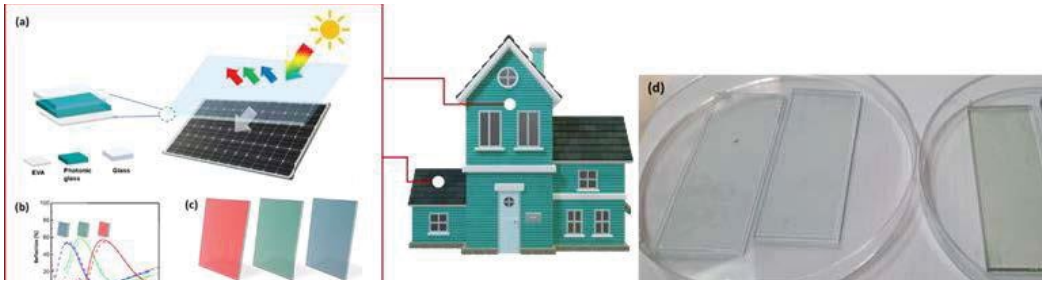
Abstract: The integration of Building Integrated Photovoltaics (BIPV) into urban architecture is crucial for zero-energy buildings and sustainable communities. Enhancing the visual appeal of photovoltaic (PV) panels without compromising power conversion efficiency (PCE) is a significant challenge. Our research addresses this by developing a photonic glass layer colorization technique for PVs using metal oxide nanoparticles, leveraging the selective light-reflective and absorptive properties of materials like titanium dioxide (TiO_2), and vanadium pentoxide (V_2O_5). These materials, preferred over traditional dyes due to their durability and spectral selectivity, are synthesized into monodisperse nanospheres through a solution-based method. These nanospheres are then applied to PV panel glass using ultrasonic spraying to create a 2-3 micrometer thick photonic glass layer that offers angle-independent color perception through Mie scattering. Initial coatings of TiO_2 nanospheres (480 nm diameter) on glass resulted in a pronounced green hue, validating our approach. Multilayer coatings are expected to enhance color richness and intensity. The fabricated mini-panels, incorporating PERC c-Si cells, will undergo comprehensive colorimetric measurements and performance testing under various conditions to ensure efficacy and durability. This research advances PV technology by combining functionality with architectural aesthetics, supporting the adoption of sustainable energy solutions in urban settings.

Figure 1



(a) A high-efficiency color PV device with a functional layer that selectively reflects visible light. (b) A high-efficiency color PV should have increased reflectivity in the wavelengths of visible light (represented by the color band). (c) The colored panels. (d) Glasses coated with TiO2 nanospheres made as a preliminary study.

Keywords: BIPV, colored solar panel, metal oxide, nanospheres, photonic glass, aesthetic impact

Pub No: O-057

Building Shape Impact on BIPV Performance with Different PV Module Technologies

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[1]Department of Architecture, Cukurova University

Abstract: Building form plays an important role in energy efficiency and solar energy gain as well. Energy-efficient building design is depended on the contextual principles and local climatic conditions of the specific site. However, building envelope plays dual function of energy transition and creation through its surfaces. Also, the building shape and its orientation makes significant effect on BIPV solar yield regarding energy creation considered in the early-stage design process. Different building form types with the same floor area in the mid-latitude climate of Ankara studied to find out the most energy-efficient form by overall balance between the solar gain potential and heat losses through the building envelope. The study investigates the influence of building shapes on the performance of BIPV with various PV module technologies. It employs simulations to analyze multiple building geometries, incorporating flat, sloped, and curved surfaces, under varying environmental conditions. Also, the calculation represents that optimized roof size, orientation and building form with an appropriate ratio of compactness for the selected form types, resulted in better BIPV performance for energy creation. Additionally, the study compares the performance of distinct PV technologies, including monocrystalline silicon, polycrystalline silicon, and thin-film solar cells, across these architectural configurations. Findings indicate significant variability in BIPV efficiency based on building shape, with optimized designs enhancing energy yield by up to 30%. The study highlights the critical role of architectural considerations in maximizing the effectiveness of BIPV systems and provides guidelines for integrating PV technologies in urban planning and sustainable building design.

Keywords: Building Shape, Solar Yield, BIPV Performance, PV Module Technologies, Energy Balance

Pub No: O-058

A Cost-Benefit Analysis of Photovoltaic Building Facades: A Case Study in Northern Cyprus

Amirhossein Karimizadeh [1], ***Ercan Hoskara*** [1]

[1]Eastern Mediterranean University

Abstract: It is predicted that buildings of the future will shift from being just resource consumers to actively contributing to energy generation. Since façades are one of the most important elements of a building, they should not only offer benefits like daylighting and thermal comfort, but they should also significantly increase the value of energy generation through the use of suitable technologies like photovoltaic (PV) systems. In comparison to other renewable energy sources, photovoltaic system technology is expanding quickly. This is particularly relevant for building-integrated photovoltaics (BIPV), which has gained widespread recognition throughout the world for both its energy-generating capabilities and its use as a type of construction material (Biyik et al, 2017). While Cyprus Island has a high potential to use solar energy as a renewable energy in the building sector, in Northern Cyprus PV panels are typically mounted on building rooftops, however, building facades, are not commonly utilized for this purpose. In addition, there has been a gap in the literature analyzing the cost-benefit of BIPV systems, which is crucial for promoting their acceptance and application.Therefore, the primary aim of this study is to evaluate the cost benefits of utilizing BIPV in building facades. To achieve this, the payback period and net present value (NPV) of a BIPV façade on an office building in Northern Cyprus will be examined. This research seeks to support the promotion of BIPV investments for building facades by demonstrating their acceptable range of cost benefits.

Keywords: Northern Cyprus, building facades, cost-benefit, payback period, net present value (NPV), building integrated photovoltaic (BIPV)

Pub No: O-059

Sustainable Conversion of Agri-food Waste using HTL Reactor Integrated with Concentrated Solar Energy, Thermal Energy Storage and Solar PV

Deniz Değirmenci [1], ***Batuhan Ülkütaşır*** [1], ***Nikolaos I. Tsongidis*** [3],

Charikleia A. Poravou [3], ***George Karagiannakis*** [3], ***Derek Baker*** [2], ***Onur Taylan*** [2]

[1]ODTÜ Center for Solar Energy Research and Applications (ODTÜ-GÜNAM)
[2]Middle East Technical University (METU / ODTÜ)
[3]Centre for Research & Technology Hellas (CERTH)

Abstract: This study presents a novel approach for converting agri-food waste into valuable bio-oil and fertilisers through hydrothermal liquefaction (HTL) powered by concentrated solar energy coupled with thermal energy storage (TES) and solar photovoltaic (PV). The energy requirement of the HTL reactor is covered by a parabolic trough collector (PTC), and a packed-bed TES is integrated to provide night-time provision to the process. When PTC cannot cover the entire energy requirement, PV with electrical heaters will cover the energy deficiency. The design has been proposed under the Horizon Europe SolarHub project, and two hubs from this project have been selected: Ankara and Thessaloniki. Each HTL reactor run takes about 2.5 hours and requires 8.625 kWh of energy. The PTC collector is modelled with an aperture area of 18 m2, TES has 72% roundtrip efficiency, and PV is modelled using the HDKR model. The results show that the PTC generates about 13 and 15 MWh/a of energy, corresponding to about 43% and 50% of the HTL's energy requirement in Ankara and Thessaloniki, respectively, assuming 7/24 operation of the reactor throughout the year. When the system is coupled with TES, these ratios increase to 74% and 86%. In the selected cities, about 26- and 29-kW PV installation is required to cover these loads, assuming the net-metering scheme (i.e., the grid is used as a storage system). The proposed system offers a promising and fully sustainable alternative to valorising agri-food waste, contributing to advancing a circular economy and clean energy transition.

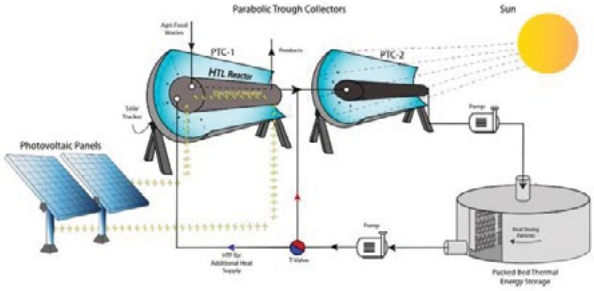
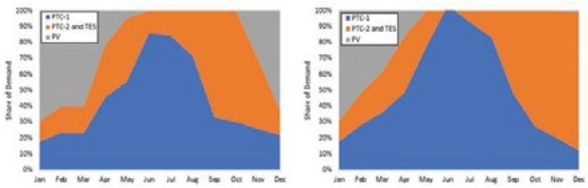


Figure 2



Keywords: agri-food waste, hydrothermal liquefaction, parabolic trough collector, photovoltaic, SolarHub, thermal energy storage

Pub No: O-060

Towards Large-Area Luminescent Solar Concentrators: CsPbBr3 Quantum Dot-Embedded Glass Nanocomposite Integration Strategies

Emre İlter [1], ***Utku Ekim*** [1], ***Constantin Tsoi*** [2], ***Elshan Asadi*** [2],

Ali Erçin Ersundu [1], ***Miray Çelikbilek Ersundu*** [1], ***Selçuk Yerci*** [2]

[1]Yildiz Technical University
[2]Middle East Technical University

Abstract: The escalating global energy demand, coupled with the imperative to mitigate environmental degradation, has spurred a growing interest in renewable energy sources, particularly solar cells. Luminescent solar concentrators (LSCs) have emerged as a promising alternative to conventional photovoltaic technologies, offering scalability, cost-effectiveness, and versatility in various lighting conditions. To date, many QDs have been integrated into LSCs to increase photon harvesting and conversion efficiency. However, integration methods mainly polymer based have been investigated, each presenting unique challenges and opportunities. At that juncture, encapsulation of QDs within glass is particularly compelling, offering high stability and spectral efficiency. Despite recent advances, the scalability and performance evaluation of glass nanocomposite (GNC)-based LSCs have yet to be elucidated. This research aims to systematically measure the performance of CsPbBr3 GNC-based LSCs across increasing surface areas, corroborating experimental findings with analytical Monte Carlo Ray Tracing simulations. The ongoing research endeavors to uncover production limitations and optimization opportunities, providing valuable insights for future research directions in the realm of large-area QD-embedded GNC LSCs, with significant implications for practical applications in solar energy harvesting.

Keywords: Luminescent Solar Concentrator (LSC), Quantum Dot (QD), Glass Nanocomposite (GNC)

Pub No: O-061

Enhancing Heat Pump Efficiency Through Integrated Photovoltaic Thermal Systems

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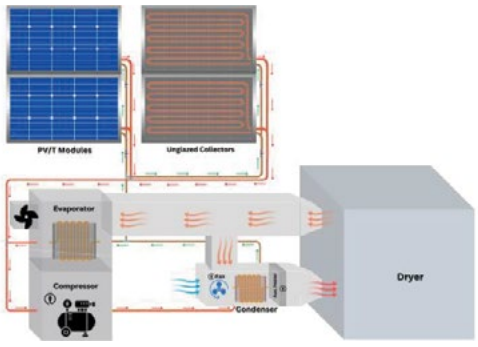
Abstract: As energy efficiency becomes increasingly crucial in sustainable development, integrating photovoltaic thermal (PV/T) systems with heat pump technology presents a promising solution. This study evaluates the performance of a heat pump system enhanced with photovoltaic thermal (PV/T) collectors under different operational conditions aimed at heating a dryer cabinet. The system was tested with cabin temperature settings of 50°C and 60°C and an air velocity of 2 m/s. As seen in Figure 1, the system includes a two-stage compressor, a condenser, two fans, and three evaporator groups comprising PV/T modules, unglazed solar thermal collectors, and a conventional heat exchanger. Results show that using PV/T collectors as the heat pump evaporator—providing both heat and electrical energy—increases the Coefficient of Performance (COP) by 47% and 27% for the temperature settings of 50°C and 60°C respectively (Bilgilioglu, 2022). Additionally, cooling the photovoltaic panels with the heat pump system enhances their efficiency by 2.70% to 4.24%. These findings are supported by broader research indicating that such integrations can reduce the temperature of PV/T modules by up to 10°C, thereby enhancing electricity production efficiency by approximately 25% (Miglioli et al., 2023). The average COP of these systems remained around 3.0 throughout the heating season, confirming their technical feasibility and environmental benefits (Abu-Rumman et al., 2020). This study demonstrates the potential for significant energy efficiency improvements in heat pump systems through PV/T integration, suggesting a promising pathway for enhancing sustainable heating technologies.

Figure 1. Schematic illustration of the PV/T integrated heat pump drying system.



Keywords: Energy Efficiency, COP, Solar Assisted Heat Pump, Drying, PV/T.

Pub No: O-062

Rooftop Segmentation Approach with Unclassified Data for PV Potential Estimation

Ilkim Canli [1], ***Emircan Ucar*** [2], ***Sinan Kalkan*** [2], ***Ipek Gursel Dino*** [2]

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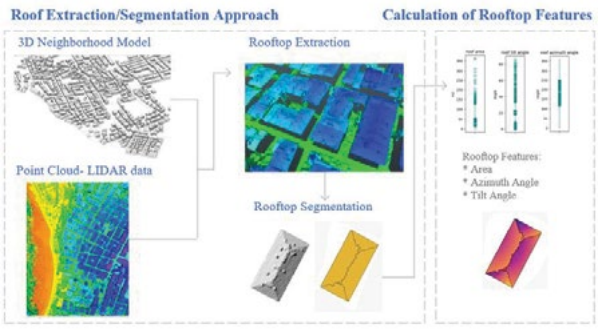
[2]ODTÜ

Abstract: PV systems can be integrated into different building parts, with the most common PV installation being on the roof. Precisely calculating roof characteristics such as area, azimuth angle, and inclination is crucial for accurately estimating urban roofs' PV potential. Several methods have been developed for estimating the rooftop features and potential of rooftop PV systems. Depending on the available data format, PV estimation studies can be categorized into 2D, 2.5D, and 3D [1]. 3D approaches, including LIDAR data, yield more accurate PV potential estimation. In studies that classified LIDAR point cloud data is available [2,3], the points have been categorized into distinct classes, such as building, ground, and vegetation. Buildings were extracted by clipping the corresponding coordinates in the point cloud, generating a list of potential roofs. However, the calculation of realistic roof features at the urban scale is challenging because (i) the proximity of closely spaced buildings, making accurate delineation of individual roofs difficult, and (ii) the presence of various structures such as chimneys and terraces on roofs, complicating the determination of suitable areas for photovoltaic installations. The study aims to develop a method for the realistic calculation of rooftop features, including area, azimuth angle, and slope, that can be used to estimate PV potential from rooftops at urban scale. The developed methodology (Figure 1) enables the extraction of rooftop features from unlabeled point cloud data. Our study is novel as we developed an extraction/segmentation method considering the different formations on adjacent buildings and roofs on a large scale.

Figure 1. An overview of the three main steps of the proposed approach.



Keywords: BIPV, segmentation, pv potential estimation, point cloud

Pub No: O-063

Maximizing Solar Energy Harvesting Efficiency: AI-Based Prediction for PV Panel Systems Positioning

Cem Özkurt [1], ***Ceyda Aksoy Tırmıkçı*** [2], ***Cenk Yavuz*** [2], ***Hasan Tenli*** [1]

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[2]Sakarya University
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[4]Sakarya University Innovation Center

Abstract: Solar PV technology, the leader of renewable energy technologies, proposes zero emissions during the operation. However, PV technology has embodied greenhouse gas emissions depending on the energy source to produce and to transfer the technology. Optimum positioning of solar PV modules is vital to decrease the greenhouse payback time (GPBT) and to minimize the carbon footprint of PV systems. The accuracy of artificial intelligence based solar PV forecasting has put it forward in the field. In this study, the annual output of two different roof-type PV systems located on the same latitude in Sakarya, Türkiye was predicted by Long Short-Term Memory (LSTM). The data sets consist of meteorological parameters of the region from Meteoblue and hourly PV energy generation data obtained from the owners of the systems (Figure 1). The input parameters of LSTM model were meteorological parameters while the target parameter was PV energy output. The results show that the North-South system with an inclination angle of 13° has a better performance than the East-West horizontal system. MSE loss value of the LSTM model was obtained as 0.024 and the energy generation of North-South system with an inclination angle of 13° was predicted 0.2 MW more than the generation of East-West horizontal system. This finding reveals that the meteorological parameters of the region play a critical role in estimating the direction and angle of solar PV modules. As a result, this study plans to provide an important road map for more effective and efficient use of renewable energy resources.

Map_presentation

Figure 1. Map representation of the analyzed PV systems

Keywords: PV Panel Positioning, LSTM (Long Short-Therm Memory), Meterogical Data, Comparative Analysis

Pub No: O-064

Nonpalanar PV system application on water tower

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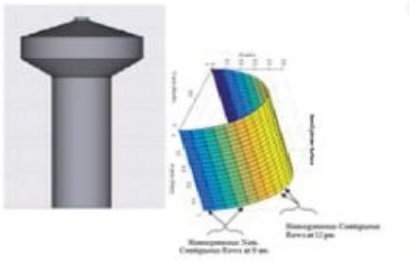
[2]Electrical & Computer Engineering Department, Texas A&M University ,College Station Tx, USA

Abstract: In this paper we explored the nonplanar photo- voltaic application for water tower tanks and buildings. Water tank and water tower buildings have nonplanar surfaces that can be modelled by solid geometries including cylindrical, spherical, semi-spherical and others. Most photovoltaic (PV) applications today are relegated to a flat planar surface; this is due to several pragmatic limitations of the previous technologies. The first generation of crystalline material is possible only in a planar form only because of how they are fabricated and the inflexibility of the rigid structure. While the flexibility of thin-film (TF) eliminated the planar form factor restriction, it retained the planar form factor of the module. As second reason is the partial shading effect that is inherent when the module is non-planar. We consider the application of PV material to the non-planar surfaces for water tank, and investigate the electrical generation capabilities unique to this geometry. More broadly, considering non-planar photovoltaics (NP-PV) extends the variety of the potential applications, offering a wide array of possibilities at any scale. Water towers are an ideal application because they are often located in open areas and taller than their surroundings so there are no shadows and only open skies. The three-dimensional arrangement of nonplanar panels would enable the tower-based application to harvest energy throught the daily and seasonal variations. A key imperative is to ensure that the water tower structure can support the additional weight of the solar panels.

Acknowledgement: This publication was made possible by grant # AICC04-0809-210014 from the Qatar National Research Fund (a member of Qatar Foundation). The statements made herein are solely the responsibility of the authors.

Covered with nonplanar PV surface of water tower



Covered with nonplanar PV surface of water tower

Keywords: Nonplanar surface, Flexible PV systems, Solar energy, Water tank, Renewable energy, Shadow, Energy efficienc

Pub No: O-065

Cooling Optimization for Concentrating Photovoltaics Modules: A Study of Convective and Radiative Cooling with a Focus on Plate Fin Applications

Deniz Değirmenci [1,2], ***Ertuğrul Çubuk*** [1,2], ***İlker Tarı*** [1,2], ***Özgür Selimoğlu*** [3]

[1]ODTÜ-GÜNAM Center for Solar Energy Research and Applications
[2]Middle East Technical University
[3]Ankara University

Abstract: In concentrating photovoltaics (CPV) applications, cooling is a vital requirement for maintaining operable temperatures and optimal efficiency. The most energy-efficient cooling strategy is using natural convection and radiation to cool the solar panel. However, natural convection yields low heat transfer coefficients as the air is trapped at the back of the solar panel and the available heat transfer area behind the solar panel is quite limited. To overcome this, fins that extend to the front of the solar panel can be employed to increase the exposed area. This study investigates convective and radiative cooling of a CPV module using plate fins mounted on the back of the cells through parameter sweeps and sensitivity analysis. The proposed concept is designed to create a digital twin of the module, demonstrated in Figure 1, to test with CFD and to facilitate further prototyping efforts. The study to obtain a digital twin of the system was conducted through experiments and computational modeling, which simulated both stagnant ambient air and windy conditions. The study revealed that the system is highly sensitive as there is very low heat release from the back and limited temperature differences. To validate the model, inverse analysis was conducted to determine the actual emissivity and insulation resistance values. The validated model can be used to determine the ideal fin height. Temperature results for the forced convection cases are presented in Figure 2. The 12-cm fin is showing optimum performance than the other fin lengths for the proposed model geometry.

Figure 1. Simplified geometry considered in the CFD simulations. (1a- heating layer, 1b- solar cell, 1c- lamination layer, 2- aluminum fin, 3- PMMA lens, 4- solid enclosure, 5- insulation)

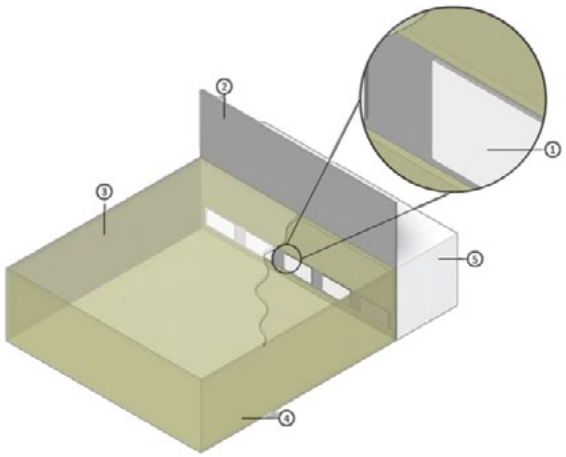
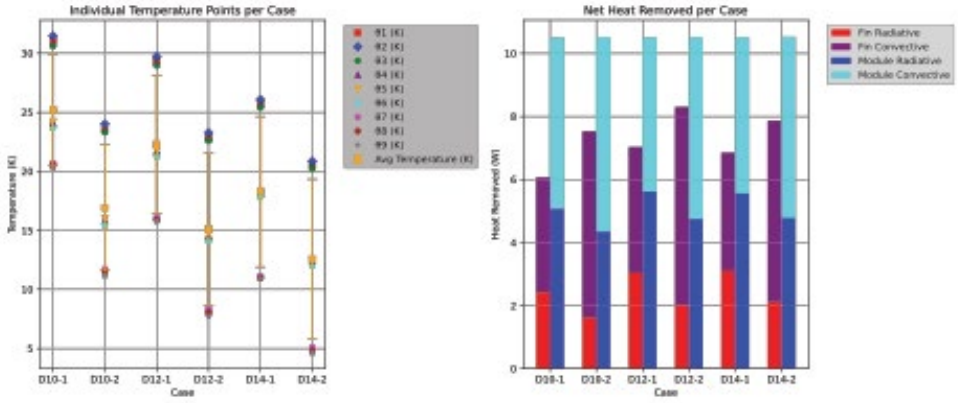


Figure 2. Probe point temperatures and net heat removal data from simulations for different cases.



Keywords: Concentrating photovoltaics (CPV), natural convection, radiative cooling, sensitivity analysis

Pub No: O-066

MOBILE ENERGY APPLICATIONS IN MOBILE OFFICES

Seniye Eşkin Uzun [1], ***Berathan Yıldırım*** [1], ***Burcu Büyükkınacı*** [1], ***Yüksel Yalçın*** [1]

[1]İSTANBUL ENERJİ A.Ş.

