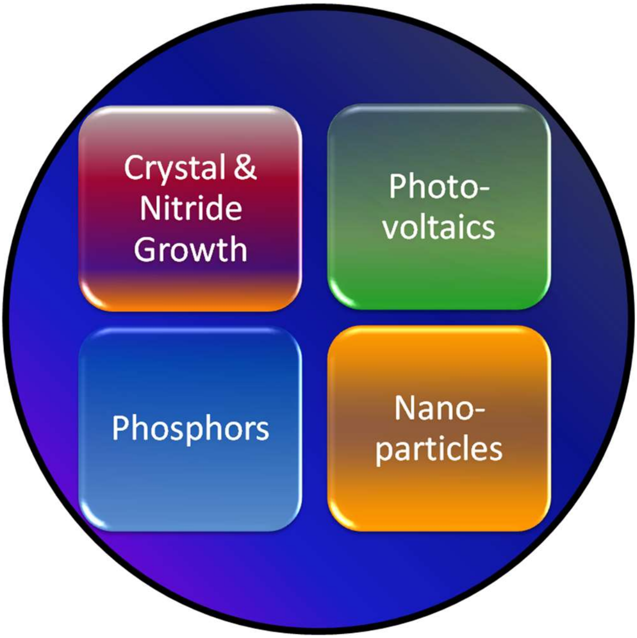
FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT
Department of Materials Science and Engineering

Materials for Electronics and Energy Technology



ANNUAL REPORT 2020

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Prof. Dr.-Ing. Peter Wellmann
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1. Vorwort

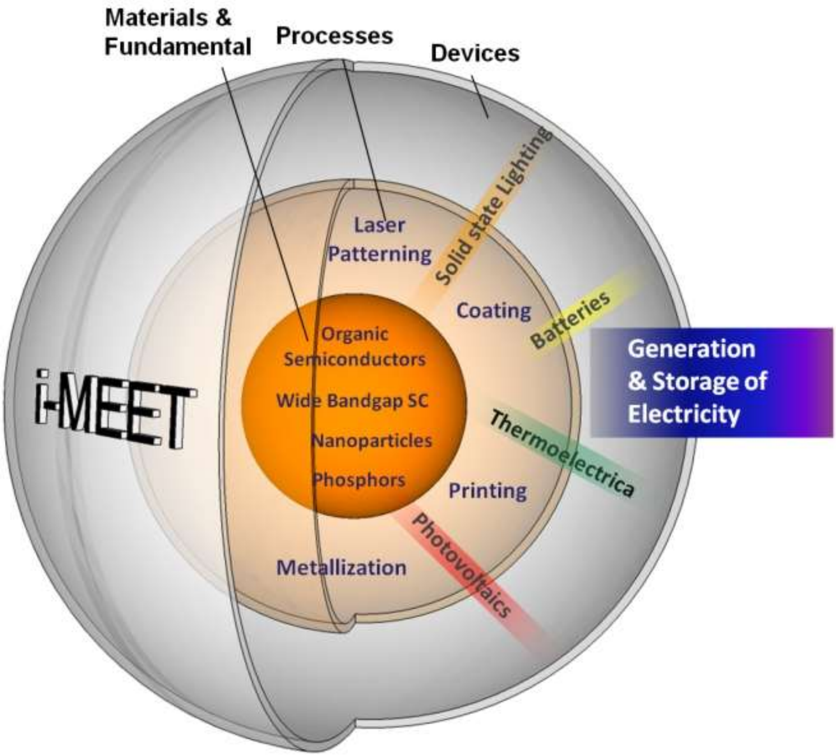
Herzlichen Dank an unsere Studenten, Doktoranden, Mitarbeiter und Gruppenleiter für ihre fantastischen Leistungen in 2020. Das Jahr 2020 stand im Fokus der Corona Krise.
Ich möchte allen danken, die mit unermüdlichen Einsatz und akribischer Genauigkeit für eine rigorose Umsetzung der Corona Richtlinien gesorgt haben, Vorlesungen für das Internet designt und gehalten haben, unsere Praktika digitalisiert haben und sogar die Durchführung der Next Generation Solar Energy Conference 2020 (ngse.info) meistern konnten.
Besonders herzlichen Dank an unser Verwaltungsteam und unsere technischen Angestellten – ohne sie wäre es nicht möglich, das i-MEET so erfolgreich zu führen. Ihnen allen, den Kooperationspartnern und Unterstützern des i-MEET danke ich für die erfolgreiche Zusammenarbeit in 2020 und wünsche viel Spaß beim Lesen unseres Tätigkeitsberichts.