Abstract: The use of fossil fuels to meet energy needs has started to be questioned in terms of environmental and economic dimensions. This situation is increasing the importance of renewable energy sources, also known as clean energy, and promoting their widespread use. The most commonly used renewable energy sources worldwide are solar and wind energy. Despite the many advantages of renewable energy production, such as sustainability, there are some disadvantages including high initial investment costs, low efficiency, and intermittent production. Studies are being conducted on hybrid renewable energy systems to ensure the continuity of renewable energy systems and increase system efficiency.In this study, a Mobile Energy Tower design was implemented for the Halk Ekmek Buffet located in Reşitpaşa Neighborhood, Sarıyer District. The Mobile Energy Tower is a system that produces electrical energy by using renewable methods, stores it, and makes it available for use. It utilises the principle of converting solar energy into electricity with solar panels and wind energy with a wind turbine. This system consists of solar panels, a wind turbine, a cabin, and a supporting structure. After fully charging its batteries, the Mobile Energy Tower can meet the planned demand for 2 days without sunlight.Design of "Mobile Energy Tower" enables the electricity needs of mobile offices (such as security booths, sales kiosks, etc.) operating independently from the electricity grid to be met with renewable energy sources. Different dimensional adjustments can be made by analyzing the requirements according to the location.

Keywords: renewable energy, hybrid system, solar energy, wind energy

Pub No: O-067

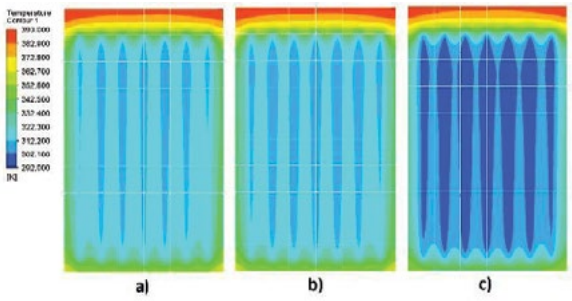
INVESTIGATION OF THE EFFECT OF A NEW ABSORBER PLATE DESIGN ON HYBRID PV/T COLLECTOR PERFORMANCE

Mahmut Sami Büker [1], ***Ahmet Emre Onay*** [2], ***Halil I. Dag*** [2]

[1]Necmettin Erbakan University, Energy and Semiconductors Research Group
[2]Innorma ArGE AS
[3]SOLIMPEKS Solar Co.

Abstract: PV/T panels are hybrid systems that combine photovoltaic and thermal technologies to simultaneously produce electrical and thermal energy. These panels are meticulously engineered to elevate solar panel performance by actively cooling PV cells and harnessing generated heat for practical applications. Numerous studies have investigated PV/T panels with diverse absorber designs. Ali and Uniyal explored enhancing performance through w-rib roughness addition to the absorber plate [1]. Kong et al. simulated flow and heat transfer characteristics of a super-thin, conductive thermal absorber with built-in corrugated channels [2]. Solomon compared Roll-bond and sheet-and-tube absorbers, determining Roll-bond's superior thermal performance [3].This study examines the impact of TINOX-coated aluminum and finned absorber plates on the thermal efficiency of a PV/T collector. Computational Fluid Dynamics (CFD) analysis investigates how water flow affects heat transfer and consequently enhances electrical yield. Two systems are compared to assess the performance enhancement achieved by water flow with different absorber plate geometries. CFD analysis of the PV/T collectors is conducted under Eurofins Test Conditions with 1000 W/m2 radiation and 0.042 kg/s mass flow rates, while maintaining a constant water inlet temperature of 15°C. The analysis yields circulating water outlet temperatures and corresponding increases in electrical yield of PV cells due to cooling.

Figure 1



Temperature gradient on the PV cells under 1000W/m2 of radiation with different flow rates [4]

Keywords: Hybrid PV/T collector, absorber plate, electrical efficiency

Pub No: O-068

Hybrid Water Pumping As A Complement To The Irrigation System In The Ziz Valley (East of Morocco)

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[1]Cadi Ayyad University Marrakech

Abstract: In the Oued Ziz Valley (OZV), the solar energy reaches 7.5 kWh/m2/day during May-September, and the cloudy days are rare during the whole year. The photovoltaic solar water pumping systems are suitable during day times and can be complemented by diesel pumping during the night times. The wind pumping systems are not recommended due to the irregularity of the wind in the region. We have calculated the average cost of 1m3 water pumped with solar photovoltaic systems in the OZV for two periods: Summer time (June-August) and the rest of the year. We have seen that the solar PV pumping is very competitive with diesel pumping, mainly in summer time when pumped water is needed to complement the traditional irrigation system from the Ziz river. The water level in the river is becoming very low due to the hydric stress and during the last 10 years the river is almost empty during summers. In this paper, we will present the calculated average cost of water pumped with solar photovoltaic system in the OZV in summer time and in the rest of the year. We will also discuss the financial and technical problems encountered by the rural population to buy a suitable solar water pumping system. The environmental and financial gain when using solar water pumps instead of oil engines will be addressed. The results can be extended to dry and semi-dry south Mediterranean areas.

Keywords: Photovoltaic, Ziz Valley, Dry areas, Environment, Water pumping

Pub No: P-013

Investigation of Laser-Induced Lifetime and Implied Voc Deterioration on Passivated Flat and Textured Silicon Surfaces During the Laser Ablation Process

Melisa Korkmaz Arslan [1], ***Bülent Arıkan*** [1], ***İlkcan Erdem*** [3], ***Raşit Turan*** [2]

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[2]Department of Physics, Middle East Technical University, Ankara, Türkiye
[3]Department of Micro and Nanotechnology, Middle East Technical University, Ankara, Türkiye
[4]Center for Solar Energy Research and Applications (ODTÜ-GÜNAM), Ankara, Türkiye, Department of Physics, Middle East Technical University, Ankara, Türkiye
[5]Center for Solar Energy Research and Applications (ODTÜ-GÜNAM), Ankara, Türkiye, Department of Micro and Nanotechnology, Middle East Technical University, Ankara, Türkiye

Abstract: In the manufacturing process of crystalline silicon-based solar cells, laser process emerges as the most preferred method for locally ablating dielectric layers deposited on the surface to improve passivation and anti-reflective coating (ARC) purposes [1-4]. Selecting a laser system and appropriate parameters compatible with the absorption properties of the dielectric material is crucial to complete this process with minimal mechanical and electrical damage. In this study, we employed a picosecond (ps) green laser (λ=532nm) for ablation and focused on analyzing the lifetime and implied VOC drop on Al2O3/SiOxNy:H/a-SiNx passivated p-type flat and textured surfaces during the ablation process. PCD-based minority carrier lifetime measurements were conducted with Sinton Instruments WCT-120TS, and photoluminescence (PL) mapping was carried out with the Semilab PLI 1001 setup. In Figure 1, the variations in lifetime at a repetition rate of 625kHz are illustrated across different scan groups of power, scan speed, and number of pulses, detected. Meanwhile, Figure 2 represents the changes in lifetime and implied Voc before and after laser processing. Systematic experiments and measurements have demonstrated that by adjusting the scan speed, number of pulses, laser repetition rate and power (specifically increased repetation rate and decreased power), it is possible to explore parameters that either prevent or minimize damage to the substrate. Further details and improvements will be provided during the conference.

PL Image

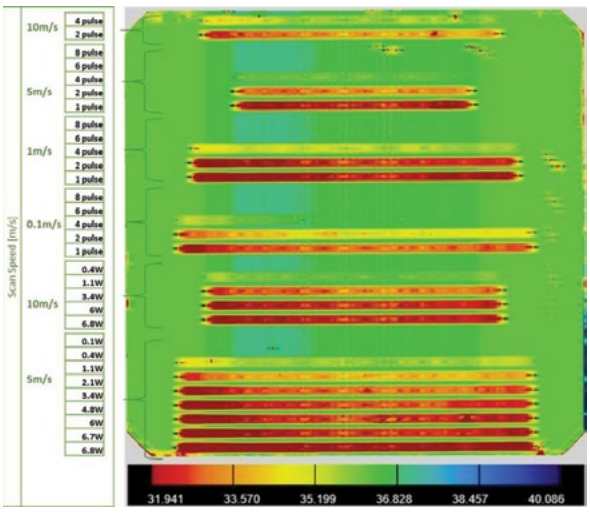


Figure 1. PL imaging at 625kHz with various scan speeds, powers, and pulse numbers.

Lifetime and Implied Voc Change

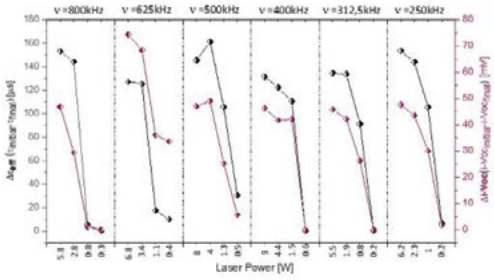


Figure 2. 532nm ps laser power at specific repetition rates vs. Δτeff and Δi-VOC.

Keywords: Silicon solar cell, Passivation, Picosecond laser, Laser ablation, Dielectric removal

Pub No: P-001

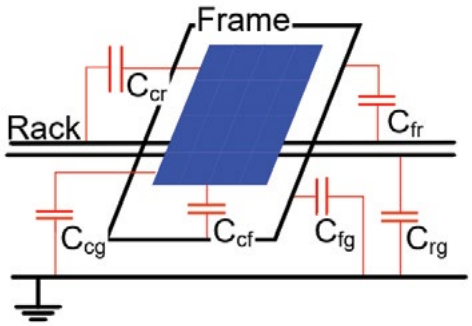
A Classification and Review of Photovoltaic Models

Nabila Elbeheiry [1], ***Robert Balog*** [1]

[1]Texas A&M University

Abstract: This paper examines the literature of commonly used photovoltaic (PV) models and classifies these models into categories based on the intended use. The paper identifies, assesses, and collates the literature to understand and identify the main purposes behind the various PV models and the key elements used for each modeling purpose. The modeling categories considered in this paper are DC electrical modeling of the cell, semiconductor physics-based modeling, and system-level modeling. DC electrical models the PV cell is concerned with the electrical characteristics (output power) of the PV under expected operating conditions. DC models ignore parasitic elements obtained due to features of the PV junction or structure of the solar panels as they are almost negligible under expected operating conditions [1]. On the other hand, semiconductor physics-based models and system-level perspective modeling are concerned with modeling changes that occur to the PV electrical behavior as they are subject to stress or have faults. While semiconductor physics-based modeling literature studies the PV cell and its P-N junction, modeling from a system-level perspective is concerned with the electrical characteristics arising from the structure of a mounted PV system. The reason for different modeling categories is to provide emphasis on the behavior of PV under different phenomena. Even within one category, literature did not converge on a single model as they provide different detail levels for the phenomenon being studied. The review and classification in this paper are intended to guide researchers in their PV model selection.

THE EQUIVALENT HIGH-FREQUENCY MODEL SUITABLE FOR SYSTEM-LEVEL ANALYSIS.



THE CAPACITANCE *Ccf* DONATES THE CELL-TO-FRAME EQUIVALENT LUMPED CAPACITANCE. *Ccr* DONATES THE FRAME-TO-RACK .*Cfr* EQUIVALENT LUMPED CAPACITANCE. ADDITIONALLY, THE GROUND ACTS AS A CONDUCTOR CREATING THE EQUIVALENT LUMPED PARAMETER CELL-TO-GROUND-CAPACITANCE *Cfg*, FRAME-TO-GROUND CAPACITANCE *Ccg*, AND RACK-TO-GROUND CAPACITANCE *Crg*.

Keywords: Photovoltaic, PV module, PV cell, DC electrical modeling of the cell, semiconductor physics-based modeling, system-level perspective modeling

Pub No: P-002

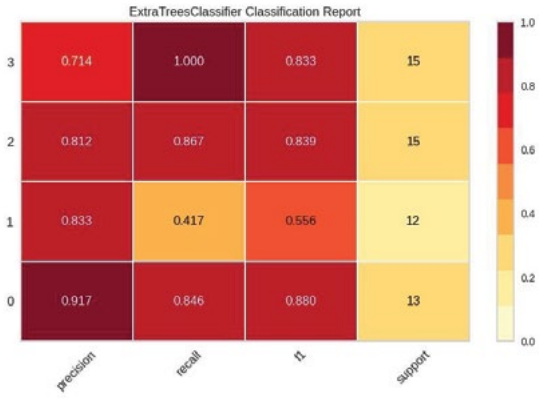
Advanced Characterization of Poly-Si Thin Film Solar Cells Deposited by E-Beam Evaporation Using Machine Learning

Seymanur Selver [1], ***Pınar Doğan*** [1], ***Cem Ayyıldız*** [2]

[1]Mugla Sıtkı Kocman University
[2]Gohm Electronics

Abstract: This study explores the advanced structural and electrical characterization of Polycrystalline-Si thin film solar cells, epitaxially grown using the electron beam evaporation method at low substrate temperatures and under moderately high vacuum conditions. We employed machine learning techniques to analyze a significant dataset, which includes structural, electrical properties, and Current-Voltage measurements of films deposited on Monocrystalline-Si wafers and Polycrystalline-Si seed layers prepared on glass via the Aluminum-Induced Layer Exchange process. During this process, the Si nuclei formed on the glass grew and formed Si grains in different crystallographic orientations [(100), (111),(110)]. Therefore, samples of Monocrystalline-Si wafers with different crystal orientations have been used as references. The films were grown across a range of substrate temperatures (450°C to 700°C) and Si deposition rates (40nm/min to 475nm/min), to evaluate their impact on key performance metrics such as Short Circuit Current density, Open Circuit Voltage, Fill Factor, Efficiency, Parallel Resistance, and Series Resistance. An innovative image detection method was applied to analyze Scanning Electron Microscopy and Electron Backscatter Diffraction images, which significantly reduced the error rates compared to traditional manual methods and provided new insights into the crystallographic orientation of Si grains. Our findings indicate improved characterization accuracy and potential enhancements in solar cell performance, highlighting the benefits of integrating machine learning into solar cell production processes. These advancements could lead to more cost-effective and efficient solar cell technologies, offering substantial benefits for sustainable energy applications.

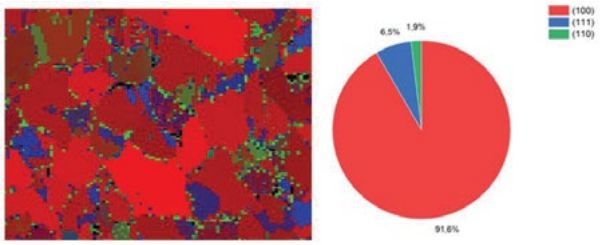
ExtraTreesClassifier Classification report



Evaluation of classification performance by ExtraTreesClassifier on the Substrate temperature dataset: An heatmap is employed to display accuracy, recall, F1 score, and support metrics for four distinct classes (class 0 is epi on Si(100) with H-pass, class 1 is epi on Si(100) without H-pass, class

2 is epi on Si(111) with H-pass, class 3 epi on Si(111) without H-pass). Each cell presents scores for the respective class and metric using a color scheme, where dark red represents low and light yellow represents high values. The model particularly stands out with a high recall rate in class 3, while highlighting class 1 as an area requiring improvement due to its low recall score.

Electron Backscatter Diffraction orientation map and distribution chart



Electron Backscatter Diffraction orientation map and distribution chart of the poly-Si on glass substrate grown at 600°C. The distribution chart (100) indicates that grains in the crystal orientation are 91.6% more dense, while grains in the (111) and (110) crystal orientations are less dense.

Keywords: Machine Learning, Polycrystalline Si Thin Film Solar Cells, Advanced Characterization

Pub No: P-003

Application of Copper Iodide Inorganic Hole Transport Layer in Perovskite Solar Cells

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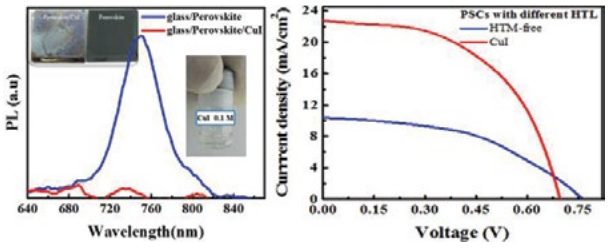
[1]Abdullah gül university
[2]Sharif University of Technology
[3]Arak university

Abstract: In this study, the impact of an inorganic Copper Iodide (CuI) hole transport layer (HTL) on perovskite solar cells (PSCs) is explored. A mixed halides perovskite (Cs0.05(MA0.17FA0.83)0.95Pb(I0.83Br0.17)3) was utilized as the light-absorbing layer in the traditional PSC structure. Copper Iodide, with a high mobility of 0.5–2 cm2/Vs and a large bandgap energy of 3.1eV, emerges as a promising alternative to organic hole transport materials in solar cells. A p-type thin CuI layer was applied onto the perovskite layer using a spin coating technique with a 0.1 M CuI solution in chlorobenzene. CuI-based PSCs, with a straightforward deposition process, demonstrated impressive current density and efficiency compared to HTL-free PSCs. The highest power conversion efficiency (PCE) of 8.12% was achieved for the PSC featuring the CuI hole transport layer, marking the most efficient CuI-based dopant-free PSCs reported. Moreover, the current density increased by over 119% compared to the HTL-free PSCs.The enhanced performance of CuI-based PSCs can be attributed to the efficient hole extraction and transport properties of the inorganic material. The high mobility of CuI facilitates the rapid movement of holes, leading to improved charge collection and reduced recombination losses within the device. This, in turn, results in higher current densities and enhanced overall efficiency of the solar cell. The simplicity of the CuI layer's deposition process also adds to this approach's appeal, making it a cost-effective and scalable solution for next-generation perovskite solar cells. CuI-based PSCs hold great promise for achieving even higher efficiencies and advancing the field of photovoltaics.

Figure 1



Photoluminescence spectra of the glass/perovskite and glass/perovskite/CuI. The real images of these layers and 0.1M CuI solution are shown in the inset. The incident photon to current conversion efficiency analysis of PSCs with FTO/TiO2 /perovskite/CuI/Au and FTO/ TiO2/perovskite/Au structures.

Keywords: CuI, Perovskite, Hole transport layer, Solar cells

Pub No: P-004

Exploring the Catalytic Potential of Silver-Doped Zinc Oxide in Photocatalytic Degradation of Waste Dyes

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Abstract: Silver-doped zinc oxide (Ag-ZnO) and pristine zinc oxide (undoped ZnO) particles were synthesized using a cost-effective, energy-efficient, straightforward, and innovative mechanochemical approach, followed by calcination at 500°C. Various concentrations (0.5 wt%, 1 wt%, and 2 wt%) of silver-doped zinc oxide (Ag-ZnO) were prepared and employed for the degradation of methylene blue through a decomposition process. The progression of structural and morphological changes in the chosen porous zinc oxide (ZnO) particles was analyzed using X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), and scanning electron microscopy (SEM) techniques. Furthermore, BET analysis of 1% Ag-ZnO which had the best photocatalytic role, was carried out in particular and its surface area was measured at 19.4 m^2/g. Various concentrations (0.5 wt%, 1 wt%, and 2 wt%) of silver-doped zinc oxide (Ag-ZnO) were produced and assessed for their efficacy in decomposing methylene blue. The photocatalytic capabilities were examined by utilizing 0.1g of powder catalyst in a 100 mL aqueous dye solution (methylene blue) under simulated solar light exposure at a pH of 7. The 1% Ag-ZnO nanoparticles, upon exposure to simulated solar radiation, exhibited superior photocatalytic performance in degrading Methylene blue within a 45-minute timeframe in an aqueous solution. This enhanced activity can be attributed to the nanoparticle's expansive surface area, modified porous nanostructure, and optical characteristics. Employing straightforward and cost-effective techniques, novel catalysts designed to operate under sunlight and characterized by established optimal efficiencies will not only advance scientific knowledge but also provide a blueprint for exploring new application domains.

Keywords: Ag-ZnO; Water treatment; Mechanochemical method; Photodegradation; Methylene blue

Pub No: P-005

Influence of Deposition Electrolyte Concentration on the Characterization of Molybdenum Sulfide Thin Film via Electrodeposition For Solar Cell Applications

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Zul Atfyi Fauzan Mohammed Napiah [1], ***Radi Husin Ramlee*** [1],

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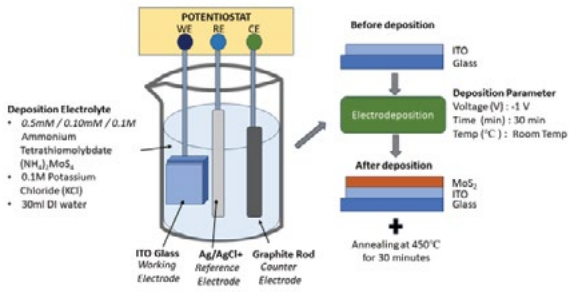
Abstract: Solar cells, also referred to as photovoltaic (PV) cells, utilise the photovoltaic effect to transform light energy into electricity. Third-generation solar cells combine thin film technologies with second generation deposition methods to achieve highly efficient devices. Molybdenum sulfide (MoS2), is a type of transition metal dichalcogenide (TMDC) with excellent properties. It exhibits high electrical conductivity and impressive catalytic activity, making it a promising candidate for third generation solar cells like Dye Sensitised Solar Cells (DSSC) and Perovskite Solar Cells (PSC). In addition, electrodeposition can be used to deposit MoS2 thin film. However, its reported that concentration of the deposition electrolyte is one of the factor that can influence the properties of fabricated thin films in electrodeposition. In this study thin films of MoS2 were deposited using electrodeposition at different concentrations: 0.5mM, 0.10mM, and 0.1M. The deposited MoS2 thin film was characterized via Scanning Electron Microscopy (SEM), Energy-dispersive X-ray (EDX), Cyclic voltammetry (CV) and Ultra-violet visible (UV-vis) to analyze the influence of concentration of deposition electrolyte on morphological, electrochemical and optical properties of the thin film. The findings show that the concentration of the deposition electrolyte significantly affects the thin film's grain distribution and structure. It also impacts the electrochemical properties, such as the rate of electron and mass transfer between the electrode and the electrolyte. Higher concentrations result in faster electron and mass transfer. Additionally, higher concentrations lead to lower absorption and light transmission, making lower concentrations better in optical properties of thin film.

The summarization of electrodeposition process of MoS2 thin film



Keywords: Deposition, Third generation solar cells, Thin film, Characterization, Photovoltaics

Pub No: P-006

A Roadmap and Feasibility Study on GW-Scale PV Manufacturing in Türkiye

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Abstract: With the rapidly increasing demand on renewable energy sources, global PV module shipments have been increased from 295 GWp in 2022 to 502 GWp in 2023 [1]. As of today, the PV industry has gained more attention from investors. Hence, the feasibility, CapEx & OpEx calculations and life cycle assessment (LCA) depend on the area where the investment is planned; the total cost of ownership of investment varies on different strategy configurations. Decisions to be taken when determining technology and capacity; it is important to catch up with next generation ingot, wafer and cell technologies and the path to be followed in case of capacity increase. In this work, a comprehensive feasibility and roadmap study is carried out on different solar cell manufacturing technologies such as TOPCon, SHJ, and ingot & wafer & module manufacturing in Türkiye. For photovoltaic cell and ingot manufacturing a certain roadmap should be followed in order to make the most feasible decisions in the investment and feasibility process. In the defined roadmap, important topics that need to be addressed at the contract stage are; process equipment, automation, MES (manufacturing execution system), utility components, know-how transfer, training, and ramp-up. The techno-economical assessment of the PV solar cell manufacturing in Türkiye carried out in this work shows that, including other PV-value chain components (polysilicon, ingot, wafer) to the roadmap is a strategic decision in order to have a competitive stage in the photovoltaic market. More detailed analysis of the suggested roadmap will be presented at the conference.