Many thanks to our undergraduates, graduate students, staff, and group leaders for their fantastic accomplishments in 2020. The year 2020 was dominated by the Corona crisis. I would like to thank everyone who worked tirelessly and meticulously to ensure rigorous implementation of Corona policies, designed and delivered lectures digitally, digitized our lab courses and supported the successful delivery of the 2020 Next Generation Solar Energy Conference (ngse.info). Special thanks to our administrative team and our technical staff - without them, it would not be possible to run i-MEET so successfully. I would like to thank all of you, the cooperation partners and supporters of the i-MEET for the successful cooperation in 2020 and hope you enjoy reading our activity report.

Best, Christoph Brabec

Please note that some of our highlights can be found on i-MEET's youtube channel i-MEET Lab.
(https://www.youtube.com/channel/UC6RHRl5xyzL1b-lcJ6FG3PA).

Please note also our alumni network at LinkedIn (Institute i-MEET).



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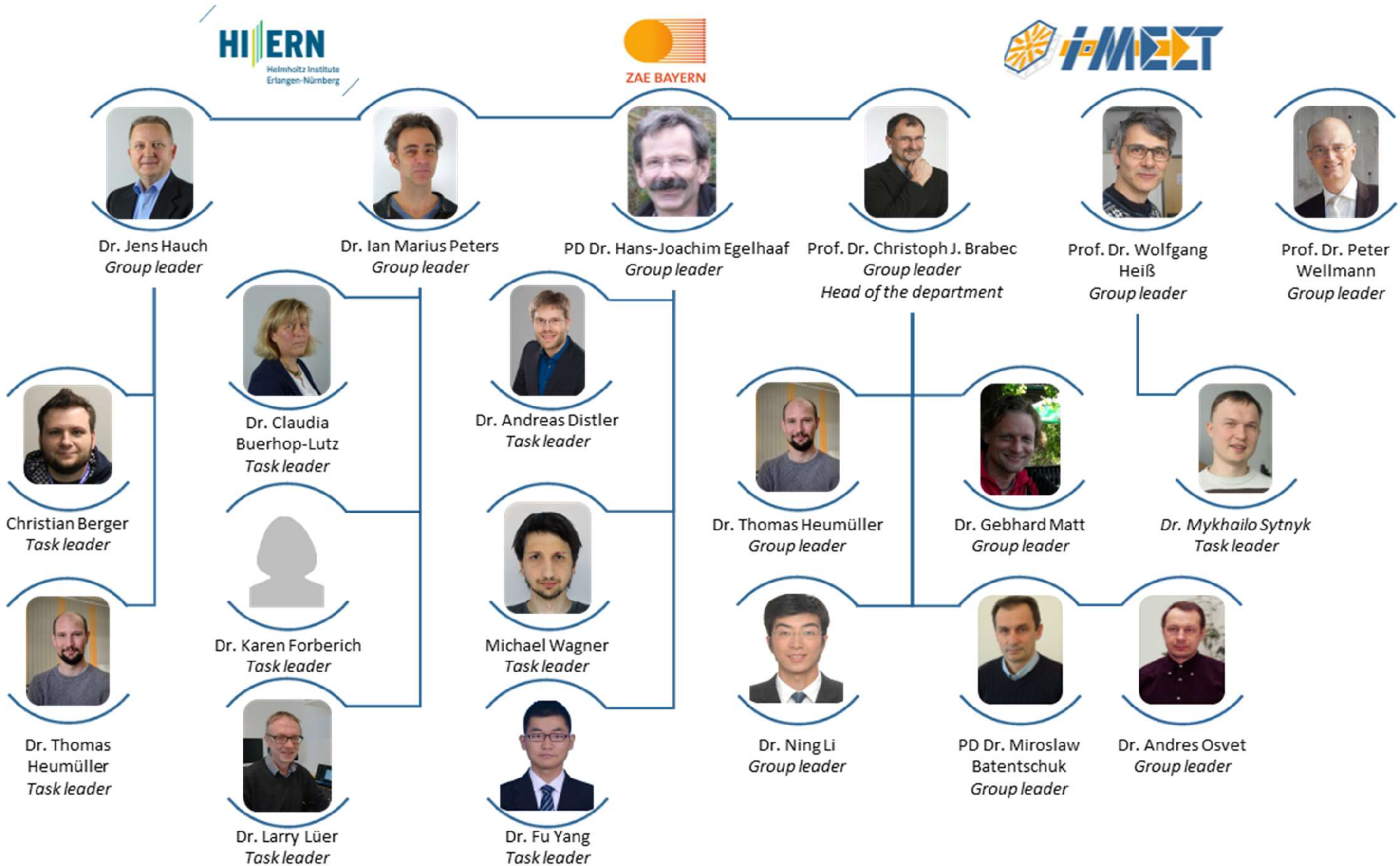
(Albrecht Winnacker) (Miroslaw Batentschuk)

Erlangen, April 2021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Solar and Semiconductor Devices (SSD)

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Andres Osvet
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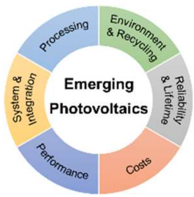
Research of the group is devoted to the design, simulation, processing and analysis of modern innovative semiconductors, electronic materials as well as advanced devices. Next generation concepts for electronic devices and future light harvesting techniques complete our research focus.

Development of low cost, long lived and highly efficient printed solar cells is one major vision of this research group. This includes the development of stable and efficient materials, the development of printed multilayer tandem technologies, ternary sensitization and controlling microstructure formation. Advanced organic semiconductors, p-type & n-type interface layers, printed transparent / opaque electrodes, flexible substrates and low cost barriers are further activities of this research group.

Organic semiconductors, perovskite hybrid composite semiconductors as well as colloidal quantum dots are the material fundament of our device engineering and process development activities. Further activities include low temperature processed chalcogenides and kesterites.



The **Device** Group at i-MEET focuses on the development of solution-processed emerging photovoltaic devices with excellent performance and device stability, in particular for organic- and perovskite-based photovoltaic technologies. In order to develop efficient, cheap and stable optoelectronic devices, we explore advanced materials, novel device architectures and characterize relevant fundamental and loss mechanisms. In close collaboration with partner groups at i-MEET, HI-ERN and ZAE Bayern, the scientific research findings obtained by the Device Group will help further promote the industrialization of emerging photovoltaic technologies.

Research of **Phosphors & Light (P&L)** group is focused on the development of phosphors for light conversion, but also on semiconductors for optical or x-ray detectors, and other materials used in optoelectronic devices. The applications of the light conversion phosphors range from LED-based ambient or horticultural lighting to liquid crystal displays. A specific application is harvesting the ultraviolet and infrared solar emission in solar cells, based on transforming the emission by up- or downconversion effect into the most efficient spectral range of a solar cell. The materials can be roughly divided into rare-earth or transition metal doped inorganic phosphors on one hand, and semiconductor quantum dots, thin films, and micrpowders on the other hand. In addition, new light-converting luminescent materials for white light emitting diodes, as well as storage phosphors for the application as markers in the medical and biological research are developed and studied. New phosphors for the high temperature thermometry are another part of activities, in co-operation with EnCN and the Chair for Technical Thermodynamics

(Lehrtsuhl für Technische Thermodynamik, Prof. Will). Our expertise in optical spectroscopy is used in close cooperation with the Organic and Solution-based Photovaltaics Groups in the development and optical characterization of solar cell materials.

The **Lifetime group** develops novel characterization methods and device architectures to improve the long-term stability of organic solar cells. Advanced optical and electrical time resolved measurements are combined with in-situ stability testing under controlled atmosphere, illumination and temperature.

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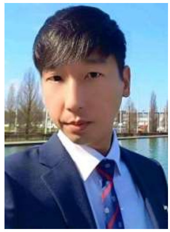

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Solution-Processed-Semiconductor-Materials (SOPSEM)

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Prof. Dr.
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Dr.
Mykhailo Sytnyk
Task leader

Solution processed semiconductor materials are synthesized as a basis for the development of electronic devices. The materials include colloidal nanocrystal quantum dots and metal-halide perovskites. For the perovskites their epitaxial growth has been achieved by inkjet printing on various substrates, as a first step towards the development of epitaxial heterostructures. Micro-crystallites of perovskites are grown to provide laser cavities, which exhibit lasing under optical pumping. Metal-oxide nanocrystals are applied as electrochromic materials, exhibiting within an electrochromic device color changes upon intercalation or de-intercalation of Li-ions. For their application as electrodes in the devices, films of the colloidal nanocrystals are prepared, whose function rely heavily on ligand treatments procedures which are developed in our group. The resulting electrochromic devices have the potential to be used in smart windows, providing diming from sun light upon electrical activation. PbS nanocrystals are synthesized and applied as absorber in infrared-photodiodes and solar cells. For their fabrication within a single deposition step the ink formulation is of uppermost importance. Solvent mixtures are applied, in order to allow the deposition of ~ micron thick films within a single step, which are smooth, free of cracks and contain a minimum amount of organic residuals. Such inks are usable not only by spin coating but also by doctor blade deposition, enabling the scaling of the device fabrication to large areas. They are used for the development of infrared solar cells and photodetector arrays.