Keywords: PV manufacturing roadmap, techno-economical assessment, PV value chain, total cost of ownership, life-cycle assessment (LCA)

Pub No: P-007

Determination of the Passivation Effect of Organic Nonafluorobutane Sulfonic Acid on Crystalline Silicon

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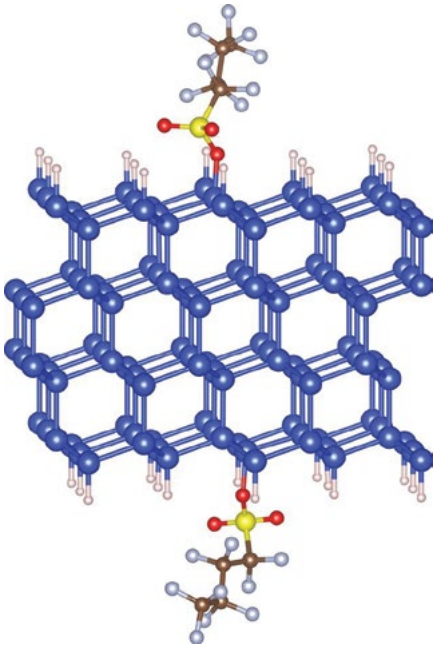
[1]Middle East Technical University/Micro and Nanotechnology
[2]Center for Solar Energy Research and Applications (ODTÜ-GÜNAM)
[3]Middle East Technical University/Physics
[4]Middle East Technical University/Electrical and Electronics Engineering

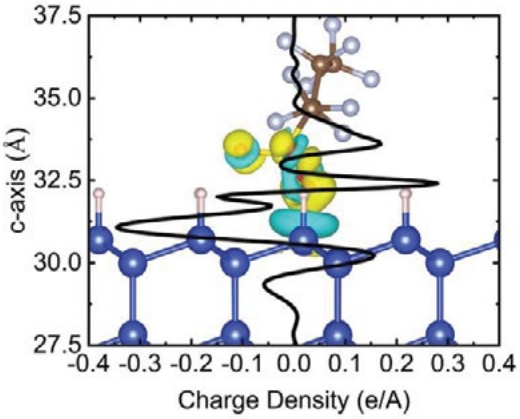
Abstract: This study is a Density Functional Theory (DFT) based theoretical investigation into the surface passivation capabilities of nonafluorobutane sulfonic acid (C4HF9O3S), an organic superacid (SA), on crystalline silicon surfaces, aiming to enhance silicon solar cell performance. SA, with its unique head (SO3H), tail (CF3), and linker (C-F) groups, shows promise for effective surface interaction. By examining various silicon surface scenarios, including defect-free hydrogen-terminated Si(111) as as well hydrogen and silicon vacancies, we aim to gain insights into SA's adsorption characteristics. Our DFT analysis includes the identification of optimized adsorption geometries, binding energies, work functions, charge density differences, and partial Bader charges. Our results indicate that for the most part SA bonds to the surface via H-bonds and van der Waals forces, albeit with fairly large binding energies. However, in cases where two hydrogen vacancies are present, Si-O covalent bonds may also form through dissociative adsorption where a hydrogen from the SA molecule detaches and is incorporated into the surface. The charge redistribution that occurs with bond formation highlights SA's potential to reduce surface recombination and enhance device efficiency through stable surface interactions. This comprehensive study provides a deeper understanding of SA's passivation mechanisms, guiding the design of more efficient silicon-based devices.

Geometrically Optimized SA on Silicon Surface



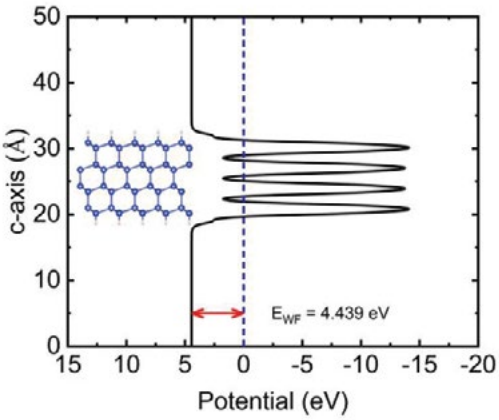
Final geometric optimization of the SA molecule and Silicon surface showing Si-O covalent bond

Charge Density Difference Graph



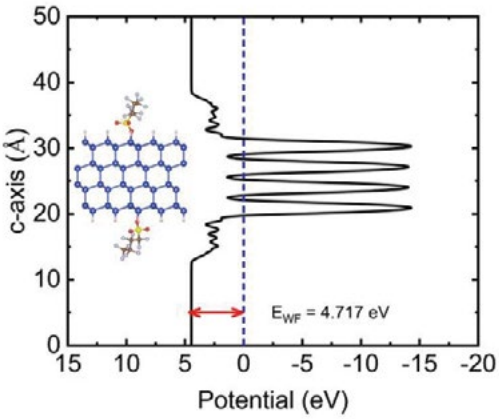
Integrated charge density difference graph along c-axis after Si-O bond occurs

Bare Silicon surface work-function graph



Bare Silicon surface work-function graph, Fermi level is shifted to zero and shown with blue dashed line

Work-function graph of system after Si-O bond occurs



Work-function graph of system after Si-O bond occurs, Fermi level is shifted to zero and shown with blue dashed line

Keywords: Density Functional Theory, Surface Passivation, Crystalline Silicon, Nonafluorobutane Sulfonic Acid

Pub No: P-008

Developing stable and long life irradiance sensor

Elsen Aydin [1], ***İlhan Bora Serin*** [2], ***Melisa Korkmaz Arslan*** [3], ***Hasan Hüseyin Canar*** [3], ***Oğuzhan Oğuz*** [3], ***Can Gündüz*** [2], ***Salar Habibpur Sedani*** [3], ***Bülent Arıkan*** [3], ***Raşit Turan*** [4]

[1]Center for Solar Energy Research and Applications - GÜNAM, Ankara, Türkiye, Middle East Technical University - METU, Archaemoetry Department, Ankara, Türkiye
[2]Seven Sensor Solutions
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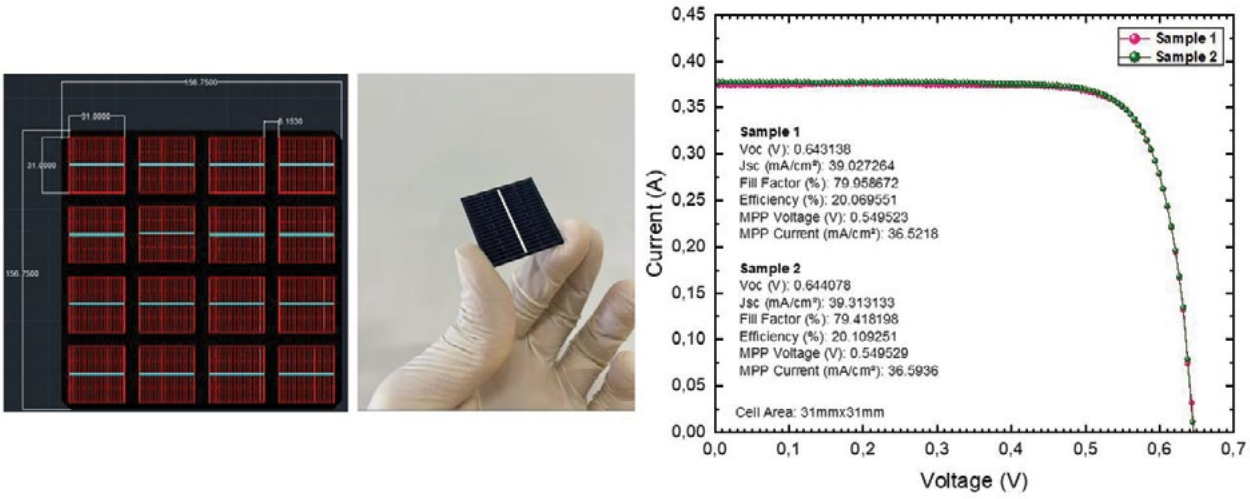
[4]Center for Solar Energy Research and Applications - GÜNAM, Ankara, Türkiye Department of Physics, Middle East Technical University, Ankara, Turkey

Abstract: The photovoltaic pyranometer, also known as the reference cell radiation sensor, accurately measures the radiation value directly affecting the efficiency of solar power plant. These solar cells used in the sensors mentioned have the same structure as solar cells found in the field and are physically scaled-down versions. Due to their lifespan of over 20 years and stable behavior, crystalline silicon-based solar cells are preferred for radiation sensor production. In this study, the Griddler simulation program was used for the perfect production process and to detect losses. With the approach reached after the simulations, fabrication of PERC type solar cells was realized. To prevent the Light Induced Degradation (LID) effect caused by Boron-Oxygen complexes, gallium-doped p-type silicon wafers were selected for cell fabrication. The process of cutting small size cells (3.1×3.1cm2) defined on M2 sized silicon wafers with laser without loss was optimized and I-V tests of the cells were performed (Figure 1). The details of the simulation studies and the stability test results of the cells will be presented at the conference.

Figure 1. I-V curve for produced referance cell



Keywords: Silicon solar cell, Reference cell, Simulation, Irradiance sensor

Pub No: P-009

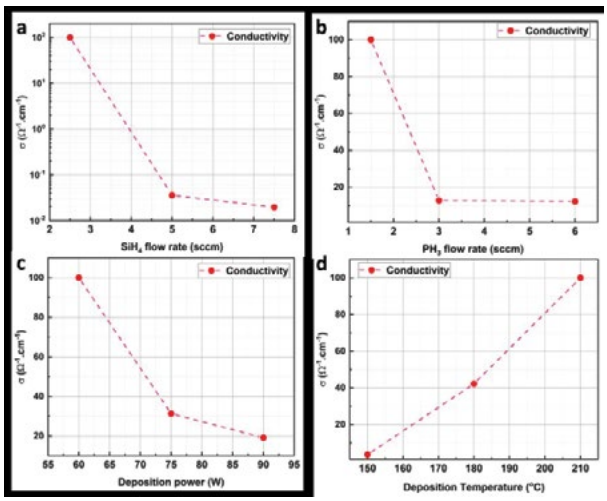
Effect of Deposition Temperature, Power Density, SiH4 Flow Rate and PH3 Doping Concentration on the Nanocrystal Growth in n-Type Amorphous Silicon Layer

Milad Ghasemi [1], ***Arghavan Salimi*** [1], ***Hisham Nasser*** [1], ***Raşit Turan*** [1]

[1]ODTÜ-GÜNAM

Abstract: This investigation explores different deposition parameters influencing the modulation of crystal domain and size within the amorphous silicon matrix. By exploring factors such as silane (SiH4) flow rate, phosphine (PH3) doping concentration, power density, and deposition temperature, we observed their distinct impacts on the crystallinity factor and nanocrystal (nc) size which subsequently affect nanocrystal layer conductivity. The hydrogen (H2) gas flow rate throughout the study remained constant at 500 sccm. Increased flow rate, PH3 concentration[1], and power density adversely affected nanocrystal formation, resulting in a reduced crystallinity factor. The SiH4 flow rate notably influenced crystal formation, demonstrating a threefold increase in SiH4 flow rate leading to a substantial 5100-times reduction in conductivity (from 100 to 0.019 Ω-1 .cm-1) and a 14-times decrease in crystallinity factor (from 26.9% to 1.88%). Conversely, the impact of power density and PH3 concentration on conductivity and crystallinity factor was less pronounced when compared with SiH4 flow rate and deposition temperature. Although higher values for power density and PH3 concentration resulted in reduced crystallinity factor. Elevated deposition temperature corresponded to an increased crystallinity factor, with the nanocrystal layer at 210°C exhibiting conductivity 100 times greater than that at 150°C, as employed in this study for deposition. These results show the impact of deposition parameters on nc formation and significantly impact conductivity, especially by changing the SiH4/H2 ratio, doping concentration, and deposition temperature.

Conductivity



a) Conductivity variations regarding the SiH4 flow rate b) Effect of doping concentration on the conductivity of nanocrystal layer c) The role of deposition power on the conductivity of nanocrystal layer d) Effect of deposition temperature on the conductivity of nanocrystal layer

Keywords: Nanocrystal, power density, flow rate, conductivity, deposition temperature

Pub No: P-010

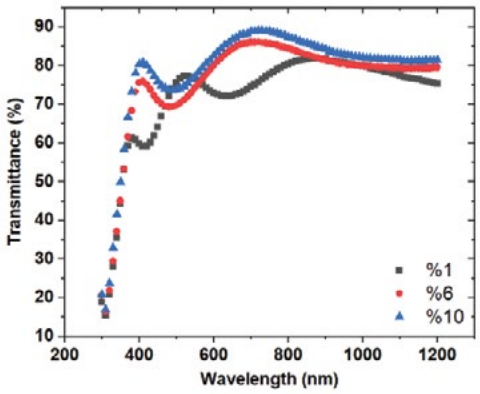
EFFECT OF HYDROGEN CONTENT ON CONDUCTIVITY IN HYDROGENATED INDIUM OXIDE AS TRANSPARENT CONDUCTIVE OXIDES

Ozan AYDIN [1], ***Milad GHASEMI*** [1], ***Gökhan ALTINER*** [1], ***Hisham NASSER*** [1], ***Raşit TURAN*** [1]

[1]ODTÜ-GÜNAM, Middle East Technical University, 06800, Ankara, TURKEY.
[2]Micro and Nanotechnology Graduate Program of Natural and Applied Sciences, Middle East Technical University, 06800, Ankara, TURKEY.
[3]Department of Physics, Middle East Technical University, 06800, Ankara, TURKEY.

Abstract: Transparent conductive oxides (TCOs) have a significant role in fabrication of new generation cell types such as silicon heterojunction cells [1]. TCOs show high optical transparency in the visible range to transmit the incident light to the solar cell that the cell can benefit from light to the maximum extent. Hydrogenated indium oxide (In2O3:H or IO:H) is a promising material as highly-conductive TCO [2]. In this work, we investigated the effect of hydrogen content in IO:H thin films. The IO:H films were prepared on glass in an RF sputtering system with a three-inch of indium oxide target. Argon ions were used as plasma in the sputtering process. 99.999% pure hydrogen was given into the vacuum chamber directly to dope the H ions in the In2O3 thin film. The base pressure of the vacuum chamber was around 1×10-6 Torr. The process pressure was determined as 4 mTorr. Different plasma powers were applied between 80 – 100 Watts and the hydrogen flow to the system varying from 1% to 10% by flow. The sheet resistance of the films was measured by four-point-probe. The minimum sheet resistance was measured as 30,32 Ω/□ in the maximally hydrogenated sample and the transparency of the samples were measured over 85% which are quite good properties and useful for using IO:H as TCO. This work was supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK) under grant nr. 218M944 (Black Dash project).

Figure 1.



Transmittance values of the deposited IO:H on glass with different percentage on glass.

Keywords: indium oxide, hydrogenated, transparent conductive oxide, sputtering, sheet resistance

Pub No: P-011

Overview of mandatory and optional additives in wet chemical process steps in manufacturing for industrial TOPCon solar cells

Damian BRUNNER [1]

[1]RENA Technologies

Abstract: Tunnel Oxide Passivated Contacts (TOPCon) solar cells are on the way to become the next leading cell concept in industrial solar cell manufacturing. However, the efficiency gain in relation to state of the art PERC cells comes with higher expenses for additional processes in the manufacturing route. It is therefore of utmost importance to increase the profitability of the TOPCon cell architecture by reducing the capital and operational expenses as much as possible. Next to the development of high throughput and low footprint manufacturing machines the main lever for wet chemical processes is to reduce the consumption of costly chemicals and additives whilst maintaining a high process quality.In this work, this goal is pursued with a focus on all wet-chemical steps containing additive´s steps along the value chain from poly silicon to final IV measurement. In a TOPCon line basically all wet-chemical process steps contain at least one mandatory additive. This consumable is strongly affecting the running costs since for most process steps it's the most expensive expandable material. The goal of this work is to present an overview of all five mandatory and two optional additives applied in a modern TOPCon manufacturing line (see Fig. 1). Each mandatory additive will be introduced, and its working principle explained in a general manner. Furthermore two new options for additive will be introduced: i) a KOH etch-rate increase, and ii) an acidic process cleaning enhancing additive will be introduced.

Fig 1

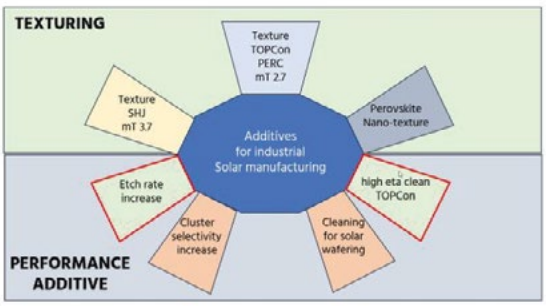


FIG. 1: Overview of (five) mandatory (framed in black) and (two) optional (framed in red) additives for industrial solar cell manufacturing. In the upper half the different texturing additives are shown. Each is customized for the best possible texturing for i) TOPCon, ii) SHJ, and iii) Perovskite-Tandem cells. In the lower half of this overview two mandatory additives for cluster processing (edge isolation and poly-Si wrap around removal) and solar wafering (deglueing and cleaning) are displayed. Furthermore two new options for additives are shown (red frame): i) a KOH etch-rate increase, and ii) an acidic process cleaning enhancing additive.

Keywords: Industrial, TOPCon, Additive, Review, Wet-Chemistry

Pub No: P-012

HIGH QUALITY P-TOPCon WITH EX-SITU DOPING ON FLAT SILICON SURFACES FOR BOTTOM CELLS IN TANDEM SOLAR CELLS

Yiğit Mert Kaplan[1], ***Gökhan Altıner***[1], ***Eni Muka***[1], ***Seda Kılıçkaya***[1], ***Sven Kluska***[3], ***Raşit Turan***[1], ***Hisham Nasser***[1]

[1]Center of Solar Energy Research and Application (ODTÜ-GÜNAM), Çankaya, 06800 Ankara, Türkiye
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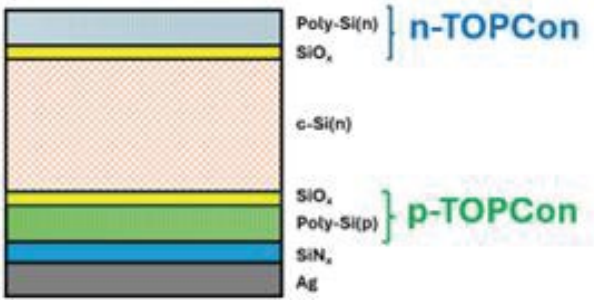
[3]Fraunhofer Institute for Solar Energy Systems, Heidenhofstr. 2, 79110 Freiburg, Germany
[4]Department of Physics, Middle East Technical University, Çankaya, 06800 Ankara, Türkiye

Abstract: Tunnel Oxide Passivating Contact (TOPCon) in TOPCon2 c-Si bottom cell for tandem solar cells has gained attention because of its better carrier transport and contact properties [1]. However, p-TOPCon exhibits drawbacks that lead to poorer passivation quality compared to n-TOPCon counterpart. Since boron atoms have higher diffusivity in SiOx [2], it is very challenging to control the desired dopant profiles for achieving high quality boron doped poly-Si. Therefore, boron doping recipes needs atmost attention specifically on optimization of thermal budget of the process to attain high-quality p-TOPCon. In this work, different ex-situ boron doping recipes together with the pre-annealing step prior to doping [3] were investigated in terms of passivation quality, doping profile, and contact resistivity parameters. Moreover, grain size characterization, and crystallinity measurements of the poly-Si layer will be investigated to unveil the insights of the effect of pre-annealing step. Finally, samples resulted in high passivation quality with iVOC > 718 mV and J0, per side < 9.7 fA/cm2 on polished surface before Fast Firing (FFO) and iVOC >716 mV and J0,per side <8.7 fA/cm2 after FFO. Combined with ex-situ doped n-TOPCon (iVOC >720 mV), Quokka3 simulations for TOPCon2 structure will be provided.

TOPCon2 bottom cell structure



Keywords: p-TOPCon, BBr3 Diffusion, Tandem

Pub No: P-013

Investigation of Laser-Induced Lifetime and Implied Voc Deterioration on Passivated Flat and Textured Silicon Surfaces During the Laser Ablation Process

Melisa Korkmaz Arslan [1], ***Bülent Arıkan*** [1], ***İlkcan Erdem*** [3], ***Raşit Turan*** [2]

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[2]Department of Physics, Middle East Technical University, Ankara, Türkiye
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[5]Center for Solar Energy Research and Applications (ODTÜ-GÜNAM), Ankara, Türkiye, Department of Micro and Nanotechnology, Middle East Technical University, Ankara, Türkiye

Abstract: In the manufacturing process of crystalline silicon-based solar cells, laser process emerges as the most preferred method for locally ablating dielectric layers deposited on the surface to improve passivation and anti-reflective coating (ARC) purposes [1-4]. Selecting a laser system and appropriate parameters compatible with the absorption properties of the dielectric material is crucial to complete this process with minimal mechanical and electrical damage. In this study, we employed a picosecond (ps) green laser (λ=532nm) for ablation and focused on analyzing the lifetime and implied VOC drop on Al2O3/SiOxNy:H/a-SiNx passivated p-type flat and textured surfaces during the ablation process. PCD-based minority carrier lifetime measurements were conducted with Sinton Instruments WCT-120TS, and photoluminescence (PL) mapping was carried out with the Semilab PLI 1001 setup. In Figure 1, the variations in lifetime at a repetition rate of 625kHz are illustrated across different scan groups of power, scan speed, and number of pulses, detected. Meanwhile, Figure 2 represents the changes in lifetime and implied Voc before and after laser processing. Systematic experiments and measurements have demonstrated that by adjusting the scan speed, number of pulses, laser repetition rate and power (specifically increased repetation rate and decreased power), it is possible to explore parameters that either prevent or minimize damage to the substrate. Further details and improvements will be provided during the conference.

PL Image

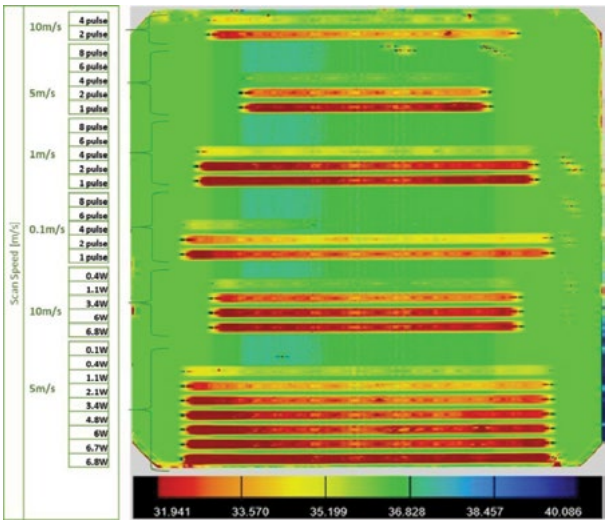

Figure 1. PL imaging at 625kHz with various scan speeds, powers, and pulse numbers.

Lifetime and Implied Voc Change

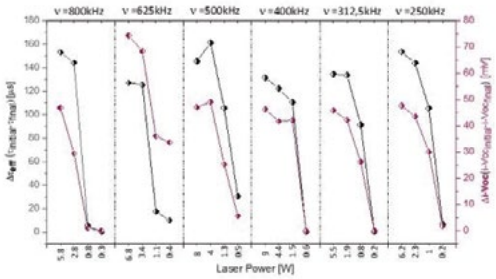

Figure 2. 532nm ps laser power at specific repetition rates vs. Δτeff and Δi-VOC.

Keywords: Silicon solar cell, Passivation, Picosecond laser, Laser ablation, Dielectric removal

Pub No: P-014

2D Phosphorene Integration for Enhanced DSSC Performance and Outdoor Stability

Meriem Lougdali [1], ***Sarah Derbali*** [1], ***Ghassane Tiouitchi*** [2], ***Omar Mounkachi*** [3], ***Omar Moudam*** [1]

[1]Applied Chemistry and Engineering Research Centre of Excellence (ACER CoE), Mohammed VI Polytechnic University, Ben Guerir, Morocco
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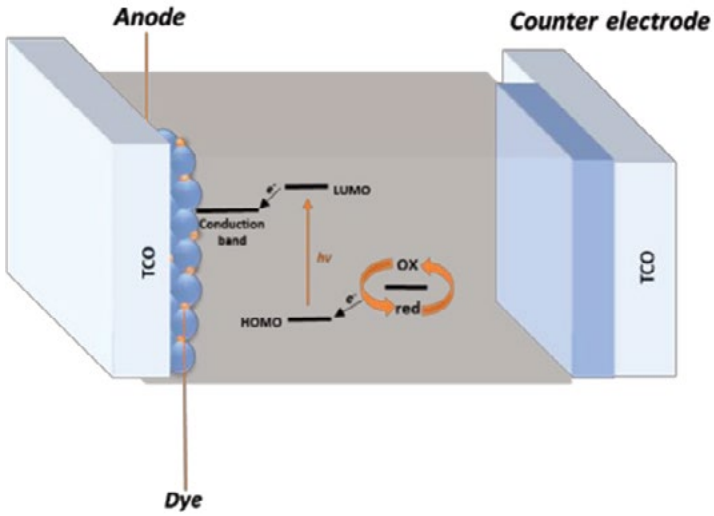
Abstract: Dye-sensitized solar cells (DSSCs) represent a promising avenue for renewable energy generation, as the third generation and stand out in the category of photovoltaics characterized by their low-cost fabrication, flexibility, and environmentally friendly [1]. The counter electrode plays a crucial role in enhancing electron transfer kinetics and overall device performance [2]. By incorporating novel materials with tailored properties, such as enhanced catalytic activity and stability, significant improvements in DSSC efficiency and durability can be achieved. In this study, we focus on the integration of 2D phosphorene into the counter electrode of DSSCs, aiming to enhance device performance and to investigate outdoor stability,since Phosphorene is a two-dimensional material that has exceptional electronic and optical propertiesand holds great promise for advancing DSSC technology [3]. Furthermore, our research studiesthe stability of the phosphorene integrated DSSC in outdoor conditions, including temperature variations, humidity, and exposure to sunlight. By monitoring device performance over extended periods, we assess the life time of the fabricated DSSCs under outdoor operating conditions.

Illustration of the structure of the Dye-sensitized solar cells



Keywords: Dye-sensitized solar cells (DSSCs), 2D materials, Phosphorene, Outdoor stability

Pub No: P-015

A Strategy for Improving Perovskite Film Characteristics through MACl Vapor Annealing

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Wonkyu Lee [2], ***Jae-Keun Hwang*** [2], ***Solhee Lee*** [2], ***Dowon Pyun*** [2],

Ji-Seong Hwang [2], ***Jiyeon Nam*** [2], ***Seok-Hyun Jeong*** [2], ***Sujin Cho*** [2],

Kyunghwan Kim [2], ***Donghwan Kim*** [2], ***Youngho Choe*** [3]

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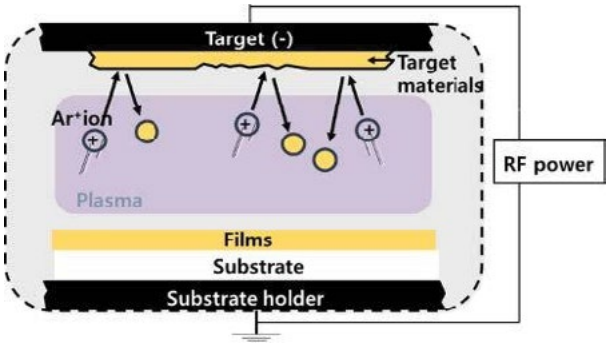
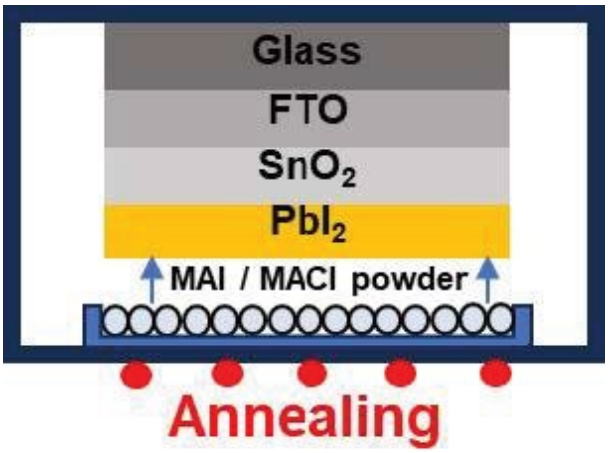
Abstract: Research on silicon perovskite tandem solar cells, which exceed the theoretical efficiency limits of silicon solar cells, is actively underway. Despite the short research period, silicon perovskite solar cells have achieved a maximum efficiency of up to 33.9% [1]. To deposit on a textured silicon wafer to apply silicon-perovskite tandem solar cell, it is crucial to implement the fabrication process for pin-hole-free thin film with optimal crystalline morphology and full coverage [2]. We use a two-step deposition method to deposit perovskite thin films. First, we deposit PbI2 precursor using sputtering, and then we convert it into MAPbI3 perovskite thin film using the close spaced sublimation method. In the second step, using the close spaced sublimation method, we employ MAI powder as a source on the opposite side of the PbI2 precursor substrate. After annealing, we sublimate MAI powder and react it with the PbI2 precursor to form the MAPbI3 perovskite thin film. To enhance the characteristics of the perovskite thin film and improve device efficiency, we mix MACl powder with MAI powder. The effects of MACl passivation include improvements in film characteristics such as increased grain size and enhanced absorbance, leading to improved device efficiency. We expect this passivation effect and perform passivation in-situ by mixing MACl powder with MAI powder. In conclusion, we have found the optimal passivation conditions by adjusting the concentration of MACl powder in the source.

Figure 1



(a) Deposition of PbI2 precursor using the sputtering method.

Figure 1



(b) Conversion to MAPbI3 using the close spaced sublimation method.

Keywords: Perovskite, Thin film deposition, Evaporation, Close spaced sublimation, MACl passivaiton

Pub No: P-016

ANGLE-INDEPENDENT DIFFRACTIVE OPTICAL ELEMENTS FOR ENHANCED SOLAR CELL EFFICIENCY: FABRICATION VIA STEREOLITHOGRAPHY 3D PRINTING

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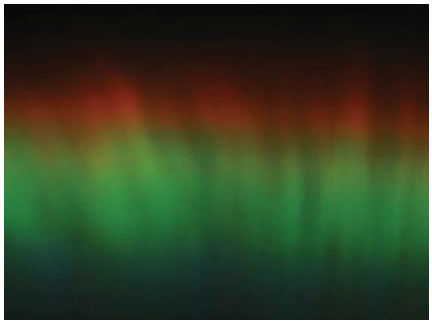
Abstract: Advancements in solar cell efficiency demand innovative approaches to manage broadband light effectively. Utilizing diffractive optical elements (DOEs) offers exciting possibilities for manipulating light due to their unique wavefront shaping capabilities[1]. Still, their widespread adoption is hindered by the complexity and cost of current fabrication methods[2]. We present customized DOEs fabricated via stereolithography 3D printing for enhanced solar cell performance. Traditional DOEs are limited by fixed incident angles, hindering their adaptability to varying environmental conditions. In response, our tailored DOEs, termed SpliCon, are designed to be angle-independent, allowing for efficient spectral splitting and concentration across a wide range of incident angles. Utilizing the versatility of 3D printing, we precisely control the geometry of the SpliCon, ensuring optimal performance under varying illumination conditions. The 3D-printed SpliCons are tested, and we investigate the angle response of our SpliCon using a 4f system, confirming its robust angle independence over a ±40° span. This versatility makes our angle-independent SpliCon well-suited for real-world solar applications where incident angles vary throughout the day and seasons. Our findings highlight the potential of 3D-printed customized DOEs in revolutionizing solar energy technologies. By accommodating changing environmental conditions, angle-independent SpliCon paves the way for cost-effective and environmentally sustainable solar solutions.

Raw image obtained from the CCD camera



This Figure shows the successful splitting and concentration of the broadband light using our 3D-printed SpliCon.

Keywords: Solar Cell Efficiency, Spectral Splitting, Concentration, SpliCon, Additive Manufacturing

Pub No: P-017

CO-EVAPORATION AND FLASH EVAPORATION TECHNIQUES PRODUCTION METHOD COMPARISON FOR SEMITRANSPARENT LEAD FREE MA-BiI PEROVSKITE ABSORBER

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[2]Burdur Mehmet Akif Ersoy University/Department of Energy Systems Engineering

Abstract: The rapid progress in the efficiency of solar cells, especially the increase in the efficiency of next generation perovskite solar cells (from ~3% to ~26%), has attracted the attention of scientists working in this field[1]. However, there are two main problems with high efficiency perovskite solar cells. The first one is the instability of the solar cells and the second one is the toxicity caused by lead (Pb) in the absorption layer[2-3]. Scientists are in search of elements that can replace Pb in perovskite absorption layers and increase stability. In this search, the closest candidate to replace Pb is bismuth (Bi). Scientists prefer to produce perovskite solar cells based on chemical solutions due to production costs and ease of applicability, but problems arise in the morphology of the thin films produced and in the structure due to the solvents used. The production of perovskite absorption layers with vacuum-based evaporation systems, enables the production of thin films with homogeneous and repeatable. In vacuum-based evaporation systems, compounds can be evaporated with more than one source. Instead, producing compounds in a common crucible by flash evaporation in a single step will prevent the problems that may arise from co-evaporation. In this study, thin films in the form of (CH3NH3)3Bi2I9 used as absorption layer in perovskite solar cells were manufactured by co-evaporation and flash evaporation. XRD, SEM and UV-Vis measurements were used for structural, morphological and optical analysis of the grown thin films.

Keywords: perovskite absorber layer, co-evaporation, flash evaporation, degradation, instability

Pub No: P-018

Development Of Metal Oxides Using High-rate Atmospheric Pressure Spatial Atomic Layer Deposition For Highly Efficient And Stable Perovskite And Tandem Applications

Jons Bolding [1], ***Gökhan Altıner*** [2], ***Floor Souren*** [1], ***Yiğit Mert Kaplan*** [2], ***Hindrik De Vries*** [1], ***Hisham Nasser*** [2], ***Paul Fassl*** [3]

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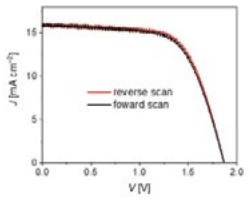
[2]ODTÜ-GÜNAM
[3]Karlsruhe Institute of Technology

Abstract: Spatial atomic layer deposition (sALD) can be utilized in novel perovskite and tandem based solar cells at high-rate (web speed up to 1.5 m/s), large-area (upscalable to 1200 mm wide, also on R2R) deposition of metal oxides (Mos) such as SnO2, Al2O3 [1], and AZO as electron transport layer, passivation layer, and recombination junction, respectively. In this work, these 3 MOs are employed in solar cells to enable stable, highly efficient, and indium-free devices. AZO layers were deposited with different deposition parameters such as temperature, web speed, and gas delivery flow which resulted in highly transparent (>90% at wavelengths >380 nm for 22 nm thickness) films with varying restivities (1-800 mOhcm cm), inversely dependant on the AZO thickness (22-200 nm). As shown in figure 1, AZO deposited on top of M2 SHJ c-Si bottom cells showed an increase in lifetime to >1.5 ms dependant on the deposition tempeture and thickness. The best AZO layers are utilized in tandem devices, see figure 2.Furthermore, SnO2 layers were employed as ETL in PSCs. The SnO2 deposition temperature was varied between 90 and 120 °C, and the deposition speed was varied between 300 and 600 mm/s. As shown in figure 3, SnO2 deposition at 90°C leads to a slight s-shape in the JV curve while deposition at 120°C leads to excellent devices with PCEs >17%. Furthermore, an increase in deposition speed is beneficial. This deposition speed is relevant for high volume manufacturing as it is equivalent to a throughput of >11.500 M10 wph.

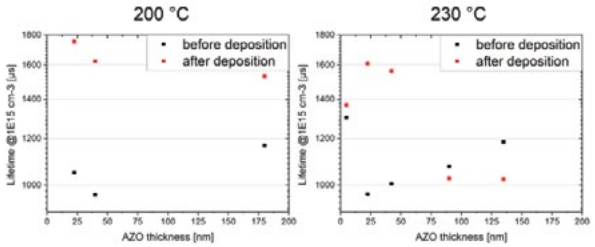
Figure 2. JV curve of tandem device with AZO as RJ.



	J_{sc} [mA cm^{-2}]	V_{oc} [V]	FF [%]	PCE [%]
Reverse scan	15.7	1.87	67.3	19.8
Forward scan	16.0	1.87	64.7	19.3

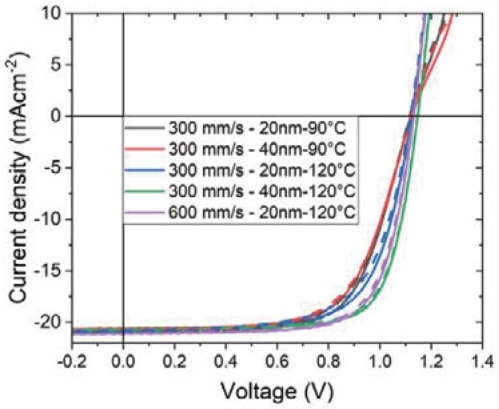
Tandem device showing promosing use of conformal 40 nm AZO as RJ without shunts. To improve the FF and Jsc, thinner AZO layers are investigated which will be presented at PVCon2024.

Figure 1. Lifetime of SHJ bottom cell before and after deposition of AZO



Lifetime of SHJ bottom cell before and after deposition of AZO with varying thickness (GPC of 0.18 nm/cycle) deposited at left) 200°C and right) 230°C

Figure 3. JV curve of perovskite solar cell with SnO2 as ETL.



JV curve of PSC devices with SnO2 as ETL with varying thickness and deposition speed.

Keywords: AZO, spatial atomic layer deposition, Al2O3, SnO2, perovskite, tandem, solar cell

Pub No: P-019

DIKETOPYRROLOPYRROLE (DPP)-BASED POLYMERIC PASSIVATORS: THE RISING STAR IN PEROVSKITE SOLAR CELLS (PSCS) TO OVERCOME STABILITY-RELATED BARRIERS

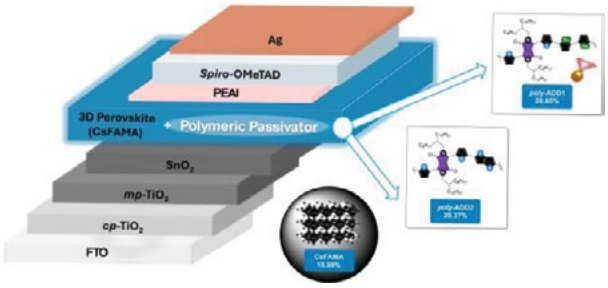
Dr. Aliekber Karabag [1], ***Dr. Figen V. Yaylali*** [1], ***Zeynep G. Karabag*** [1],

Busra Ileri [1], ***Assoc. Prof. Selcuk Yerci*** [1], ***Assoc. Prof. Gorkem Gunbas*** [1]

[1]ODTÜ-GÜNAM

Abstract: Passivators have shown great potential to control the crystallinity and morphology of perovskite materials and extend the lifetime of perovskite solar cells (PSCs).[1-4] Herein, diketopyrrolopyrrole (DPP)-based polymers with biselenophene (poly-ADD1) and thienothiophene (poly-ADD2) donor units are individually incorporated into cesium formamidinium methylammonium (CsFAMA)-based 3D perovskite material as passivating agents. Due to their bulky, long-range, and well-ordered molecular structure, notable improvements in crystallization, defect modulation, and both overall efficiency and thermal stability of n-i-p structured PSCs are achieved. The morphology and crystallinity of polymeric passivator-treated perovskite are studied by Scanning Electron Microscope (SEM) and X-ray diffraction (XRD). The results prove that these passivators can highly control the size and greatly improve the film quality of perovskite crystals. Furthermore, the perovskite films with polymeric passivators exhibit reduced PL intensity, indicating enhanced hole extraction resulting in an improved fill factor (FF: 82.26%). As a result, PSC with poly-ADD1 achieves a champion power conversion efficiency (PCE) of 20.65%, which is better than the pristine one (18.99%). Additionally, the poly-ADD1-containing champion PSC reveals excellent thermal stability, maintaining 63% of its initial PCE after being stored in a humid ambient air condition without any encapsulation at 85 °C after 1600 h of storage, whereas the pristine one experiences a relatively greater loss of 56% under the same condition. This systematic research is expected to provide a guideline for developing novel, robust DPP-modified polymeric passivators that will be a game-changer in overcoming the stability-related barriers that PSCs face and accelerate the path to commercial viability for PSCs.

Polymeric Additives in CsFAMA-based perovskite material



Keywords: perovskite materials, diketopyrrolopyrrole, perovskite solar cells, power conversion efficiency, thermal stability, polymeric passivators

Pub No: P-020

EFFECTS OF Fe-DOPING ON THE STRUCTURAL AND OPTICAL PROPERTIES OF LEAD-FREE ALL-INORGANIC Cs2AgInCl6 DOUBLE PEROVSKITE PARTICLES

Aybüke Şenol [1], ***Gülcihan Güzel Kaya*** [1], ***İsmail Cihan Kaya*** [2]

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Abstract: Lead-based organic-inorganic metal halide perovskites have attracted attention in the field of photovoltaics due to their impressive optical and electrical properties. However, toxicity and instability issues associated with these compounds have hindered the commercialization of solar cells fabricated with them. Therefore, the search for new perovskite compounds that do not contain lead and organic components has gained momentum. Halide double perovskites with the structural formula of A2B1+B3+X6 have emerged as lead-free candidates in photovoltaic applications. Among them, Cs2AgInCl6 has been extensively studied due to its direct optical bandgap characteristics. Nevertheless, the large optical bandgap (~3.2 eV) of this material has restricted its usage in photovoltaics. Doping stands out as one of the most attractive strategies to modify the band gap of perovskite compounds. Thus, in this study, undoped and Fe-doped Cs2AgInCl6 perovskite particles were synthesized via a wet-chemical method. X-ray diffraction (XRD) analysis confirmed the formation of phase-pure double perovskite synthesis. UV-vis measurements revealed that the band gap of Cs2AgInCl6 decreased with increasing Fe doping ratio, enabling light absorption in the visible region of the electromagnetic spectrum.This study was supported by Scientific and Technological Research Council of Turkey (TUBITAK) under the Grant Number 122M345. The authors thank to TUBITAK for their supports.

Keywords: Perovskite, all-inorganic, lead-free, Cs2AgInCl6, ion doping

Pub No: P-021

Enhancing Ambient Stability of Formamidinium-Cesium Lead Halide Perovskite Solar Cells Fabricated under Air Ambient Conditions

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Basudev Lahiri [4], ***Trilok Singh*** [3]

[1]School of Nano Science and Technology, Indian Institute of Technology Kharagpur, India
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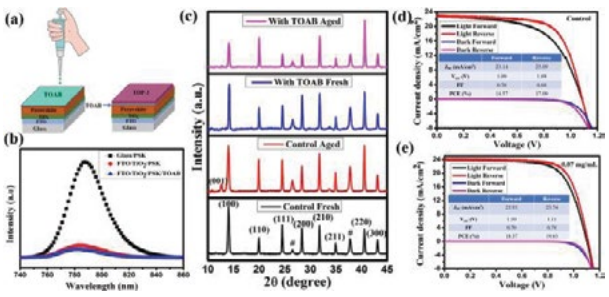
Abstract: Stability remains a key challenge in front of commercialization of Perovskite solar cells (PSCs). Formamidinium-cesium lead halide perovskites have shown improved thermal stability compared to single-cation/halide perovskites. However, moisture instability still persist in FA-based perovskite due to the hydrogen bonding between FA+ and H2O molecule present in the air. In this study, tetraoctylammonium bromide (TOAB) is applied as a passivation layer between FA0.90Cs0.10Pb(I0.85Br0.15)3 and hole transporting layer (HTL) in planar PSCs (Figure 1a). By systematically investigating the effect of TOAB we found that it serves a dual purpose, acting as a defect passivation agent as indicated by PL spectroscopy (Figure 1b) and enhances the hydrophobicity of the perovskite film. However, no significant change in morphology and in crystal structure are observed while applying TOAB. To study the ambient stability of the perovskite film, films were kept at ambient conditions for 30 days at an average temperature of 30 °C and average relative humidity of 65%. A PbI2 peak at 12.72° has appeared in XRD pattern for control film after 30 days, which is absent in TOAB-coated film (Figure 1c). Moreover, compared to control device improved power conversion efficiency (PCE) of 19.63% with less hysteresis has been achieved in TOAB-coated device (Figure 1(d) and 1(e)). Impressively, the unencapsulated passivated device retained 87% of their initial PCE after 1500 h of dark storage under ambient conditions while control device retained 77% of initial PCE. This study also demonstrates utilization of highly promising new HTL i.e. Top-3, for stable and efficient perovskite technology.

(a) Schematic of fabricated PSCs, (b) PL spectroscopy of Perovskite film with and without TOAB, (c) XRD pattern of the fresh and aged perovskite films with and without TOAB, (d) J-V curve of control device and, (e) J-V curve of TOAB passivated device



Keywords: Moisture stability, Perovskite Solar Cell, Hole transporting layer, Mixed-cation mixed-halide perovskite, Solar Energy

Pub No: P-022

Enhancing Stability of Perovskite Solar Cells through RbI Passivation

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Abstract: This study investigates the stability enhancement of formamidinium lead iodide (FAPbI3)-based perovskite solar cells (PSCs) through rubidium iodide (RbI) passivation compared to cesium iodide (CsI) passivation. We analyzed structural, chemical, and morphological changes in PSCs before and after thermal treatment. Our results show that RbI passivation at grain boundaries significantly improves stability, with PSCs retaining approximately 88% of their initial efficiency after 30 days, compared to 75% for CsI passivation and 65% for unpassivated cells. These findings highlight the superior efficacy of RbI in mitigating degradation mechanisms, making it a more effective strategy for enhancing the thermal stability of perovskite solar cells.