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Crystal Growth Lab (CGL)

(Scientifical staff, doctoral candidates)

Prof. Dr.-Ing. Peter Wellmann
Group leader

The research activities in the crystal growth lab of Prof. Dr.-Ing. Peter Wellmann at the electronic materials and energy technology (i-meet) division of the materials department (University of Erlangen-Nürnberg) are devoted to modern topics in semiconductor technology and include crystal growth, epitaxy and characterization of various electronic materials. In the current focus of research and development are materials for energy saving:

(i) Silicon carbide for power electronic devices is a key player for energy saving.

(ii) The CIGSSe thin film solar cell materials recently have reached a maturity that allows the realization of commercial solar panels. CZTSSe is believed to play the role of a succeeding thin film solar cell material.

(iii) Printed electronic layers offer a great potential of a wide range of (opto-)electronic and photovoltaic device applications.

(iv) In the field of characterization, a large variety of electrical, spectroscopic and structural techniques are used which serve the better understanding of materials processing. Special emphasis is put on topographic methods.

(v) In all fields service for industrial and institutional partners may be provided.

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Task leader

Michael Wagner
Task leader

Dr
Fu Yang
Task leader

The "Solar Factory of the Future" develops advanced concepts of printed photovoltaic (PV) modules and of high-throughput-processes for their production. The main goal of our activities is the upscaling of highly efficient small size solar cells to industrially viable roll-to-roll (R2R) producible large area solar modules at minimum efficiency losses. This involves: the formulation of inks based on green solvents, the optimization of R2R printing and coating processes, the development of advanced patterning processes for high efficiency organic and perovskite solar modules by laser ablation and ink jet printing, development of novel concepts for the encapsulation of printed PV modules, and the integration of our modules in mobile applications and in building integrated PV installations.

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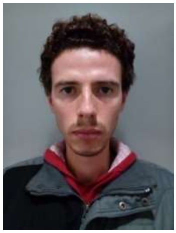

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HI ERN
Helmholtz Institute
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Dr.
Ian Marius Peters
Group leader

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Dr-Ing.
Thomas Heumüller
Task leader

Dr
Ning Li
Guest Scientist

The research unit „High Throughput Methods in Photovoltaics“ at the HI ERN aims to develop materials, processes and technologies fostering a sustainable and significant cost degression of photovoltaic technology, from small non-gird connected energy harvesting to large scale energy production and from the Watt scale to the Terawatt scale. The research combines achievements from automated materials research, digitization, simulation and big-data methods with the specialized knowledge of Photovoltaic technology. The research unit is a cooperation between the Bavarian Center for Applied Energy Research (ZAE Bayern), the Friedrich-Alexander-University Erlangen-Nuremberg (FAU) and HI ERN and performs its research in two active research groups:

- High Throughput Materials and Devices for PV
- High Throughput Characterization and Modelling for PV

With their research the groups address specific challenges in the fields of materials and device development, highly productive processes for the manufacture of PV-modules as well as the maintenance and operations of very large scale solar power plants.

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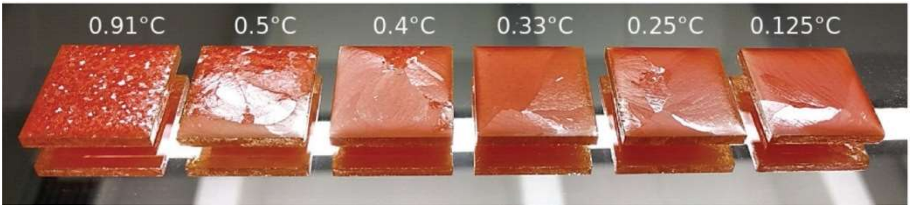
Ahmad Razi, University of Olomouc, Czech Republic

Lorena Dhamo, Division Biophotonics, Federal Institute for Materials Research and Testing (BAM), Berlin

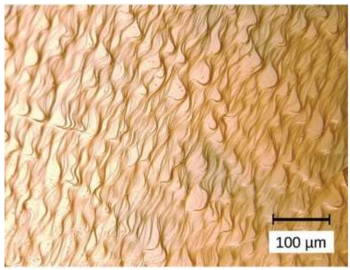
Dr. Li Nian, South China Academy of Advanced Optoelectronics, South China Normal University (Dec. 2019 – Nov. 2020)

3. Highlights 2020

Gebi demonstrates a “state of the art” perovksite X-Ray detector fabricated via a simple melt process