Keywords: Perovskite solar cells, RbI additive, stability, thermal stability, moister stability

Pub No: P-023

Glove Box-Free Deposition for Enhanced Performance of Planar CH3NH3PbI3 Solar Cells Using Sol-Gel Synthesized ZnO Nanoparticles

Buse Koçak [1], ***Sevval Öztürk*** [1], ***Nilay Ağaçkesen*** [1], ***Tuğba Demirbay*** [1],

Pelin Kavak [1], ***Hamed Moeini Alishah*** [1], ***Fatma Pınar Gökdemir Choi*** [1]

[1]Yıldız Technical University

Abstract: Perovskite solar cells have emerged as promising candidates for renewable energy; however, their adoption is restricted by their sensitivity to environmental factors such as oxygen in air, humidity, and UV radiation. Here, we try to manage this challenge by introducing a glove box-free deposition method for fabricating planar CH3NH3PbI3 solar cells with sol-gel synthesized ZnO nanoparticles. These nanoparticles are employed in or on top of the main fullerene-based electron transport layer (ETLs). The choice of ETL is essential in determining the efficiency and stability of solar cells. PCBM is the most common organic ETL for inverted PSCs, known for passivating the perovskite layer. Additionally, modifying this ETL with inorganic ZnO nanoparticles further may allow improved performance and the stability. ZnO nanoparticles are synthesized via a fast and straightforward sol-gel route, enabling their integration into the solar cell fabrication process conducted entirely in ambient air. Investigations reveal a significant increase in current densities and enhanced stability when utilizing ZnO nanoparticles. Structural and optical properties of the fabricated devices are characterized using XRD, SEM, AFM, Raman, and UV-Vis spectrophotometry. Besides the performance of the solar cells is systematically measured and monitored electron-only devices fabricated and examined.

Keywords: ZnO, nano particle, electron transport layer, PCBM, perovskite, planar, inverted, CH3NH3PbI3

Pub No: P-024

INFLUENCE OF MICROALGAE ADDITION ON THE PERFORMANCE OF PEROVSKITE SOLAR CELLS

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Fatma Pınar Gökdemir Choi [1], ***Hamed Moeini Alishah*** [1],

Macide Cantürk Rodop [1], ***Bestami Özkaya*** [2], ***Serap Güneş*** [1]

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Abstract: Due to their remarkable power conversion efficiencies (PCEs) and promise for cheap production costs, perovskite solar cells (PSCs) have become one of the most promising photovoltaic technologies. The inverted planar heterojunction, or p-i-n structure, is one of the device structures that has attracted a lot of interest due to its special benefits in terms of manufacturing and stability. A hole transport layer (p-type), an intrinsic perovskite layer (i-type), and an electron transport layer (n-type) are the usual components of this structure. With its high efficiency, enhanced operating stability, and versatile production options, p-i-n type perovskite solar cells mark a significant breakthrough in photovoltaic technology. In order to establish p-i-n PSCs as a leader in the field of renewable energy solutions, ongoing research aims to address issues with long-term durability and efficiency.In this work, p-i-n type PSCs consisting of NiOx as hole transport layer, methylammonium lead iodide (MAPbI3) as perovskite and PCBM as an electron transport layer were fabricated using the antisolvent washing method. The cells were produced without a glove box under ambient conditions (RH 55%, T<18 oC). We investigated the influences of Spirulina platensis sp. microalgae addition both to the perovskite precursor and also to the washing solution.On the other hand, the effect of concentration change on the cell performance was investigated.We observed that the devices employing Spirulina platensis sp.microalgae performed better than their algae-free counterparts.Acknowledgement:This study was supported by Scientific and Technological Research Council of Turkey (TUBITAK) under the Grant Number 121F382.The authors thank to TUBITAK for their supports.

Keywords: Perovskite solar cells, p-i-n type, Microalgae

Pub No: P-025

Investigating Passivation Effects in Inverted Planar Perovskite Solar Cells via Thiol Treatment

Nilay Ağaçkesen [1], ***Buse Koçak*** [1], ***Sevval Öztürk*** [1], ***Tuğba Demirbay*** [1],

Pelin Kavak [1], ***Hamed Moeini Alishah*** [1], ***Fatma Pınar Gökdemir Choi*** [1]

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[2]Tübitak Sage

Abstract: Effective passivation techniques are crucial for enhancing the performance and stability of planar perovskite solar cells (PSCs). Here, we investigate the effectiveness of thiol-based passivation in improving the morphological and optoelectronic characteristics of PSCs. Planar solar cells, configured as ITO/NiOx/perovskite/PCBM/BCP/Ag, were fabricated using a glove box-free antisolvent washing route. By incorporating different cations such as MAI and FAI into the perovskite layer, we aimed to scrutinize the influence of thiol passivation on device performance. From this organosulfur family; 1-Pentanethiol is used as an additive in toluene during the antisolvent washing step. Through X-ray diffraction, scanning electron microscopy, atomic force microscopy, photoluminescence, and photovoltaic characterization techniques, we elucidated the beneficial effects of thiol passivation on the morphological and optoelectronic properties of planar PSCs with different organic cation ingredients. Our findings underscore the potential of thiol-based passivation as a promising strategy for optimizing PSC performance.

Keywords: Perovskite, passivation, thiol, trap density, antisolvent washing, planar, mixed cation

Pub No: P-026

Investigation Of Lead-Free Material For Perovskite Solar Cells As Absorber Layer Using Oghmanano And Taguchi Method

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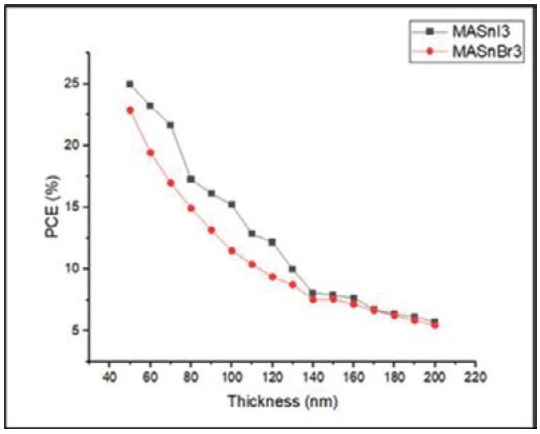
[2]University Putra Malaysia (UPM), Serdang, Malaysia
[3]Universiti Tenaga Nasional (UNITEN), Putrajaya, Malaysia
[4]University Science Malaysia (USM) Penang, Malaysia
[5]Newcastle University, United Kingdom

Abstract: Lead-based perovskite solar cells have been widely used as their present issues in terms of toxicity, environmental impact, stability and reproducibility. As a result, there is a need for non-toxic and eco-friendly materials to create lead-free perovskite solar cells that are highly efficient. To address this issue, researchers have explored non-toxic materials with robust optoelectronic properties. One promising approach involves substituting lead (Pb) with tin (Sn). Tin-based perovskite solar cells have been found to exhibit robust optoelectronic properties and offer a potential solution to the toxicity concerns surrounding lead-based solar cells. By optimizing the tin-based perovskite layer, researchers can achieve the highest efficiency of perovskite solar cells. To analyze the various parameters of solar cell configurations, including Power Conversion Efficiency (PCE), Fill Factor (FF), short circuit current density (Jsc) and open circuit voltage (Voc), researchers utilized the OghmaNano and Taguchi Method to simulate tin-based perovskite solar cells. The optimization process shows that MASnI3 has a higher efficiency of 29.33% compared to MASnBr3 at 26.98%. With further research, it is expected that lead-free perovskite solar cells can achieve a PCE of more than 20%. These findings may pave the way for the development of highly efficient and environmentally friendly perovskite solar cells.

PCE for Lead-free Material based on the thickness.



graph of power conversion efficiencies for Lead-free material based on the thickness

Keywords: Lead-free perovskite solar cells, Tin-based material, Methylammonium, OghmaNano, Taguchi Method

Pub No: P-027

Maximizing the Photovoltaic Performance of Planar Perovskite Solar Cells with Indium-Chloride Toluene-Based Antisolvent Washing

Şevval Öztürk [1], ***Buse Koçak*** [1], ***Nilay Ağaçkesen*** [1], ***Tuğba Demirbay*** [1], ***Pelin Kavak*** [1], ***Hamed Moeini Alishah*** [1], ***Fatma Pınar Gökdemir Choi*** [1]

[1]Yildiz Technical University

Abstract: Metal halide perovskite solar cells have gained considerable attention due to their remarkable optoelectronic properties and the potential for high power conversion efficiency (PCE). In this study, we concentrate on improving the PCE of inverted planar perovskite solar cells by employing indium chloride as an additive in the anti-solvent washing step. The incorporation of indium chloride aims to enhance the efficiency of the solar cells by optimizing their crystallization and optoelectronic quality.All fabrication was performed under ambient air conditions with high humidity and low temperature. The cell configuration used is ITO/NiOx/CH3NH3PbI3/PCBM/BCP/Ag. Investigations include a range of characterization techniques, including X-ray diffraction (XRD), atomic force microscopy (AFM), scanning electron microscopy (SEM), photoluminescence (PL), and UV-Vis spectroscopy, in addition to solar cell characterization. The experimental results demonstrate a significant improvement in both open-circuit voltage (Voc) and short-circuit current density (Jsc), leading to higher PCEs. The use of the optimum amount of indium chloride as an additive offers a promising avenue for enhancing the performance of inverted planar perovskite solar cells under environmentally challenging conditions. Our findings provide a valuable understandings of the optimization of device performance through additive engineering.

Şevval Öztürk

Keywords: Perovskite, doping, antisolvent washing, CH3NH3PbI3, indium chloride, inverted, planar.

Pub No: P-028

Mg-Doped ZnO Nanoparticles: Dual Application in Aqua Media Dye Photocatalysis and Dye-Sensitized Solar Cells

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[1]solar energy
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Abstract: A facile mechanochemical method used for synthesizing doped ZnO photocatalysts. Mg-ZnO, and undoped ZnO nanoparticles were prepared by an inexpensive, energy saving and novel mechanochemical method with subsequent calcination at 500oC. To determine the doping effect, different rates of these oxides were synthesized 1 and 5 wt% Mg-ZnO and performed for the decomposition and dye sensitized solar cells. The structural and morphological evolution of the selected porous zinc oxides were then characterized by (XRD) and (SEM). Furthermore, (BET) analysis was performed for samples. Especially, 5% Mg doped ZnO showed the best photocatalytic role and its surface area was measured 18.9095 m^2/g. Their XRD patterns exhibited the characteristic wurtzite structure of ZnO. Photocatalytic assessments were conducted utilizing 0.1g of nanopowder catalyst for both 100 mL aqueous dye solutions, namely Methylene Blue and Rhodamine B, The 5% Mg-doped ZnO particles demonstrated superior efficiency in dye decomposition. Employing cost-effective and straightforward methodologies, novel catalysts demonstrating optimal efficiencies under sunlight will not only contribute to scientific advancements but also stand as a paradigm for exploration in new application domains.Subsequently, an exploration of the anode involved an investigation into the application of pure and Mg-doped ZnO paste onto conductive glass (FTO) utilizing the Doctor Blade method. The cathode was then fabricated by employing a platinum solution on conductive glass, resulting in the completion of dye-sensitized solar cells. The physical and electrical properties of the manufactured solar cells were meticulously obtained through the utilization of an I-V characteristic device and quantum efficiency spectroscopy (EQE).

Keywords: Mg-ZnO, Photocatalyst, Water treatment, Mechanochemical, Photodegradation, DSSC, quantum efficiency.

Pub No: P-029

Optical, Structural and Morphological Properties of CdS Thin Films Produced by CBD Method.

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Abstract: CdS thin films have been grown on a glass substrate by a Chemical Bath Deposition (CBD) method using CdCl2 (0,0037 M) and CS((NH2))2 (0,032 M) solutions at a bath temperature of 80°C. Optical properties of CdS thin film were studied by the UV-Visible spectrometry. The energy band gap of CdS was obtained from the absorbance measurements in the visible range and found to be 2.4652 eV. Exciton binding energy was obtained as 4.1 meV. Morphological studies of the CdS thin films have been studied by SEM. SEM results have showed that the grain sizes of the CdS thin films varied between 200 and 250 nm. Local elemental characterization of the CdS thin film was carried out using EDS. Using the ZAF correction method, the quantitative result of EDS has also shown that the ratio of Cd to S on the film is 53.4:46.6 (at%). Structural properties of CdS nanostructures have been performed by x-ray diffraction (XRD).

Keywords: Chemical Bath Deposition, CdS, Energy band gap, Solar cell

Pub No: P-030

Optimization of FTO/ZnS/MASnI3/CZTS Perovskite Solar Cells through Numerical Analysis Using SCAPS-1D

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Abstract: Amidst the continuous progress in the field, there has been an escalating demand for environmentally sustainable and economically viable alternative energy solutions. Extensive research has positioned perovskite as a promising substitute in the realm of solar panels. Specifically, MASnBr3 has been identified as an absorbent layer characterized by its stability and non-toxic properties. Despite the limited volume of research on MSnBr3, our study delves into an examination of the performance of P-I-N solar panels. We evaluated and simulated the photovoltaic performance of Perovskite Solar Cell based on MASnBr3 by varying the materials of the electron and hole transportation layers using the simulator SCAPS_1D. We studied the effect of perovskite adsorption layer thickness and doping density (Nt) using different structures (HTL/MASnBr3/ETL/FTO), where we also examined the influence of the ETL (ZnS) and the HTL (Spiro-MeOTAD) on the cell performance. Our results demonstrated high photovoltaic performance, achieving an efficiency above 32%.

Keywords: Perovskite solar cell, SCAPS 1D, High efficiency, Defect density, Thickness effect.

Pub No: P-031

PAN, LiClO4 AND TEABF4-BASED COMPOSITE POLYMER ELECTROLYTES FOR SUPERCAPACITORS

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Abstract: SCs have advantages over batteries such as fast charge/discharge, power density and cycle life, but lower energy density and cell voltage. In SCs, energy density and cell voltage must be increased while maintaining power density. Since the energy density (E=CV2/2) is directly proportional to the square of the cell voltage, increasing the cell voltage can solve the energy density problem. The choice of electrolyte is important as the cell voltage depends on the electrolyte. The use of GPEs increases the energy density and capacitance of SCs while preventing liquid evaporation and leakage. Various polymers such as PAN, PMMA, PEO and PVDF are used in GPEs. PAN is preferred for its thermal stability, electronic conductivity, wide electrochemical windows and compatibility with lithium anodes. Since PAN has no oxygen atoms in the polymer chain, ionic salts can be better separated. PAN-based electrolytes containing lithium salts such as LiClO4, LiAsF6 and Li(CF3SO2)2 have very high ionic conductivity and lithium ion transfer numbers. The use of composite electrolytes in PAN-based GPEs improves thermodynamic stability. Organic electrolytes with high cell voltage (2.5-3.0 V) and reasonable ion mobility are a good choice for SCs. TEABF4 has good electrochemical stability and ionic conductivity. In this study, a series of PAN/LiClO4/TEABF4 composite GPEs with excellent mechanical strength and high conductivity were prepared and characterized by DSC, FTIR, EIS and LSV measurements. Capacitance, energy density and power density calculations of SCs prepared with AC//PAN/LiClO4/TEABF4//AC were performed by CV, EIS, GCD measurements.

Keywords: supercapacitors, gel polymer electrolyte, polyacrylonitrile, lithium perchlorate, tetraethylammonium tetrafluoroborate

Pub No: P-032

Performance Evaluation of Mxene-based Flexible Substrate for Perovskite Solar Cell Applications: A Comparative Study with ITO

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[2]Alzahra University

Abstract: Within the scope of this study, performance evaluations were made against ITO, which is widely preferred in the literature, by using MXene electrode structures compatible with flexible substrates for flexible perovskite solar systems. ITO, a commercially available electrode source, has its limitations. It exhibits limited mechanical performance due to the high cost of the raw material, high roughness, and brittleness of ITO. For these reasons, MXenes, which benefit from low reinforcement, high transparency, flexibility, and simple fabrication, are promising alternatives to expensive electrodes. MXenes, a versatile class of two-dimensional materials, have superior properties such as excellent metallic conductivity, abundant surface functional arrangement, tunable operating properties, high optical transparency, and mechanical robustness. Unlike normal metals, especially in Ti3C2Tx MXenes, the dispersion state, and Fermi levels can change due to surface terminations, therefore changes in work function increase the applicability of such materials in many areas. In this context, MXenes may offer promising potential and are among the effective alternatives for various components of perovskite solar cells due to their unique properties. As a result, MXene structures were coated on glass and PET as an electrode material compatible with these configurable flexible substrates, and performance evaluations were made against ITO. Structural characterization by XRD, electrical conductivity, permeability, and film scanning results were obtained. The preparation and characterization of the materials in this study were carried out in the laboratories of Ege University Solar Energy Institute.

Keywords: MXene, electrode, polyethylene terephthalate (PET), ITO (Indium Tin Oxide)

Pub No: P-033

Performance of Mixed Cation Wide Bandgap Perovskite-based Solar Cells Under Different Indoor Light Sources

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Abstract: Recent interest in indoor photovoltaic (IPV) devices has surged due to their ability to power small electronics and IoT sensors, by harvesting energy from artificial light sources like LEDs, fluorescent, and halogen lamps.[1] Due to the spectral nature of the indoor light sources, wide bandgap materials are suitable for efficient light harvesting.[2] Here, a wide bandgap mixed cation mixed halide perovskite ($FA_{0.83}Cs_{0.17}Pb(I_{0.5}Br_{0.5})_3$) with a bandgap of 1.85 eV has been utilized in a normal structured Perovskite Solar Cell (PSC) (device structure: Glass/FTO/TiO2/perovskite/spiro-OMeTAD/Au) and then device performances are studied under different light sources (FL, LED 3000K i.e. warm white LED, and LED 6500K i.e. cool white LED) by simulation. We have systematically varied the absorber thickness, parasitic resistances (series and shunt), and bulk defect density to optimize the device performance under indoor illumination. Fig. 1(a) and 1(b) shows the device structure and the optimized PSC performance under three different lights at 1000 lux, respectively. The optimized PSC with absorber thickness of 500 nm resulted impressive efficiency under all three lights. A PCE of 34.87% was obtained under LED 6500K illumination. Moreover, fig. 1(c) depicts the PSC performance under 1 Sun which indicates that the utilized perovskite is not suitable for outdoor operation although it yielded high efficiency under indoor illumination. References [1] Mishra, Snehangshu, Subrata Ghosh, Binita Boro, Dinesh Kumar, Shivam Porwal, Mrittika Paul, Himanshu Dixit, and Trilok Singh. “Solution-processed next generation thin film solar cells for indoor light applications.” Energy Advances 1, no. 11 (2022): 761-792.

Figure 1. (a) PSC device structure, J-V curve under (b) indoor light sources and (c) 1 Sun condition.

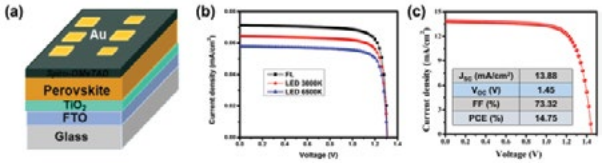

Fig. 1(a) and 1(b) shows the device structure and the optimized PSC performance under three different lights at 1000 lux intensity, respectively. The optimized PSC resulted impressive efficiency under all three lights. A PCE of 34.87% was obtained under LED 6500K illumination. Moreover, fig. 1(c) depicts the PSC performance under 1 Sun which indicates that the utilized perovskite is not suitable for outdoor operation although it yielded high efficiency under indoor illumination.

Keywords: Indoor Photovoltaics, Wide bandgap Perovskites, IoT, Perovskite Solar Cells, Solar Energy

Pub No: P-034

PEROVSKITE THIN FILM PRODUCTION AND OPTIMIZATION STUDIES WITH ALKYL/ARYLAMMONIUM SALTS CONTAINING FLUORINATED AND NON-FLUORINATE LIGANDS

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Abstract: Film morphologies are extremely important in perovskite devices prepared using the solution processing method. Perovskite thin film studies are widely carried out based on the one-step spin coating method without using any additives or other processes. The deposition method often used for known perovskite devices is the one-step (or multiple) spin coating method, in which two precursor salts (organic halide and metal halide) are dissolved in an organic solvent (or more) and then spin-coated onto a substrate (Wang, et. al., 2016).The stability of perovskite materials, especially under ambient conditions, is an important research topic. Therefore, adding mixed anionic and/or cationic additives to perovskites and synthesizing the core-shell structure for surface passivation of perovskites through post-treatment are frequently used to increase the stability of perovskites under exposure to oxygen, water and heat (Yu, et. al., 2022). Within the scope of this study, a material containing fluorine atoms showing the above-mentioned properties and another material containing no F-atoms were selected and studied as a reference material. Within the scope of the study, alkyl/arylammonium salts with and without F-atoms were synthesized in the laboratory of Ege University Solar Energy Institute, using the literature as a reference, and perovskite thin films were prepared for two different materials. The structural and/or morphological characterization results of these films are compared and presented. The morphologies and optical properties of R1-xMABrxPbBr2 (alkyl/arylammonium salts with and without R: F-atom) perovskite thin films with different starting material ratios were examined by looking at X-ray diffraction, emission, absorption and AFM properties.

Keywords: Fluorinated, non-fluorinated perovskite materials, thin film characterization

Pub No: P-035

Power Generation from Perovskite Architectural Elements

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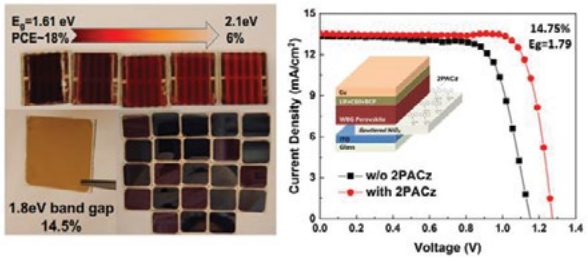
Abstract: As the drive for climate neutrality intensifies, reducing greenhouse gas emissions has become crucial. Renewable energy, particularly Building-Integrated Photovoltaics (BIPV), plays a central role in this effort. BIPV is vital in curbing carbon emissions, supported by initiatives like PV Implementation and Energy Efficiency Actions1. Innovations such as perovskite solar cells offer promising solutions. Perovskites, characterized by the ABX3 formula, allow for adjustable bandgaps from 1.25 eV to over 3.0 eV, providing compositional flexibility. While obtaining colorful perovskite solar cells with wide bandgaps may seem straightforward due to the lightness of perovskite2, such gaps present challenges, notably a significant deficit in open circuit voltage, leading to reduced efficiency. Adjusting the bandgap necessitates modifying transport layers and interfaces to enhance open circuit voltage and mitigate interface recombination. One effective approach is using functionalized Self-Assembled Monolayers (SAMs)3, such as 2PACz, which can interact with wide-bandgap perovskite surfaces to reduce phase separation and improve stability and performance.Our focus is on enhancing perovskite solar cells for BIPV through bandgap engineering, aiming for seamless integration into buildings. Our objectives include developing efficient processes for perovskite solar cells on architectural substrates, achieving a power conversion efficiency (PCE) of 12% for color-neutral semitransparent devices and 15% for colored devices.

The current density-voltage of fabricated 1.79 eV bandgap perovskite solar cell with and w/o 2PACz interfacial layer and schematic structure of the related device.