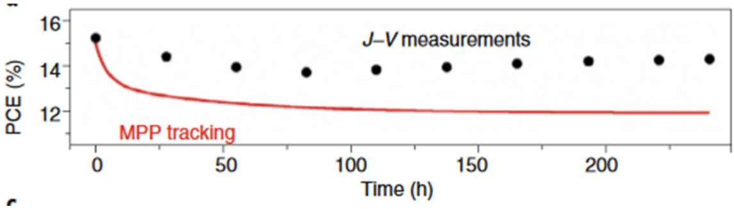


The current state-of-the-art X-ray to current converter technology is based on Cd(Zn)Te. The into crystalline wafer processed material, offers ideal properties but requires demanding production processes such as zone melting, the Bridgman method or epitaxial growth. Beside the high costs, most limiting is the small size of the Cd(Zn)Te wafers. On the other hand, metal-halide perovskites for direct X-ray to current converter showed a rapid progress and are approaching the performance of single crystalline Cd(Zn)Te detectors. In his recent paper in Advanced Materials Interfaces, Gebi demonstrate excellent electro-optical properties of single crystalline CsPbBr3 layers processed by a simple melting process of CsPbBr3 powder directly on substrates of any size. Although the principles of this method go back on an ancient technique, the “vitreous enamel” glazings, only few reports regarded this concept for perovskite processing.



Gebi built X-Ray detectors from the molten films and found state of the art performance, comparable to high end CZT detectors. The findings are published in the current issue of Advanced Materials Interfaces.

i-MEET and HI-ErN join the ISOS consortium in publishing a critical perspective on assessing perovskite stability in Nature Energy



Until now, the perovskite community lacked cohesion and consistency in identifying key tests that could reveal failure modes specific to perovskite cells, which is both cause and consequence of the limited understanding of device degradation. More effort is needed to understand degradation mechanisms in the first instance. To address this challenge, Monica Lira-Cantu and Eugene Kats brought together a wide number of researchers in the field from universities, research centres and companies to reach a consensus on how to test perovskite solar cells for stability and how to accurately report data. The resulting Consensus Statement is published in this recent Nature Energy publication.

nature energy

CONSENSUS STATEMENT

https://doi.org/10.1038/s41560-019-0529-5

OPEN

Consensus statement for stability assessment and reporting for perovskite photovoltaics based on ISOS procedures

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Improving the long-term stability of perovskite solar cells is critical to the deployment of this technology. Despite the great emphasis laid on stability-related investigations, publications lack consistency in experimental procedures and parameters reported. It is therefore challenging to reproduce and compare results and thereby develop a deep understanding of degradation mechanisms. Here, we report a consensus between researchers in the field on procedures for testing perovskite solar cell stability, which are based on the International Summit on Organic Photovoltaic Stability (ISOS) protocols. We propose additional procedures to account for properties specific to PSCs such as ion redistribution under electric fields, reversible degradation and to distinguish ambient-induced degradation from other stress factors. These protocols are not intended as a replacement of the existing qualification standards, but rather they aim to unify the stability assessment and to understand failure modes. Finally, we identify key procedural information which we suggest reporting in publications to improve reproducibility and enable large data set analysis.

To ensure economic feasibility and competitive levelized cost of electricity, new photovoltaic (PV) technologies must offer long-term stability alongside high power conversion efficiency (PCE). For instance, the lifetime expectation for a PV module in a power plant is 20–25 years, to match the reliability of silicon-wafer-based modules. At present, the long-term stability of emerging technologies such as organic photovoltaic (OPV) cells, dye-sensitized solar cells (DSSCs) and halide perovskite solar cells (PSCs) is not meeting this target and improvements are hampered by a lack of understanding of the module failure modes.

The existing qualification tests described in the International Electrotechnical Commission (IEC) standards on terrestrial PV modules (such as IEC 61215)[1–3] are designed for the field performance of silicon panels to screen for well-understood degradation modes generally associated with issues at the module level. These tests, however, are unlikely to be well-suited to OPV cells, DSSCs and PSCs because of their fundamentally different material properties and device architectures. In fact, various reports have shown that the stability of these devices cannot be fully assessed by the procedures developed for conventional PV products[4–10], which led to the publication of various studies that attempted to understand the degradation mechanisms in emerging PV systems. Unfortunately, these studies lacked consistency in the assessment and reporting procedures, which prevented data comparison and, consequently, the identification of various degradation factors and failure mechanisms.

In light of such shortcomings, in 2011, a broad consortium of researchers developed recommendations for evaluating the stability of OPV cells[11]. These standardized ageing experiments (the so-called ISOS protocols) were established at the International Summit on Organic PV Stability (ISOS) held in Roskilde, Denmark, in 2010. They outline a consensus between researchers in the OPV field on performing and reporting degradation studies in a controlled and reproducible way. These protocols are not intended to be a standard qualification test, nor are they suited for application by industry or insurance agencies; however, it is worth mentioning that tests based on the ISOS protocols were recently considered at the IEC level

A full list of affiliations appears at the end of the paper.