Keywords: Wide Band-gap Perovskite, SAMs, 2PACz, BIPV

Pub No: P-036

Reliable and Comprehensive I–V Characteristic of Emerging PV Devices

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Abstract: The I–V(current versus voltage) characteristic curve is fundamental in evaluating a photovoltaic(PV) cell's performance parameters. The process of measuring the I-V curve for PV cells is detailed in various standards that provide a structured and consistent methodology to obtain accurate and reliable measurements. According to current standards, I-V scans typically involve fast I–V scanning protocols. While the standardized methods for evaluating the I–V characteristics are robust and widely used for traditional technologies, they may need adjustments when applied to emerging PV devices. These adjustments are necessary due to the unique material properties and unstable characteristics of different PV technologies. Emerging PV technologies, including Organic Photovoltaics (OPV), Dye-Sensitized Solar Cells (DSSC), and Perovskite Solar Cells (PSC), frequently respond slowly to changes in external conditions. This slow response lead to ambiguity in efficiency measurements if fast I–V scanning protocols are applied without considering the specific requirements of the technology. Therefore, the study focuses on characterizing the performance of emerging PV devices by measuring their I-V curves under standard test conditions as well as indoor conditions. The study finds that applying a preconditioning step through light soaking stabilizes the device, leading to more reliable steady-state measurements. It is observed that each different PV technologies exhibit different hysteresis behaviors under different lighting conditions. To obtain accurate and reproducible results while avoiding hysteresis effects, it is recommended to perform measurements with preconditioning using light soaking, scan the device using smaller voltage steps, and control the scanning speed to minimize transient effects under different lighting conditions.

Keywords: Emerging PV Devices, PSC, DSSC, OPV

Pub No: P-037

SEMITRANSPARENT INORGANIC HALIDE PEROSVKITE (CsBiX and CsSbX, (X=I, Cl, Br)) ABSORBER LAYERS PRODUCTION BY FLASH EVAPORATION TECHNIQUE

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Abstract: Currently, research into halide perovskite materials for optoelectronic applications heavily favors solution-based deposition methods due to their rapid advancement in laboratory settings and potential for future cost-effective, high-volume production. However, transitioning these techniques from the lab to an industrial setting poses significant challenges. Even established leaders in the optoelectronic industry struggle to achieve satisfactory production yield and consistency when implementing solution-based methods in industrial production chains. Consequently, it's unsurprising that vapor-based deposition techniques continue to dominate in industry, particularly in photovoltaic manufacturing. The production of perovskite absorption layers with vacuum-based evaporation systems, enables the production of thin films with homogeneous and repeatable. In vacuum-based evaporation systems, compounds can be evaporated with more than one source. This situation also brings with it problems arising from the operator's experience. Instead, producing the compounds in a common crucible by flash evaporation in a single step after pre-treatment will prevent problems that may arise from coevaporation. This study examines the manufacturing of semitransparant inorganic (CsBiX and CsSbX, (X=I, Cl, Br)) absorber layers by flash evaporation technique. The manufactured absorber layers were subjected to post-production treatments (such as heat and light soaking) and the changes in their structure, morphology and optical properties were characterized by XRD, SEM and UV-Vis techniques. In the light of the findings, information will be obtained on the instability mechanisms of absorber layers and semitransparent solar cell applications.

Keywords: inorganic perovskite, semitransparent, flash evaporation, degradation, instability

Pub No: P-038

Semitransparent organic photovoltaic (ST-OPV)

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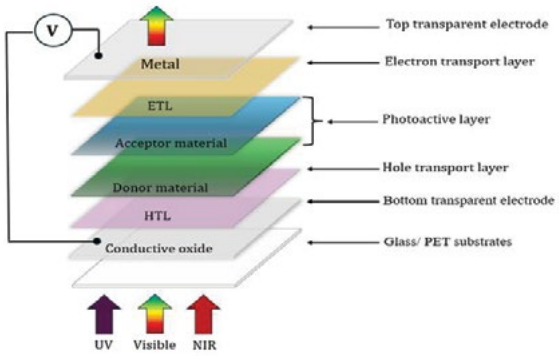
Abstract: Organic photovoltaic (PV) is entering its first stage of commercialization and becoming a promising alternative energy option due to its lightweight properties, environmental friendliness, and solution processability. The certified power conversion efficiency (PCE) of organic PV (OPV) has already exceeded 19% in the lab scale by a combination of novel materials and morphology optimization[1], [2]. In the new technology's commercialization, the critical point is to position itself in a niche market by providing innovative services, and unique product characteristics that can be reached by exploring new properties such as transparency which the organic semiconductors might become the best alternative absorber[3]. However, to reach a balance between good efficiency and optimum transparency, more effort is needed to develop new absorber materials, solution-processable interlayers, and electrodes. Herein we explore new strategies adopted to achieve high-performing ST-OPVs, their potential applications, and the major challenges that should be addressed to the research community in order to make a transition towards a mature commercialized technology.

Structure of semi-transparent organic solar cells



Keywords: Organic photovoltaic, semitransparent solar cells, power conversion efficiency, organic semiconductors, absorber materials

Pub No: P-039

Solvent engineering of hole transport layer for improved efficiency and stability in perovskite solar cells

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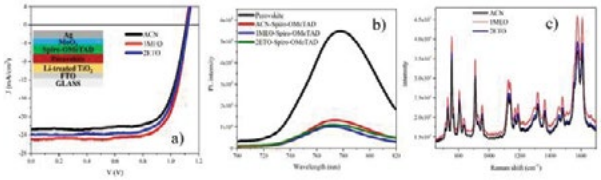
Abstract: Perovskite solar cells (PSCs) have emerged as a promising photovoltaic technology due to their high power conversion efficiency (PCE) and low-cost fabrication. However, their commercialization is hindered by stability issues, particularly under harsh environmental conditions. One key challenge lies in the commonly used solvent, acetonitrile (ACN), which can corrode the perovskite thin film, leading to performance degradation [1]. In this study, we investigate the use of alternative solvents, 1-methoxy-2-propanol (1MEO) and 2-ethoxy-ethanol (2ETO), to address the ACN-induced stability issues [2]. These solvents possess higher boiling points, lower dielectric constants, and lower dipole moments compared to ACN, making them less corrosive towards the perovskite layer. To evaluate the performance of the modified PSCs, we employed electrochemical impedance spectroscopy (EIS), time-resolved photoluminescence (TRPL), and space charge-limited current (SCLC) measurements. The results demonstrate a significant enhancement in device stability when using 1MEO and 2ETO solvents. PSCs fabricated with these solvents exhibited reduced recombination rates, improved charge transport, and lower trap densities at the perovskite/hole-transporting layer (HTM) interface. Furthermore, 45-day stability test demonstrated a 31.2% decrease in the control device's initial efficiency, while the 1MEO and 2ETO devices exhibited more favorable stability, with efficiency reductions of 12.2% and 7.7%, respectively. The efficiency of the control device using ACN decreased by 31.2%, while the 1MEO and 2ETO devices retained 87.8% and 92.3% of their initial PCE, respectively. This study highlights the potential of 1MEO and 2ETO as replacements for ACN in PSC fabrication, offering a promising pathway towards more stable and efficient perovskite solar cells.

Figure 1



a) J-V graphs of PSCs under reverse bias, b) steady-state PL of triple-cation perovskite and perovskite/Spiro-OMeTAD thin films with ACN, 1MEO and 2ETO and c) Raman spectrum of Spiro-OMeTAD thin films with ACN, 1MEO and 2ETO.

Table 1

Summary of the Best Photovoltaic Parameters of PSCs, and N_{trap} values calculated from hole only devices prepared with 1MEO and 2ETO.

Parameters	J_{SC} (mA/cm^2)	V_{OC} (mV)	FF (%)	PCE (%)	Avg. PCE (%)	HI	N_{traps} (cm^{-3})
ACN	22.8	1110	74.7	18.9	18.1	0.17	$4.7x10^{16}$
1MEO	25.0	1115	76.0	21.3	20.8	0.12	$4.4x10^{16}$
2ETO	23.9	1120	74.7	20.0	19.0	0.15	$4.5x10^{16}$

HI: hysteresis index. The average PCEs of the devices were determined from 10 individual devices.

References

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Keywords: less-toxic solvents, hole-transport materials, perovskite, stability

Pub No: P-040

SYNTHESIS OF NOVEL CONJUGATED STRUCTURES AND THEIR USE IN PEROVSKITE SOLAR CELLS

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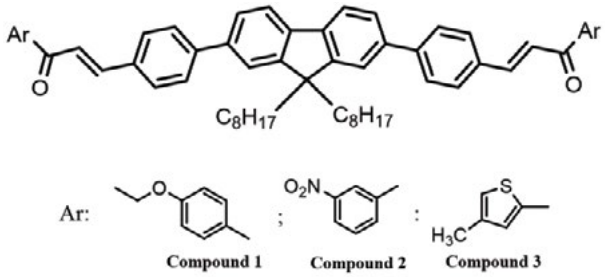
Abstract: Considering the unavoidable increment energy request of the world, ensuring sustainability involves not just meeting this demand but also how we meet it. This is leading to increased research into renewable sources, particularly in photovoltaics for efficient solar energy harnessing and various research opportunities. Perovskite solar cells (PSCs) have become a frequently preferred area of study due to the diversity of additives, doping methods, and application areas. In light of these factors, our study focused on the synthesis and characterization of molecules designed for PSC applications, specifically coating them onto perovskite solar cells and evaluating their role in efficiency improvement. Initially, a starting material was obtained through a Suzuki Coupling Reaction using a fluorene-based molecule. Then, three different novel chalcone molecules were synthesized. Characterization of the products was performed using spectroscopic methods such as FTIR, 1H-NMR, 13C-NMR and LC-MS. In the experimental section, perovskite solar cells were fabricated using each chalcone compound in the determined configuration. Characterization of perovskite solar cells with and without chalcone molecules were done under AM 1.5 illumination inside a glove box. The results obtained were evaluated in terms of the contributions of chalcone molecules to the device performance. The results related to the effect of chalcone molecules on the device performance and further strategies for improvement will be discussed.

Figure 1. Synthesized chalcone molecules



Keywords: Chalcones, Fluorene derivatives, Perovskite solar cells, Photovoltaics

Pub No: P-041

Synthesis of TiB2 and TiB2@Co Nanocomposite structures developed as Electrode Materials and Supercapacitor Applications

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[2]Çanakkale Onsekiz Mart University

Abstract: Metal borides are among the preferred materials in the production of high-capacity supercapacitors due to their high surface area, low resistivity, good conductivity and low cost. Metal borides show rich diversity in terms of crystal structure and chemical bond formation; thus, they exhibit favorable properties for potential applications in superconductivity, electronics, and catalysis. Titanium boride (TiB2) is more economical than other metal diborides. The electrode materials used in these systems directly affect performance properties such as capacitance and energy density. For this reason, the electrode materials used in supercapacitors must have properties such as high surface area, low resistivity and high conductivity. TiB2 is currently used in supercapacitor applications. TiB2, used as an electrode in supercapacitors, provides easier access to boron planes, which are more catalytically active than graphene. TiB2 has attracted great attention in regular electrochemical energy storage devices due to its outstanding electrochemical performance. As an alternative approach, a new nanocomposite structure (NCS) containing exfoliated TiB2 integrated with Co nanoparticles, called exfoliated TiB2@Co, was developed. Electrochemical measurements in the three-electrode system were carried out using 3M KOH electrodes. The behavior of TiB2, exfoliated TiB2 and exfoliated TiB2@Co is presented by comparing the NCS CV, GCD, EIS results.

Keywords: Titanium oxide, Titanium Boride, Electrode, Cobalt, Synthesis, electrode, Supercapacitor

Pub No: P-042

Two-Step Sequential Vapor-Solution Hybrid Deposition of Uniform and Stable Perovskite Films Assisted by Slot-Die Coating Intended for Commercial Large-Area Photovoltaic Applications

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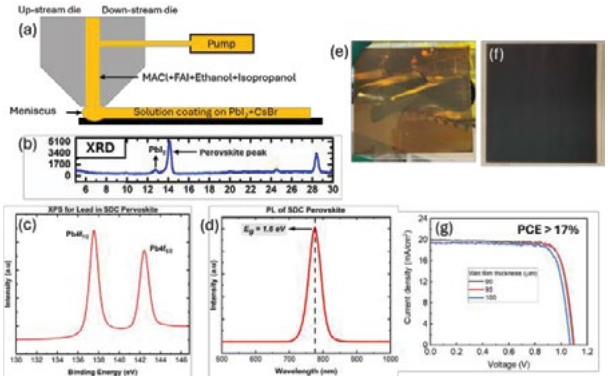
Abstract: The deposition of perovskite films by slot-die coating (SDC) offers various advantages over the ubiquitously used spin-coating techniques, including faster processing, compatibility with large-area substrates, less chemical consumption, cost-effectiveness, and high throughput. A hybrid deposition of organic-inorganic mixed halide perovskite films (MA, FA, Cs)Pb(I, Br, Cl)3 is achieved by thermally co-evaporating PbI2 and CsBr followed by an SDC procedure of a mixture containing formamidinium iodide (FAI) and methylammonium chloride (MACl) dissolved in ethanol/isopropanol and butanol. The coating parameters including chuck temperature, coating speed, and pump rate were optimized on the SDC unit while the solution concentration was adjusted to form a uniform and homogenous perovskite film (Fig e,f). The X-ray diffraction (XRD) and photoluminescence (PL) spectroscopy results confirm the existence of the α-black perovskite phase (2θ=14.2o) and a bandgap of ~1.6 eV, respectively (Fig b,d). Moreover, the uniformity of the deposited perovskite layer is depicted by a very low variance in the FWHM of both XRD and PL peaks taken throughout the large area. A surface compositional analysis done by X-ray photoelectron spectroscopy (XPS) featured all the characteristic elemental peaks of the perovskite composition while the absence of residual metallic Pb peak (Pb0) showed the viability of our technique to avoid undesired decomposition of perovskite (Fig c). With the power conversion efficiency of the PIN-configured SDC-processed solar cell (ITO/NiOx/Perovskite/LiF/C60/BCP/Cu) comparable to the conventional spin coating technique (~18%) (Fig g), this industrially favorable approach can lead to a pathway toward the commercialization of perovskite solar cells.

Slot Die Deposition of Perovskite Layers and Corresponding Nano-Characterizations



(a) Schematic of slot-die setup. (b) XRD for perovskite film. (c) XPS of Pb4f peaks for perovskite film. (d) PL of perovskite film. (e) Large area deposited substrate of perovskite (before annealing), and (f) after annealing. (g) JV results of the completed slot-die coated perovskite solar cell.

Keywords: Perovskites, Hybrid deposition, Slot-die coating, Large area substrates

Pub No: P-043

Understanding the mechanism of organic additive to fabricate stable co- evaporated CsPbI3 perovskite solar cells

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Abstract: Inorganic perovskite composition, CsPbI3 has been widely researched due to its suitable bandgap (1.73eV) for Si-perovskite tandem solar cells and its potential thermal stability. Among the various perovskite film deposition methods, thermal co-evaporation offers many advantages for fabricating low-temperature processed CsPbI3 perovskite solar cells (PSCs). However, co-evaporated CsPbI3 suffers from its non-preferred crystal orientation and further decomposition to the non-perovskite phase, leading toan unstable film microstructure and poor device performance. So far, few papers have suggested organic additives to increase the structural and humidity stability in solution process. In this work, organic additives named phenethylammonium iodide (PEAI), trimethylphenylammonium iodide (PTAI), and n-octylammonium iodide (OAI) were used as additives and passivation materials for co-evaporated CsPbI3 perovskite film by co-evaporation. These materials have similar structures but distinctive functional groups. Focusing on the effect of different functional groups, mechanisms of the additive and passivation strategy will be revealed by comparing the microstructure analysis. Also, by employing this strategy, the dangling bonds at the surface or grain boundaries will be terminated, resulting in improved device humidity stability.

Keywords: Perovskite solar cells, CsPbI3, co-evaporation, organic iodide, PEAI, PTAI, OAI, passivation treatment

Pub No: P-044

Advanced Solar Panel Design with Enhanced Color Conversion for Optimal Crop Yield and Quality

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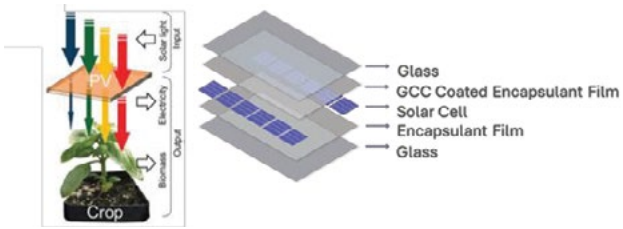
Abstract: Agrivoltaics is a sustainable solution that combines solar energy with crop cultivation to optimize land use. This approach offers several benefits, including increased land productivity, water conservation, and reduced carbon emissions [1]. Agrivoltaics systems provide shade and reduce evaporation, contributing to crop resilience and yield enhancement, making them crucial for sustainable agriculture in arid and semi-arid regions.In this study, the utilization of Glass Color Converter (GCC) material was employed within agrivoltaics panels to enhance both solar panel efficiency and agricultural output. GCC, derived from waste glass, serves as a light absorption-emission material, absorbing UV regions of sunlight and emitting it within the ideal bandgap for crops. This process enhances photosynthesis and increases agricultural yields [2]. Furthermore, a microclimate for crops is created by photovoltaic (PV) panels, mitigating temperature stress and greenhouse effects under the panels, thereby preventing excessive heat accumulation and sustaining soil moisture levels. This investigation involved incorporating GCC powder within the sandwich structure of PV panels. The results showed successful UV to red light transmission, and current-voltage (I-V) and electroluminescence (E-L) measurements indicated that integrating GCC powder did not have any negative impact on the performance of the PV panels.The synergistic utilization of agrivoltaics panels with GCC powder offers a promising alternative for sustainable land management. By combining renewable energy generation with agricultural resilience, this approach drives agricultural sustainability and facilitates the integration of renewable energy in a changing climate landscape.

Design of Agri-PV Panel for this study [2].



Keywords: Photovoltaics, Agrivoltaics, Glass Color Converter, Solar Panel Design

Pub No: P-045

Assessment of a pioneering solar PV system facilitating the coexistence of agricultural and power generation

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Abstract: Global attention towards climate change and carbon reduction has prioritized achieving net-zero emissions by 2050. Taiwan is an island nation facing land constraints with its dense population and should actively promote renewable energy. Acquiring land for photovoltaic (PV) systems remains challenging. Disputes over PV development in agricultural land persist, prompting plans to open "low-utility" agricultural land for PV use. Concerns about encroachment on cultivable land prevail among the public. Therefore, this study proposes a novel PV system, drawing from Japanese case studies, to harmonize agriculture and PV. Vertical-axis PV systems offer cost efficiency and bimodal power generation, reducing noon-time power concentration. Low-shading PV systems protect crops from intense sunlight, enhancing growth conditions. This innovative PV system not only boosts solar power generation but also balances load curves for the power grid. It considers crop sunlight exposure, fostering sustainability and local economic development. This integrated approach facilitates agricultural and energy coexistence, yielding mutual benefits and a win-win scenario.

Figure1. The vertical installation photovoltaic system

Keywords: Agricultural and light coexistence, Tilted type, Vertical type

Pub No: P-046

Automatic Detection and Classfication of Defects in PV Modules Using Electroluminescence İmaging: Artificial İntelligence Approaches

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[1]Kalyon Güneş Teknolojileri Fabrikası

Abstract: Technique of electroluminescence (EL) imaging is of critical importance in detecting imperceptible defects in the production processes of photovoltaic (PV) modules, so enhancing module quality and optimizing efficiency. Electroluminescence imaging becomes prevalent tool in the photovoltaic industry for identifying flaws within the internal structure of cells. The EL method involves the excitation of the module followed by the recording of intensity histograms of active/inactive electric fields formed on the solar cells by a camera, facilitating defect detection.The laborious and time-consuming nature of manual/visual inspection practices associated with the acquired EL images, coupled with the increasing demand for high-quality photovoltaic modules in the continuously evolving PV sector and the escalation of mass production, has led to the initiation of research into the utilization of machine vision-based automatic inspection systems and image processing techniques for automatic defect detection, as well as automatic classification algorithms.This study, directed at enhancing production efficiency within the PV industry, presents a comprehensive review of the methods utilized and investigated for automatic defect detection and quality classification in EL images. Research findings will delve deeply into the varying application scenarios, hardware requirements and software support associated with approaches incorporating deep learning methods such as Convolutional Neural Networks (CNN), Support Vector Machines (SVM), Principal Component Analysis (PCA), Inception-V3 and ResNet50. Furthermore, parameters including defect detection time, accuracy rate and space utilization limitations will be thoroughly examined for their variability within solar cells.

Keywords: Electroluminescence (EL) imaging, Automatic detection, Automatic classification, Photovoltaic module, Module efficiency, PV industry, PV module defects

Pub No: P-047

CHARACTERIZATION OF ZINC-INDIUM-TIN OXIDE THIN FILMS DEPOSİTED BY SPUTTERING TECHNIQUE

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Abstract: Transparent conductive oxides (TCOs) have garnered significant attention in the optoelectronic industry in recent years due to their potential in transparent electronics [1]. TCOs are highly doped semiconductors with a band gap exceeding 3 eV, making them both conductive and transparent in the visible light spectrum. Currently, tin-doped indium oxide (ITO) films are commonly utilized in optical devices including flexible displays, and solar cells, due to their low resistivity (around 10-4 Ω•cm) and high transmittance (over 80%)[2]. However, ITO is expensive because indium is scarce. Zinc oxide (ZnO), on the other hand, offers a promising alternative due to its similar electrical and optical properties and the abundance of zinc [1]. Therefore, quaternary compounds like zinc-indium-tin oxide (ZITO) are gaining interest to reduce the use of indium [1]. In this study, it was aimed to deposit high-quality ZITO thin films on soda glass substrates using RF and DC sputterings from ITO and ZnO targets. We thoroughly examined the impact of annealing temperature on the electrical, morphological, structural, and optical properties of the ZITO films. The findings indicated that annealing significantly affected the surface morphology, resistivity, and crystal quality of the films, although the transmittance in the visible range remained largely unchanged. The transmittance varied between 83% and 94% for both the as-grown and annealed films. The RMS (Root Men Square) values were found to be 1.528 nm, 1.744 nm, 1.880 nm, 2.052 nm and 1.523 nm for as-grown, 150 oC, 250 oC, 350 oC and 500 oC annealed ZITO films.

Keywords: TCO, ITO, Thin film, ZnO

Pub No: P-048

Design and Simulation Studies of PERC and TOPCON Solar Panels

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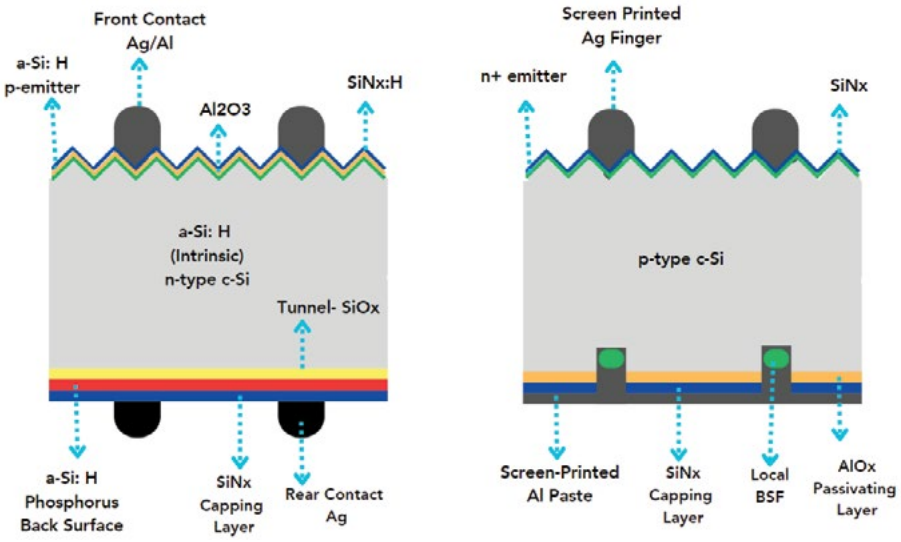
Abstract: In this study we have achieved the comparison of the houses decorated with highly promising panel types: Passivated Emitter and Rear Contact (PERC) and Tunnel Oxide Passivated Contact (TOPCon) with PvSol programme. The conditions of the roofs and house's consumption were kept (10 kwp) the same during the simulations conducted with PvSol. There are many types of solar panels for choose from. Solar cells was mostly passivated emitter rear cell technologies on p-type crystalline silicon. PERC's structure is on the p-type multicrystalline silicon substrate with 23.40% efficiency. But nowadays, tunnel oxide passivated contact solar cell on p-type Si is on the rise in terms of higher efficiency than PERC solar cell. TOPCon solar cells's structure with a thin silicon oxide passivation layer topped and a doped polysilicon efficiencies higher than 25.5%. According to the simulation results compared with the literature results, we have observed that the highest efficiency and performance were achieved with the TOPCon cell as shown in Figure 1. It provides high efficiency with a fewer number of panels and at the same time it can reduces yield reduction due to shading to 0.1%. These results are also consistent with the literature datas as shown in detail in this article.