Stefan demonstrates an acceleration factor > 50 for a self-driven laboratory over classical high throughput experimentation

Self-driven laboratories are current discussed as a fast and reliable methodology to overcome the limitation of classical high-throughput experimentation. In his most recent article in Advanced Materials, Stefan challenged a robot based high throughput process to identify the most photostable composition for multicomponent polymer blends as required for OPV. Stefan developed a method for automated film formation which allows the fabrication of up to 6000 films per day. Loic, Florian and Alan Guzik from the University of Toronto supported equipping our automated experimentation platform with a Bayesian optimization algorithm, and together we constructed a self-driven laboratory that autonomously evaluates measurements to design and execute the next experiments. To demonstrate the potential of these methods, a 4D parameter space of quaternary OPV blends was mapped and optimized for photostability. While with conventional approaches, roughly 100 mg of material would be necessary, the robot-based platform can screen 2000 combinations with less than 10 mg, and machine-learning-enabled autonomous experimentation identifies stable compositions with less than 1 mg

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Beyond Ternary OPV: High-Throughput Experimentation and Self-Driving Laboratories Optimize Multicomponent Systems

Stefan Langner, Florian Häse, José Darío Perea, Tobias Stubhan, Jens Hauch, Loïc M. Roch, Thomas Heumueller,* Alán Aspuru-Guzik, and Christoph J. Brabec*

Fundamental advances to increase the efficiency as well as stability of organic photovoltaics (OPVs) are achieved by designing ternary blends, which represents a clear trend toward multicomponent active layer blends. The development of high-throughput and autonomous experimentation methods is reported for the effective optimization of multicomponent polymer blends for OPVs. A method for automated film formation enabling the fabrication of up to 6048 films per day is introduced. Equipping this automated experimentation platform with a Bayesian optimization, a self-driving laboratory is constructed that autonomously evaluates measurements to design and execute the next experiments. To demonstrate the potential of these methods, a 4D parameter space of quaternary OPV blends is mapped and optimized for photostability. While with conventional approaches, roughly 100 mg of material would be necessary, the robot-based platform can screen 2000 combinations with less than 10 mg, and machine-learning-enabled autonomous experimentation identifies stable compositions with less than 1 mg.

With the development of novel nonfullerene acceptors fundamental performance limitations of fullerene-based organic solar cells (OSCs) have been overcome.[1,2] In the currently highest performing system PM6:Y6 ternary additives are used to improve charge carrier lifetime and mobility resulting in significantly improved performance with efficiencies up to 16.5%.[3,4] Typically in ternary systems the host donor:acceptor (D:A) ratio is kept constant, while only the content of additive is varied due to limited experimental resources. The existence of other optima beyond these constraints is usually not investigated. On the other hand, also for improvements of stability, ternary additives have successfully been introduced to stabilize morphology or prevent oxidation. These desired effects of additives are typically reverted into detrimental effects depending on the concentration and compatibility of the additive with the host system. Finding a fine balance is necessary to determine if a given additive can lead to a performance enhancement for a given host system. Currently the Achilles heel of the highest performing organic photovoltaic (OPV) systems is device stability, which motivates the use of a fourth stabilizing additive in performance optimized ternary systems.[5] On the pathway to such highly complex optimization problems with multidimensional composition space and hundreds of possible candidates for performance enhancing additives, novel experimental methods are necessary.

High-throughput experimentation (HTE) addresses these challenges by assisting the researcher in material synthesis, sample processing, and characterization. High-throughput methods for polymer samples have been used for adhesion

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Marius finds "bright spots" during COVID-19: Increased power from solar panels evidences cleaner air

During the COVID-19 pandemic, one unexpected outcome in cities around the world has been a reduction in air pollution, as people stay home to avoid contracting the coronavirus. Based on data collected in Delhi, India, researchers report that this cleaner air has led to more sunlight reaching solar panels, resulting in the production of more clean energy. The work appears June 19 in the journal Joule.

"Delhi is one of the most polluted cities on the planet," says first author Ian Marius Peters of Helmholtz-Institut Erlangen-Nürnberg for Renewable Energies in Germany. "Moreover, India enacted a drastic and sudden lockdown at the start of the pandemic. That means that reductions in air pollution happened very suddenly, making them easier to detect."

In a cooperation between HI-ERN, FAU´s i-MEET and MIT, Marius and his colleagues had previously done research in different cities, including Delhi, looking at how haze and air pollution impact how much sunlight reaches the ground and the effect of air pollution on the output of solar panels. The photovoltaic (PV) system installation in Delhi used for the earlier work was still in place, and data on the amount of solar radiation reaching the PV installation (called the level of insolation) was available for the time before and during the shutdown.