Solar Cell Structure of (a) TopCon (b) PERC



Keywords: Solar Energy, TopCon, PERC, Efficiency, PvSyst

Pub No: P-049

Effects Of Pollution On Solar Panels And Solution Suggestions

Berathan Yıldırım [1], ***Mustafa Orhan*** [1], ***Burcu Büyükkınacı*** [1], ***Yüksel Yalçın*** [1]

[1]İstanbul Energy

Abstract: Solar energy is a renewable energy source that is becoming increasingly important due to developing technology and increasing energy demand. Solar panels are the most important component of this energy generation system. However, the performance of solar panels can be adversely affected by environmental factors. One of these factors is pollution. Dust, dirt, oil and other contaminants accumulated on the surface of solar panels can significantly reduce the energy generation capacity of the panels. Contamination reduces the efficiency of photovoltaic cells by preventing sunlight from reaching the panels. In addition, heat accumulation on panel surfaces due to contamination also leads to loss of performance. The problem of contamination becomes more pronounced in areas where dust and particle pollution is intense, especially in industrial areas, urban areas and rural areas. However, contamination on panel surfaces may also vary according to the location of the solar panels, climatic conditions and maintenance and repair activities.There are various solutions to reduce the negative effects of contamination on solar panels. Measures such as regular cleaning and maintenance activities, the use of coatings that protect the panel surfaces, the use of cleaning solutions, the integration of rainwater collection systems and the installation of automatic cleaning systems can be effective in increasing the efficiency of solar panels.In this study, the effects of fouling on solar panels are tested under real conditions in the field and solutions that can be applied to optimise the performance of solar energy systems are discussed.

Keywords: renewable energy, solar energy, air pollution, cleaning techniques

Pub No: P-050

Semi-transparent Cu(In,Ga)Se2 solar cells for window applications

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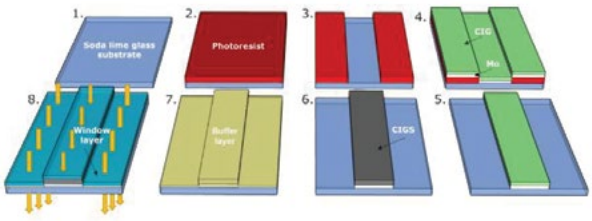
[1]International Iberian Nanotechnology Laboratory

Abstract: Clean, affordable, reliable, and sustainable energy sources, such as photovoltaic (PV) technologies, are crucial to accommodate humanity's energy demands. The main concern within cities is the lack of space for PV deployment, a void that can be filled by semitransparent PV (STPV) devices that can be integrated into large buildings' facades and windows. Combined with other clean energy sources, these STPVs can pave the way towards developing net-zero cities. We propose PV devices following a design philosophy based on long and narrow micro Cu(In,Ga)Se2 (CIGS) solar cells, separated from each other by a fully transparent gap. The solar cells absorb the light, while the gaps let light pass through, thus achieving the semi-transparency. The implementation of micro-striped solar cells aims to fabricate devices that are mostly imperceptible, minimizing any discernible visual impact and reducing visual discomfort from direct sunlight inside buildings by having high levels of transparency and good efficiencies. This innovative paradigm aligns seamlessly with the emerging trend in building-integrated photovoltaics (BIPV), promising a balanced blend of enhanced aesthetics and functionality.The fabrication of these devices (figure 1) follows a bottom-up approach, using photolithography techniques to carve their desired pattern. Sputtering is used to deposit the back contact, precursor to the absorber (Cu-In-Ga), and window layers. Chemical processes, such as selenization in a tubular furnace, which crystallizes and incorporates selenium into the absorber layer, and chemical bath deposition for the buffer layer, which completes the p-n junction, are the other main steps of fabrication.

Semi-transparent micro-striped CIGS solar cells Fabrication Process



Keywords: Building-integrated Photovoltaics, CIGS solar cells, Semi-transparent Photovoltaics, Micro-striped solar cells.

Pub No: P-051

The effect of rectifier materials on photovoltaic devices

İkram orak [1]

[1]Bingöl University

Abstract: In this study, the effect of rectifier metals were investigated photovoltaic devices. Rectifier contacts play an important role in photovoltaic (PV) systems. These contacts are very effective on the efficiency obtained from solar panels. PV are devices that convert sunlight into electrical energy. These cells are usually made of semiconductor materials and have metal contacts on them. These metal contacts provide the electrical connection of the cells and are used to transmit the resulting electrical current to the external circuit. It minimizes the electrical resistance in the cell, allowing the current to be collected more efficiently. Metal contacts may block or reflect sunlight from reaching the cell. This may affect the optical performance of the device. Metal contacts may cause some parasitic resistance on the surface of the cell. This can increase the total resistance in the cell and reduce efficiency. The use of high-quality metal contacts and appropriate design can help minimize interference resistance.

Keywords: Rectifier contact, photovoltaic, diode

Pub No: P-052

Water-harvesting and Self-cleaning Anti-reflective Coating for Agri-PV Applications

Sezen Öykü Kınacı [1], ***Damla Koçak*** [3], ***Emre Büküşoğlu*** [4], ***Hüsnü Emrah Ünalan*** [5], ***Selçuk Yerci*** [6]

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[3]Şişecam Science, Technology and Design Center (R&D Center)
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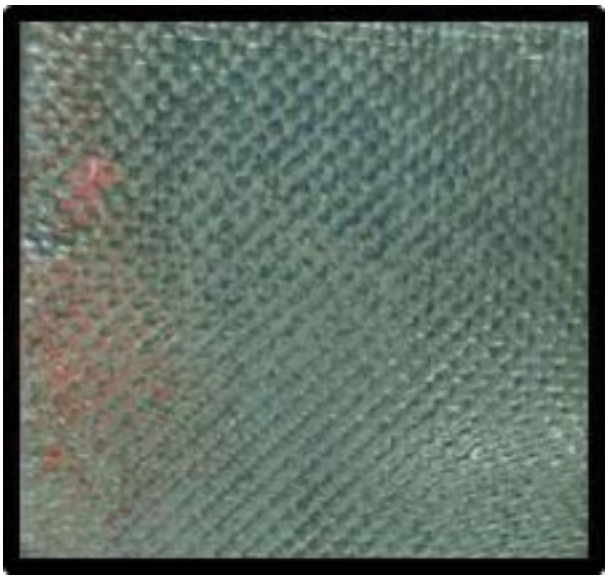
Abstract: Water scarcity has become one of the most significant challenges in recent years, alongside climate change issues [1]. In this study, an anti-reflective aerogel coating for solar panels is proposed to address the increasing freshwater needs. The proposed coating can harvest water from surrounding humid air, in addition to its anti-reflective and self-cleaning properties. Water-harvesting property is inspired by the hydrophilic/hydrophobic patterns on a Namib Desert beetle.Agrophotovoltaic (AgriPV) systems are solar panel applications that offer areas suitable for agriculture underneath the solar panels. There is a water demand in agriPV systems that stems from the need for plants and the cleaning of solar panels. The water-harvesting property of the proposed coating serves for watering the plants and the self-cleaning property prevents wasting water for panel cleaning. The proposed coating shows promising water-harvesting results even in stagnant air. The coatings exhibit water collection on their surface in less than 30 minutes within a closed environment with 96% relative humidity, without any forced airflow, showing promising potential for outdoor tests. The water-harvesting ability increases when exposed to directed air flow with rates as high as ~0.5 L/m2–h when scaled up. Our simulation results from COMSOL Multiphysics reveal that as the pattern size grows, hysteresis prevents water droplets from sliding, which can disturb self-cleaning property. These findings were consistent with the real-life experiments as the smallest patterned coating showed the lowest hysteresis, being the ideal coating for both self-cleaning and water-harvesting properties.

Water collected on the 500 micrometer square patterned coating under direct air flow with 91% relative humidity after 30 minutes.



Keywords: aerogel, anti-reflective coating, water-harvesting, self-cleaning

Pub No: P-053

Optimizing Photovoltaic Module Efficiency with Photonic Crystal Multilayer Passive Cooling via Setfos Software

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Abstract: Photovoltaic (PV) modules suffer from some common problems such as shading, dust and surface operating temperature that can adversely affect their performance. External climatic parameters such as wind speed, ambient temperature, relative humidity, accumulated dust and solar radiation are the most widespread natural factors affecting the surface temperature of a PV module. In ambient conditions, PV modules can reach up to approximately 60 °C. Each increase of 1 °C not only causes a power decrease in the range of 0.45-0.50 %, but also negatively affects the module lifetime. To improve the performance of a PV module operating above the recommended temperature at Standard Test Conditions (STC), technologies of different principles have been applied to minimize the effect of increased temperature. The cooling process in photovoltaic solar panels is conventionally carried out by air or coolant circulation from the surface of the modules, thermoelectric cooling, phase change materials (PCM). Such practices both lead to extra energy consumption and are not applicable on a large scale. Within the scope of this study, a photonic crystal multilayer that provides passive cooling on the surface of the solar module glass has been developed using Semiconducting Thin Film Optics Simulation software (Setfos) software. Thus, the infrared region is filtered, which is tolerable in terms of electrical conversion. In addition, by limiting transmission in this region and increasing reflection, optical and electrical results have been demonstrated.

Keywords: photovoltaic, radiative cooling, photonics

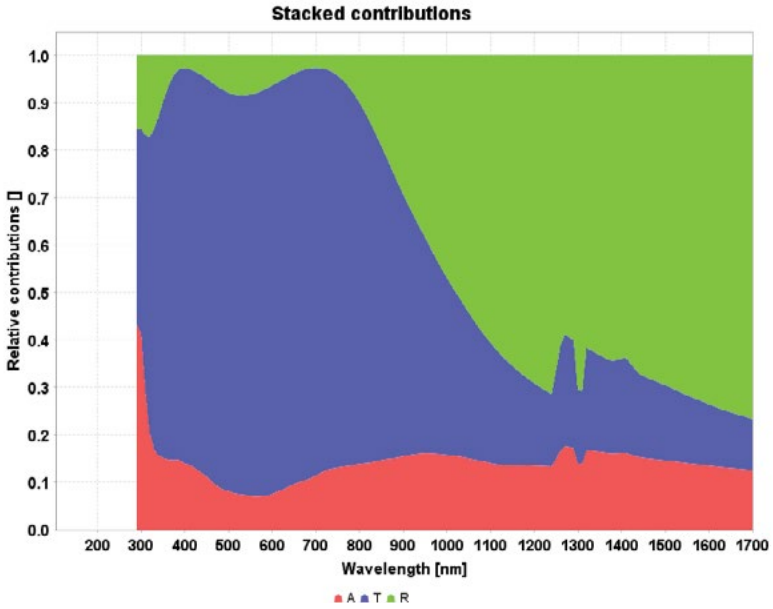

Figure 1. Absorption, reflection, transmission contribution for AM 1.5 solar spectrum

Pub No: P-054

Blocking the PID: The Power of Chemically Tempered Glass

Beyza Durusoy [1], ***Nahide Özben*** [2], ***Osman Burak Okan*** [2],
Refika Budakoğlu [2], ***Bülent Akınoğlu*** [3], ***Raşit Turan*** [4]

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Abstract: Potential Induced Degradation (PID) significantly reduces the efficiency and energy output ofphotovoltaic (PV) modules over time. This study investigates chemically tempered glass as a solutionto lower PID risk in PV modules, comparing it with widely used standard float glass in solar panel production. We assessed both glass types alongside PID-sensitive solar cells and ethylene-vinylacetate (EVA) encapsulant under conditions simulating real-world stresses, including high potential bias (1 kV) and thermal (85°C) stress for 4 hours. We monitored the key metrics such as parallel resistance, conductance, leakage current, and power loss.The data revealed a marked decrease in parallel resistance for standard glass, indicating significant PID-related electrical shunting. Conversely, samples with chemically tempered glass demonstrated minimal to no change in parallel resistance, establishing its efficacy against PID. Further electrical assessments and electroluminescence (EL) imagery also confirmed the results. Samples with standard glasses exhibited decreased current density and fill factor, and their EL images appeared darker, indicating shunting. In contrast, chemically tempered glasses maintained stable electrical propertiesand clear EL pictures, underscoring their PID resilience. This research highlights chemically tempered glass as a promising material to improve the PID resistance of solar modules, offering a path to enhance the long-term performance and lifespan of solar panels. Incorporating this innovation could substantially boost solar energy system reliability while extending their lifespan and reducing waste from degraded modules.

Keywords:

Pub No: P-055

Compositional Analysis of the Carbon-Rich Fine-Grain Layer in Solution-Processed CZTSSe Films

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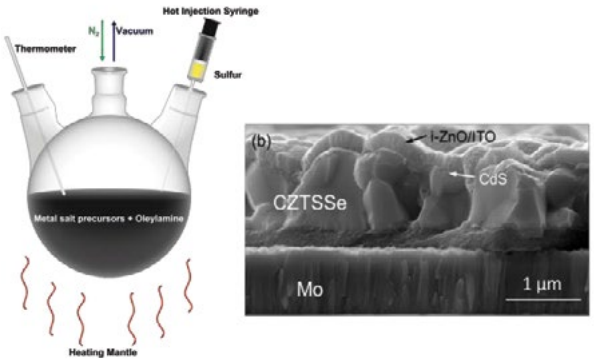
Abstract: The existence of a fine-grain (FG) sub-layer between the top large-grain (LG) layer and the back contact is widely observed in kesterite absorbers prepared with organic solvents. The distinguishing features of the lifted-off carbon-rich FG layer are investigated through direct analysis with a series of characterization techniques, including X-ray photoelectron spectroscopy (XPS), attenuated total reflectance, X-ray diffraction, and scanning electron microscopy. To access the FG layer for direct probing, a scalable and repeatable photonic lift-off method is developed for carrying out the separation of the kesterite absorber layer from the Mo-coated glass substrate. A very high light intensity of 4 kW cm−2 for a short interval of 1 ms is optimized by COMSOL simulations, and successful implementation is demonstrated. The XPS analysis has revealed significant carbon content at the exposed FG surface, which explains the hindrance of grain growth due to carbon abundance. The variations in cations and anions concentrations from FG layer leading into LG region are explored through argon ions (Ar+) assisted XPS depth profiling. The observed significant differences between the composition of FG and LG regions are speculated to negatively impact the performance of solar cells.

Carbon Rich Fine Grain Analysis in Kesterite Solar Cells (Fig.1)

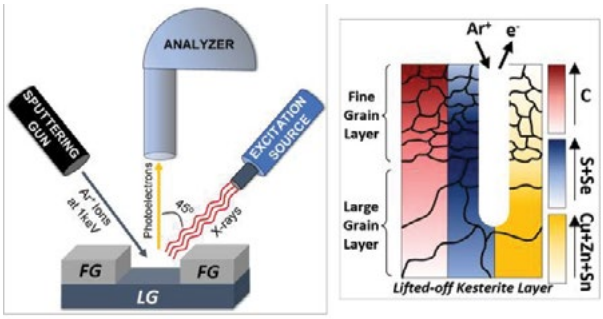


Nanoparticle Synthesis by Hot Injection Method

Cross-sectional SEM Image of Kesterite Solar Cell

1. A schematic of hot injection process used for kesterite nanoparticle synthesis. 2. Cross-sectional SEM image depicting carbon-rich fine grain layer.

Carbon Rich Fine Grain Analysis in Kesterite Solar Cells (Fig.2)



XPS-based Depth Profiling for Compositional Analysis

Schematic Showing Elemental Variation from Fine Grain to Large Grain Layer

1. Schematic of XPS used for depth profiling for elemental compositional analysis. 2. The elemental variation between fine grain and large layer.

Keywords: Kesterites, Carbon Rich, Fine Grains, XPS, Solution Processing

Pub No: P-056

DRASTIC INFLUENCE OF SUBSTITUENT POSITION ON ORIENTATION OF 2D LAYERS ENABLES EFFICIENT AND STABLE 3D/2D PEROVSKITE SOLAR CELLS

Figen Varlioglu Yaylali [1], ***Ummugulsum Gunes*** [2], ***Zeynep Gozukara Karabag*** [1], ***Xiao-Xin Gao*** [2], ***Olga A. Syzgantseva*** [7], ***Aliekber Karabag*** [1], ***Gulsevim Bensu Yıldırım*** [1], ***Konstantin Tsoi*** [1], ***Naoyuki Shibayama*** [8], ***Hiroyuki Kanda*** [2], ***Alwani Imanah Rafieh*** [2], ***Liping Zhong*** [2], ***Andreas Züttel*** [2], ***Paul Joseph Dyson*** [2], ***Selcuk Yerci*** [1], ***Mohammad Khaja Nazeeruddin*** [2], ***Gorkem Gunbas*** [1]

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[2]Institute of Chemical Sciences and Engineering, École Polytechnique Fédérale de Lausanne (EPFL)
[3]Department of Micro and Nanotechnology, METU
[4]Department of Polymer Science and Technology, METU
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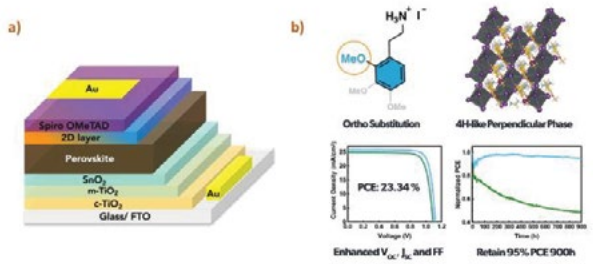
Abstract: The lack of long-term stability and reproducibility of perovskite solar cells (PSCs) is the main roadblock preventing their successful commercialization. 3D/2D PSCs are one of the most prominent ways to address these issues. Various salts that are mostly based on phenyl ethyl ammonium iodide (PEAI) have been utilized to grow a 2D perovskite layer on 3D perovskites. Herein, we report the effect of substituting the methoxy (-OMe) group at the ortho (o), meta (m), and para (p) positions on PEAI salts. Photoluminescence and time-resolved photoluminescence show that o-OMe-PEAI-treated surfaces achieve reduced defect densities and nonradiative recombination rates compared with the other analogs.Devices with PCEs over 23% are achieved for o-OMe-PEAI-based 3D/2D PSCs, and the enhanced performance is attributed to the favorable formation energy and desired vertical orientation accordingto the density functional theory (DFT) analyses. Finally, the unique orientation of the o-OMe-PEAI-based 2D perovskite results in significantly enhanced long-term, moisture, and thermal stability.

a) Illustration of the solar cell architecture; b) Effect of the position of substitution on 2D-forming cations on the performance and stability of the resulting devices.



Keywords: Stability of Perovskite Solar Cells, Interface Engineering, 2D Perovskite, Ruddlesson-Popper Phase (RP) Phase, Phenylethylammonium Iodide, Planar (n-i-p) Perovskite Solar Cells

Pub No: P-057

Exploring the Potential of MgZnO Thin Films as a Sustainable Alternative to CdS Buffer Layer in CZTSSe Solar Cells

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Abstract: Recently, Cu2ZnSnS4 [CZTSSe] absorbers based solar cells have exhibited efficiencies exceeding 14%, ending a period of stagnation lasting over a decade. Although a notable Voc deficit still exists, it is possible to enhance the overall efficiency by the optical properties of the CZTSSe device. This study aims to investigate the potential of MgxZn1-xO (MZO) as a buffer layer material for CZTSSe solar cells, with the goal of replacing the toxic CdS buffer layer. The use of MZO buffer layers offers advantages such as band alignment, high electron mobility, good transparency, and chemical stability. MZO thin films were deposited using magnetron co-sputtering with different Mg/(Mg+Zn) ratios. The sputtering conditions and film properties were optimized and analyzed. CZTSSe solar cells were fabricated using the MZO buffer layer and their performance was also evaluated. The MZO thin films exhibited a tunable bandgap ranging from 3.21 eV to 4.88 eV, depending on the Mg/(Mg+Zn) ratio. The grain size of the films increased with increasing Mg ratio and then decreased at higher Mg concentrations. The highest fficiency of 3.3% with Voc= 343 mV, Jsc=27.3 mA/cm2 and FF=35.5 % was achieved with a MZO buffer layer composition of Mg16.23Zn83.77O having a bandgap of 3.76 eV. This performance compared favorably with that of reference cells utilizing the CdS buffer. This study demonstrates the potential of MZO as a substitute for the toxic CdS buffer layer in CZTSSe solar cells. The findings contribute to the development of more environmentally friendly and efficient thin-film solar cell technologies .

Keywords: MgZnO, CZTSSe, Co-sputtering

Pub No: P-058

Fabrication of Semi-transparent Third Generation CZTS Solar Cells Via ZnO Nanorods Synthesized on Graphene Layers

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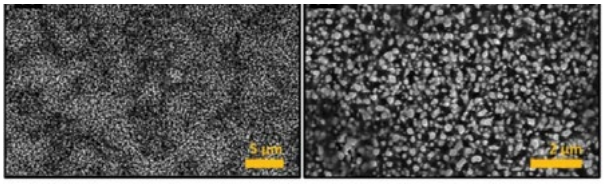
[2]Pamukkale University

Abstract: Recent extensive research has been dedicated to manufacturing environmentally friendly, semi-transparent, efficient, and affordable inorganic solar cells. A key focus area involves integrating one-dimensional nanostructures and high-quality transparent conductive layers into traditional thin-film solar cells. To date, a broad range of structures and material varieties, such as organic, dye-sensitized and amorphous Si, have been researched for the manufacture of high-efficiency semi-transparent solar cells. However, there are several significant problems involved with each of these solar cells, such as the stability concerns of dye-sensitized solar cells and the long-term stability issue of organic solar cells. A considerable research effort has therefore been made in recent years to find new photovoltaic absorber materials. Cu2ZnSnS4 (CZTS) has emerged as a promising candidate due to its superior properties . This study aims to pioneer a third-generation CZTS semi-transparent core-shell solar cell by synthesizing well-aligned ZnO nanorods (NRs) on graphene layers (figure 1). Using a novel combination of hydrothermal techniques and nanosphere lithography, we achieved well-ordered ZnO NR arrays on graphene-coated glass substrates. Furthermore, we introduced TiO2-passivated ZnO NRs to minimize defect density at core-shell interfaces. The CZTS absorber layer was deposited onto ZnO NRs via one-step thermal evaporation. This study presents the first use of a graphene/ZnO-NRs/TiO2 nanohybrid structure in CZTS systems for semi-transparent solar cells. The conducted study enable the emergence of a new generation of semi-transparent photovoltaic cells, featuring low cost, transparency, simplicity and high power conversion capacity, which are key components needed for the advancement of building integrated PV systems.

SEM images of ZnO NRs synthesized on single-layer graphene



Keywords: Graphene, Nanorods, CZTS, transparent solar cells

Pub No: P-059

High Potential of Solution-Processed TiOx as Electron-Selective Passivating Contact for Silicon Solar Cell

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Abstract: Implementation of Si-based dielectrics in carrier-selective passivating contact (CSC) schemes is typically realized by doping processes, vacuum-based systems, and high activation temperatures. Therefore, the development of dopant-free CSCs that grant a high degree of surface passivation, low contact resistivity, and are applicable through cost-effective methods is paramount. This paper presents a low-temperature and cost-effective route to optimize the electrical properties of a solution-processed TiOx. It is found that a remarkable electrical enhancement can be obtained after a short and low-temperature post-treatment. Upon 1 minute of annealing at 150°C, a high implied open-circuit voltage (iVoc) of 706 mV in conjunction with a low contact resistivity (*ic*) of 55 Ω.cm2 were achieved, indicating the high potential of solution-processed TiOx as an effective and low-cost electron-selective passivating contact (ESC). The surface passivation level obtained in this work, not only outperforms the other solution-processed ESCs by far, but also is comparable with the state-of-the art TiOx fabricated by advanced Atomic Layer Deposition (ALD) technique.

FIG. 1. (a) Measured implied open-circuit voltage (iVoc) and (b) effective minority carrier lifetime (τeff) as a function of hotplate annealing temperature for fixed 5 min.

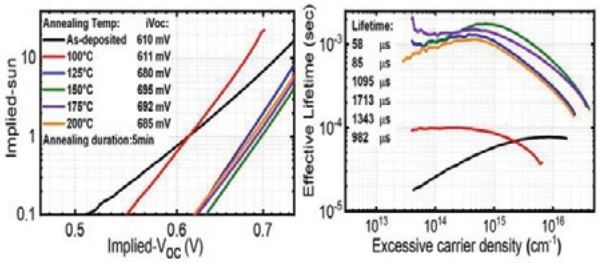


FIG. 2. (a) Measured implied open-circuit voltage (iVoc) and (b) effective minority carrier lifetime (τeff) as a function of annealing duration at fixed 150°C hotplate temperature.

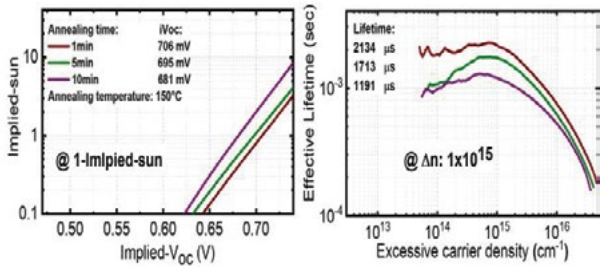


FIG. 3. Dark Current-Voltage (I-V) curves measured at Si/Al junction. (inset the TLM structure)

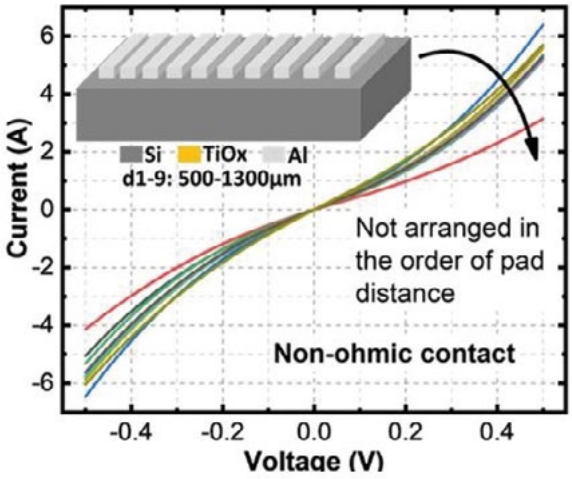
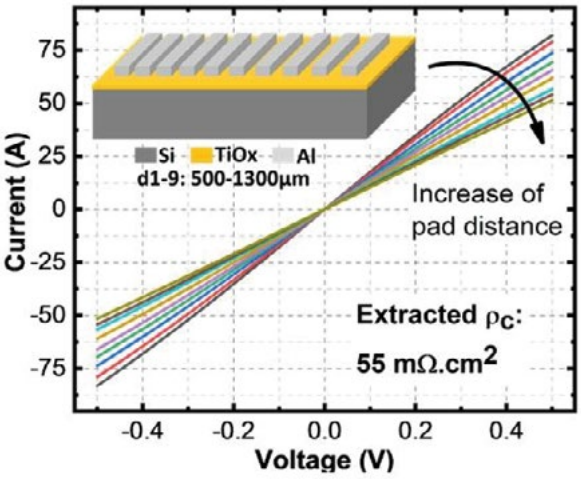


FIG. 4. Dark Current-Voltage (I-V) curves measured at Si/ TiOx / Al junction. (inset the TLM structure)



Keywords: Solution-processed, electron-selective, passivating contact

Pub No: P-060

CONTROL OF MPPT BOOST CONVERTER FOR A 5-KW HYBRID INVERTER

Muharrem BARAN [1], ***Erhan DEMİROK*** [1], ***Enis DOKURLAR*** [2], ***Yunus ÇAY*** [3], ***Ozan KEYSAN*** [3]

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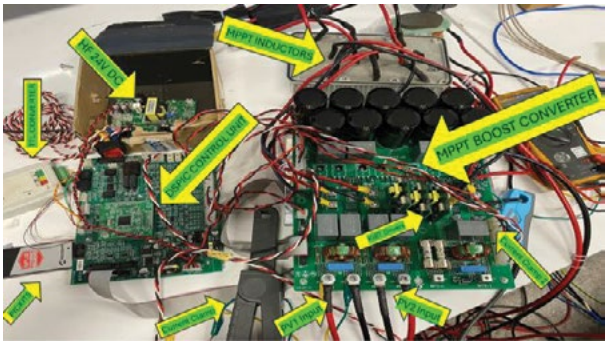
[2]Tescom R&D Center
[3]Middle East Technical University (METU)

Abstract: Hybrid inverter is a vital electronics device that converts DC electricity generated from photovoltaic (PV) panels or charged electricity in batteries to AC electricity that can be used to operate household appliances, commercial and industry loads. In this study, a crutial stage of hybrid inverter, a maximum power point tracking (MPPT) DC-DC boost converter for high conversion ratio application is proposed. Circuit elements and switching elements were selected meticulously according to the advancements of semiconductors technology regarding of design for maintenance and reliability. PV power served as the source power. Two independent PV strings, each with a maximum capacity of 2500 Watts, are part of the system. In this study, cascaded PI control structure was adopted in order to harness maximum available power from the PV power source by controlling input current and input voltage for the MPPT operation. 5 kW MPPT boost converter was designed and proved successfully under thermally stable operation of one-hour duration so that the designed MPPT boost converter was adequate to be a commercial product for hybrid inverters.

Developed Hardware for MPPT Boost Converter



The image indicates designed prototype module with all developed hardwares for MPPT Boost Converter

Keywords: Boost Converter, MPPT, PI Control Systems

Pub No: P-061

INSIGHTS TO CITIZEN-PARTICIPATORY VOUNTEERISM AND SDG 7: ENERGY, VOLUNTEERING AND NON-GOVERNMENTAL ORGANIZATIONS IN TURKIYE

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[1]Middle East Technical University/Department of Industrial Engineering
[2]Middle East Technical University/Department of Economics and Science and Technology Policies Research Center

Abstract: Non-governmental organizations (NGOs), which have a significant impact on the development of community-based social service models operate in numerous social service and assistance areas at both the national and international levels. Despite the fact that the seventh Sustainable Development Goal (SDG 7), Ensure access to affordable, reliable, sustainable, and modern energy for all, directly or indirectly supports the achievement of all sustainable development goals; NGOs are not actively involved in any activities in this crucial area. Furthermore, there is no research in the literature addressing this deficiency. NGOs engaged in fieldwork across various sectors fall short of actively promoting volunteer activities in the accessible and clean energy field. Despite the escalating critical importance of the energy sector, the global absence of citizen-participatory volunteer initiatives represents a substantial deficiency. This inadequacy creates a noteworthy gap, both in practical volunteer fieldwork and within the literature. In this regard, the study aims to address the research question: “Why is there a lack of volunteer activities in the field of accessible and clean energy?”. To address this situation we aim to conduct interviews with experts working in the identified NGOs in Turkiye. Our objective is to uncover the root causes and find solutions to this issue, with the ultimate goal of contributing to achievement of sustainable development through citizen-participatory volunteer activities and volunteer programs. This research endeavours to illuminate the reasons behind the lack of volunteer activities in the energy industry, contributing valuable insights to the literature on sustainable development and volunteerism.

Keywords: voluntarism, citizen-participatin, NGOs, energy, sustainability, SDG7

Pub No: P-062

INVESTIGATING HYBRID ENERGY SYSTEMS INTEGRATED WITH PHOTOVOLTAICS

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[1]Eastern Mediterranean University/Department of Architecture

Abstract: Electricity demand is increasing daily, a demand that cannot be met solely by non-renewable energy sources. Renewable energy sources such as solar and wind are abundantly available and environmental friendly. With over 300 sunny days and consistent coastal winds along its 648 km coastline, Cyprus presents a prime opportunity for Solar-Wind Hybrid systems. Photovoltaic-wind turbine hybrid systems offer significant efficiency across various sectors, including agriculture, plant production, and building. In the building sector, in particular, a photovoltaic-wind hybrid system offers numerous benefits, including clean energy production, reduced energy consumption costs, and increased comfort for building residents. This study analyzes the amount of energy production from the hybrid system and the energy consumption in the target municipality building located near the coastline of Gazimağusa (Famagusta), North Cyprus. The performance of the photovoltaic-wind turbine system in this case study was evaluated through a combination of interviews and statistical analysis conducted on the building. Survey findings indicate that the high cost of energy consumption for thermal comfort has led to dissatisfaction. Implementing a photovoltaic-wind hybrid system is expected to gradually reduce energy costs over time. In conclusion, this research suggests the implementation of this hybrid system for buildings due to its high potential for energy production, even at night without sunlight, and its significant reduction in the cost of energy consumption, leading to economic savings.

pv-wind turbine

This photo is a combination of two systems of mini-grid (photo voltaic)and wind turbine

Keywords: Energy production, Photovoltaic, Hybrid energy systems, wind turbines, Renewable energy

Pub No: P-063

Optimizing Machine Learning Models for Photovoltaic Arc Fault Detection

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Abstract: This paper provides a comparative analysis of machine learning (ML) optimization strategies for detecting arc faults in photovoltaic (PV) systems, which are critical for preventing fires and system failures. Early identification of these faults is vital, and it has been shown that ML algorithms are effective for real-time detection. However, optimization is required to enhance accuracy and minimize both false positives and false negatives by the detector. A review of the literature on PV arc fault detection and ML optimization from 2010 to 2021 has been conducted. A summary of the ML algorithms used for arc fault detection in PV systems, detailing the context of each algorithm, its usage frequency, and relevant references, an example is shown in Table 1. The study encompasses both theoretical and practical aspects of optimizing ML-based PV arc fault detection, examining recent techniques and methods. Various ML algorithms, their advantages, and limitations in detecting arc faults are discussed. Furthermore, the paper explores optimization strategies like simulation-based optimization and empirical validation. These methods have been employed to refine ML algorithms, improving early detection. The findings underscore the importance of early arc fault detection in reducing risks and highlight how ML optimizations contribute to this goal. This comprehensive review provides valuable insights into the application and optimization of ML strategies for PV arc fault detection, emphasizing their role in enhancing system safety and reliability.

TABLE 1 MACHINE LEARNING ALGORITHMS FOR PV ARC FAULT DETECTION

TABLE 1 MACHINE LEARNING ALGORITHMS FOR PV ARC FAULT DETECTION

Algorithm Used	Main Theme	# of Papers	Citation
Decision Tree	Classification/ Feature Selection	1	[1]
Random Forest	Classification	1	[2]
Support Vector Machine (SVM)	Classification/ Feature Selection	4	[3-7]
K-Nearest Neighbor	Classification/ Early Detection	2	[1, 8]
Convolutional Neural Network (CNN)	Real-Time Detection	2	[9, 10]
Recurrent Neural Network (RNN)	Feature Extraction	1	[11]
Deep Belief Networks (DBN)	Feature Extraction	0	
Ensemble Model	Classification	1	[12]
Autoencoder (AE)	Preprocessing/ Early Detection	1	[13]
Gradient Boosted Decision Trees (XGBOOST)	Early Detection and Classification	1	[2]
Long Short-Term Memory (LSTM)	Detection/ Classification	2	[14, 15]
Hybrid	Classification/ Early Detection	2	[11, 16]

Keywords: Photovoltaic systems, PV arc fires, machine learning, arc faults, machine learning, optimization strategies.

Pub No: P-064

SOCIO-ECONOMIC ASPECTS OF SOLAR ENERGY: SOCIAL ACCEPTANCE AND ECONOMIC IMPACTS

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Abstract: This study examines the social acceptance and socioeconomic impacts of solar energy in Turkey, a country with significant solar potential yet hindered by several barriers to its full utilization. Key obstacles include high initial costs, inadequate technical infrastructure, and a lack of public awareness about solar technology. These factors prevent the widespread adoption of solar energy technologies. The research also discusses how Turkey's reliance on energy imports and political dynamics limit solar energy investments and suggests that such investments could enhance Turkey's macroeconomic stability by reducing expensive energy imports and preserving foreign exchange reserves. The potential of solar energy to boost national energy security, create local jobs, and meet international environmental commitments is emphasized. The study advocates for energy policies that reduce dependence on imported energy through renewable resources. It recommends that the government and relevant institutions launch comprehensive education and awareness campaigns, increase financial incentives for solar projects, and improve infrastructure development. Particular attention is given to the development of technical services and support for the installation and maintenance of solar panels, especially in rural and underdeveloped regions, to facilitate energy access and ensure broader technology acceptance. In conclusion, the study highlights solar energy as not only an environmental necessity but also an economic opportunity for Turkey, stressing the importance of fully exploiting this potential for the country's future.

Turkey's Solar Energy Potential Map

Keywords: Solar Energy, Socio-Economic Impacts, Energy Policies, Renewable Energy, Energy Security

Pub No: P-065

A Novel Framework towards Transitioning into Positive Energy Districts on Neighborhood Scale

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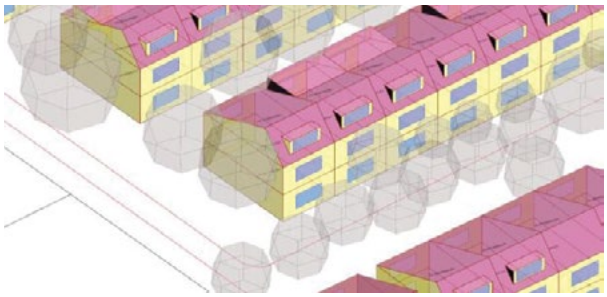
[1]Middle East Technical University (METU/ODTÜ)

Abstract: The built environment significantly impacts sustainable development progress and determines energy usage patterns in the contemporary global context. In the pursuit of mitigating the increasingly urgent difficulties associated with climate change, it is essential that we reconsider our urban environments and optimize their use of resources. This research project proposes a novel methodological framework for an automated evaluation of the existing district's potential to become a Positive Energy District (PED). In addition to fulfilling the community's energy needs, the evaluated transformation seeks to surpass them by returning excess energy to the electricity grid. The project is named "Auto characterization of PEDs for digital references towards iterative process optimisation", shortly referred to as "PED-ACT". Within the scope of the project, 14 partners from 4 countries come together to evaluate the proposed framework on five pilot areas in Ankara, İzmir, Umea, Borlange, and Lower Australia. The evaluation is carried out through a set of Urban Building Energy Models (UBEM) by generating baseline energy models and structuring strategies related to energy efficiency, flexibility and generation to see whether a PED achievement is possible within the pilot area.

Figure 1



The energy model created for PED-ACT

Keywords: Positive Energy Districts (PED), Modeling & Simulation, Energy Efficiency, Renewable Sources

Pub No: P-066

Cost-Effective Off-Grid PV Systems for Sana'a: A Techno-Economic Study

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[1]Solar Energy, EGE University, Izmir, Turkey

Abstract: All solar power projects in Sana'a, Yemen, are off-grid PV systems. Despite their low operating costs, high capital costs remain a major barrier to widespread adoption. Various studies have proposed solutions, but they have not fully met the needs of investors and users. This paper investiges the design of fixed off-grid PV system using four techniques: Liu and Jordan's model, PVGIS, NASA POWER, and Meteonorm software. The study examines two designs with PV modules mounted at 0° and at the annual optimum tilt angle, each with scenarios based on minimal and average annual solar radiation. A comparative analysis of these scenarios evaluates their techno-economic performances. The results indicate that fixed off-grid PV systems at 0° with horizontal average annual solar radiation significantly reduce life cycle costs and unit electricity prices. This study serves as a guideline for rural electrification projects.

Keywords: Solar radiation, optimum tilt angle, PVGIS, PV design

Pub No: P-067

Optimizing Solar PV Site Selection: A Comprehensive Review

Raimon Bawazir [1], ***Mohammad Sutaif*** [1]

[1]solar energy

Abstract: This study conducts a thorough review of recent literature to identify the essential methods influencing the choice of ideal locations for solar PV power plants. It highlights that the process of identifying suitable geographical locations is contingent upon the assessment of various criteria and constraints, which can vary between different case studies. In the context of grid requirements, the selection of the optimal bus bar and size is a crucial consideration for integrating new Distributed Generation (DG). Notably, the proximity of power transmission lines is a predominant criterion for finding PV sites. In other words, the optimal integration of DG has a relatively minor impact within the geographical context. Moreover, technical design and economic analysis offer limited contributions to the identification of suitable PV sites among options. The authors attempt to find the gap in the literature review and propose a solution for it. They believe that the framework and recommendations outlined in this study will trigger the interest of and provide valuable guidance to decision-makers and investors in the relevant field.

Keywords: Geographical site, Optimization algorithm, PV design, Distributed generation

Pub No: P-068

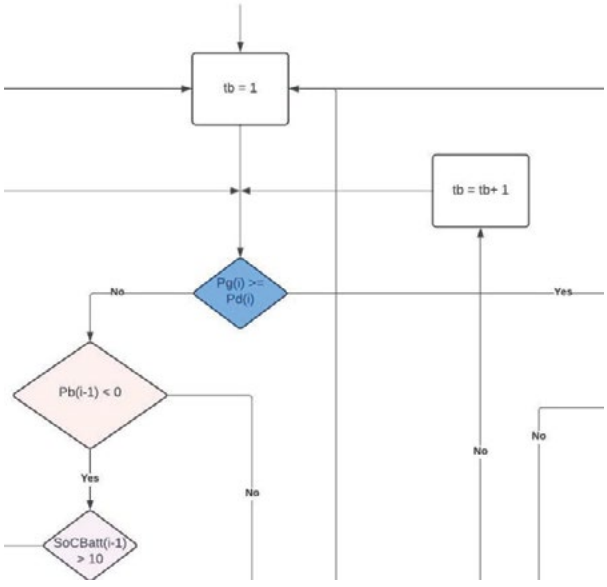
OPTIMUM BESS SIZING AND UTILIZATION USING RULE-BASED CONTROL APPROACH FOR BUILDINGS WITH PHOTOVOLTAICS

Nurhan Aydinalp [1], ***Murat Göl*** [1]

[1]Middle East Technical University

Abstract: As renewable energy sources (RESs) such as photovoltaic (PV) panels in residential areas increase and with 194 countries' signature under the Paris agreement, the concern about green energy and future is increasing rapidly. With these developments and the increase in electric vehicles (EVs), the concept of smart grid is inside of our reach. Within scope of these ideas, battery energy storage system (BESS) has a crucial role while achieving net-zero buildings and cities. The BESS not only helps reducing the electricity bill which was the first goal of its industrial utilization but also reduces the carbon emission to the nature as carbon emission is highly related to the electricity bill since most of the generation still comes from non-renewable sources such as natural gas, coal and oil. The most important part of such device is its feasibility since it is still developing, has a limited life span and is an expensive technology. Before making such investments, it is vital to optimize the size of the BESS to reduce the cost because they highly depend on each other. This paper proposes a rule-based controller for a system consisting of building integrated PV panels (BIPVs), EVs, loads and BESS, because it is essential to optimize the charging and discharging schedule of the BESS to maximize the benefit. The rule-based controller simulates the optimum BESS charging and discharging schedule considering time-of-use tariff and the health of the BESS in grid connected mode to analyze the feasibility based on the battery size.

Sniplet of decision tree



Keywords: Battery Energy Storage System (BESS), Time-of-use tariff, Photovoltaic (PV) panel

Pub No: P-069

Solar Power for a Sustainable Future: Assessing Solar Resource Availability and PV System Performance for Building Decarbonization in Turkey

Ahadollah Azami [1]

[1]Cukurova University

Abstract: Türkiye, with its abundant sunshine hours, holds significant potential for harnessing solar power to achieve a sustainable future. This study investigates the feasibility of building decarbonization through solar energy by assessing solar resource availability and photovoltaic (PV) system performance across various regions in Türkiye. The spatial variations in solar irradiation using solar resource maps are analyzed and evaluated regarding the expected electricity generation from different PV system configurations. The research aims to identify optimal locations for building-integrated PV (BIPV) systems and assess their potential contribution to reducing building energy consumption and carbon emissions. By analyzing the interplay between solar resource availability, PV system performance, and building characteristics, this study provides valuable insights for policymakers, architects, and building owners to promote solar energy adoption and accelerate building decarbonization efforts in Türkiye.

Keywords: Solar Potential, BIPV Performance, Latitude, Building Decarbonization

Pub No: P-070

HYBRID K-MEANS AND PARTICLE SWARM OPTIMIZATION MODEL TODETERMINE OPTIMUM PARCELS FOR AGRIVOLTAICS AND ELECTRICTRACTORS

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[1]Uludağ Elektrik Dağıtım A.Ş./ R&D Department, Bursa, Türkiye

[2]TOBB ETÜ / Electric Electronic Engineering Department, Ankara, Türkiye

Abstract: Scarcity of food, droughts, and energy crisis are three biggest challenges mankind will face in the upcoming future due to global warming, population growth, and urbanization. Inextricably linked nexuses, as well as the causal linkage between these issues lead states, researchers and all humanity to find new sustainable and green solutions. Agrivoltaics, and electric tractors in agriculture are so promising. Since agrivoltaics enable us to produce two assets in the same area, it might be a good solution to feed increasing population and to supply increasing energy demand due to the urbanization. The purpose of this study is to develop a predictive machine learning model, AVPHO (AgriVoltaics Parcel Hybrid Optimizer) which is hybrid implementaion of K-means and PSO, to find the optimum parcel to install solar power plants in agricultural area so as to supply energy demand of electric tractor required to grow selected crop. Proposed model has been tested by using real parcel data belonging to three different villages of Konya. The model produced results that are consistent with intuition. As a result of this study, it is concluded that planning is the most critical process in agriculture even for energy consumption and production, since energy demand of parcels will change according to crop would be produced.

Keywords: Agriculture, Agrivoltaics, Electric Tractor, K-means, Machine Learning, Particle Swarm Optimization, Photovoltaics, Solar Energy

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