Insolation is measured with a pyranometer, an instrument that determines the solar radiation flux density from the hemisphere within a given range of wavelengths. Using data from some of their previous studies, the researchers calculated the changes in insolation.

They found that in late March, the amount of sunlight reaching the solar panels in Delhi increased about 8%, compared with data from the same dates from 2017 to 2019. The insolation at noon increased from about 880 W/sqm to about 950 W/sqm. Information on air quality and particulate matter suggested that reduced pollution levels were a major cause for the rise.
"The increase that we saw is equivalent to the difference between what a PV installation in Houston would produce compared with one in Toronto," Marius says. "I expected to see some difference, but I was surprised by how clearly the effect was visible."
The new data from Delhi, combined with their earlier findings, provide a solid foundation to further study the impact of air pollution on solar resources. We further expect to also find increased output of power from solar panels in other areas where air was cleaner due to lockdown measures.
"The pandemic has been a dramatic event in so many ways, and the world will emerge different than how it was before," Marius summarizes this work. "We've gotten a glimpse of what a world with better air looks like and see that there may be an opportunity to 'flatten the climate curve.' I believe solar panels can play an important role, and that going forward having more PV installations could help drive a positive feedback loop that will result in clearer and cleaner skies."
This work was supported by the Bavarian State Government.

Joule
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Report

The Impact of COVID-19-Related Measures on the Solar Resource in Areas with High Levels of Air Pollution

Ian Marius Peters,[1,5,*] Christoph Brabec,[1,3] Tonio Buonassisi,[2] Jens Hauch,[1,3] and André M. Nobre[4]

SUMMARY

Restrictions enacted to reduce the spreading of COVID-19 have resulted in notably clearer skies around the world. In this study, we confirm that reduced levels of air pollution correlate with unusually high levels of clear-sky insolation in Delhi, India. Restrictions here were announced on March 19th, with the nation going into lockdown on March 24th. Comparing insolation data before and after these dates with insolation from previous years (2017 to 2019), we observe an 8.3% ± 1.7% higher irradiance than usual in late March and a 5.9% ± 1.6% higher one in April, while we find no significant differences in values from previous years in February or early March. Using results from a previous study, we calculated the expected increase in insolation based on measured PM2.5 concentration levels. Measurements and calculations agree within confidence intervals, suggesting that reduced pollution levels are a major cause for the observed increase in insolation.

INTRODUCTION

A very noticeable effect of the restrictions enacted to counter COVID-19 are clearer skies. Satellite data showed a reduction in air pollution levels in many areas of the world. On March 19th, the European Space Agency (ESA) reported a decline in nitrogen dioxide levels over China.[1] On April 9th 2020, NASA reported a 30% drop in air pollution over the Northeastern US.[2] On April 26th, ESA reported pollution levels fell by 45%–50% compared with those in the same period last year in some European cities.[3] In previous reports, we discussed the impact of haze[4,5] and air pollution[6] on the performance of photovoltaic (PV) systems and provided a quantitative relation between PM2.5 (particle matter) concentrations and solar resource in India and Singapore. Given the recent low levels of air pollution, we set out to explore whether there wass a noticeable impact on the available solar resource that could have lead to unusually high electricity generation from PV installations. An article in Green Tech Media (GTM) from April 22nd already mentioned that "reduced air pollution from the lockdown has contributed to new records (in PV electricity generation) in Germany and the UK."[7]

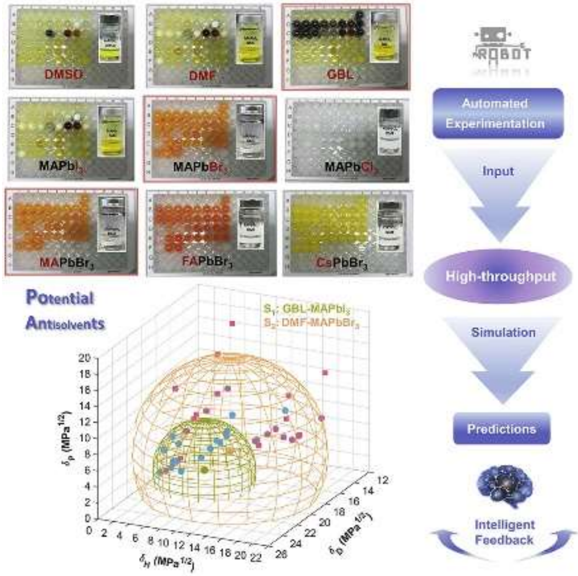
To quantify a possible impact on solar resource, we used recent air quality and weather data from Delhi, one of the most polluted cities on the planet,[8] for the years 2017 to 2020. We follow the approach described in Peters et al.[6] to quantify clear-sky insolation. Comparing air pollution and insolation characteristics from 2020 with those of previous years, we identified and quantified anomalies for the periods before and after measures were taken in India.

Context & Scale

A broadly noticed consequence of the restrictions enacted to counter the spreading of COVID-19 was unusually clear skies in many regions of the world. Better air quality has an impact on solar power generation, as fewer pollution particles in the air means that more sunlight will reach solar panels on the ground. In this study, we explore how air pollution in Delhi has developed following the lockdown on March 24th and how this reduction has affected how much sunlight the city received. First, we looked at measured particle concentration levels and noticed that after lockdown, levels dropped to about half of where they had been in previous years. Then, we looked at how much sunlight was received by solar panels. Before lockdown, insolation was similar to previous years. Yet, after lockdown, there was a clear and significant increase. In late March, insolation was up by 8.3% compared with levels in previous years. This is comparable to moving a solar panel from Toronto to Houston.

Joule 4, 1681–1687, August 19, 2020

Ening´s paper on deciphering the design rules for antisolvent perovskite engineering by robot based high-throughput screening goes online in Joule



Solution-based processing of photovoltaic materials has important advantages, including lower overall costs and easier upscaling of fabrication, where the solvents play an essential role. Antisolvent crystallization technique is often applied to achieve high-quality perovskite materials. However, the basic chemistry of the solvent-antisolvent crystallization is still not well understood. Besides, common antisolvents are toxic, and their number is limited. In this work, a novel robot-based method was used to screen and identify the most efficient antisolvents for different solvent-perovskite systems. 336 combinations of perovskite-solvent-antisolvent could be prepared and characterized by the integrated robotic platform within 2 days only. In addition, we provided a detailed working mechanism of the solvent-antisolvent crystallization approach. A detailed analysis allowed us to create a Hansen solubility sphere for the antisolvents. The quality and reliability of the plot was that high that one could immediately recognise that these anti-solvents must be solubilizing a perovskite precursor stage. With the help of molecular dynamics (MD) simulations we could identify the complexes which serve as as the crucial precursor for nucleation. Fast and complete quenching of these precursors by selective anti-solvents is the key strategy to foster large crystal growth with a low defect density.

Article

Robot-Based High-Throughput Screening of Antisolvents for Lead Halide Perovskites

Ening Gu,[1,5,6,*] Xiaofeng Tang,[1,5] Stefan Langner,[1] Patrick Duchstein,[2] Yicheng Zhao,[1] Ievgen Levchuk,[1] Violetta Kalancha,[1] Tobias Stubhan,[3] Jens Hauch,[3] Hans Joachim Egelhaaf,[3] Dirk Zahn,[2] Andres Osvet,[1,*] and Christoph J. Brabec[1,3,4,*]

SUMMARY

Solution-based processing of photovoltaic materials has important advantages, including lower overall costs and easier upscaling of fabrication, where the solvents play an essential role. Antisolvent crystallization technique is often applied to achieve high-quality perovskite materials. However, the basic chemistry of the solvent-antisolvent crystallization is still not well understood. Besides, common antisolvents are toxic, and their number is limited. In this work, a novel robot-based method was used to screen the efficient antisolvents for different solvent-perovskite systems. 336 combinations of perovskite-solvent-antisolvent could be prepared and characterized by the integrated robotic platform in 2 days. In addition, we provided a detailed working mechanism of the solvent-antisolvent crystallization approach. Furthermore, hundreds of potential antisolvents were proposed based on high-throughput screening and simulation. Verification tests match well with theory, and all reported antisolvents used for photovoltaic device optimizations are within our predicted range of the Hansen space, indicating that the predictions are reliable.

Context & Scale

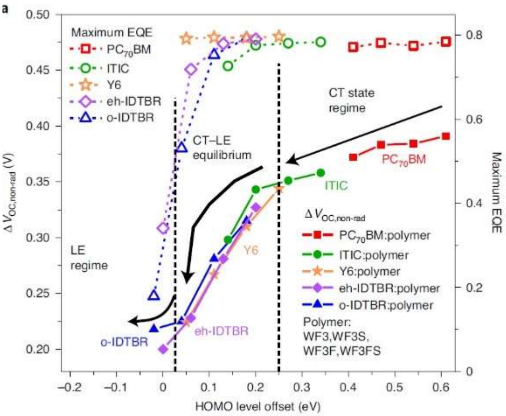
In terms of solution-processed lead halide perovskite optoelectrical materials, suitable antisolvent is essential for the crystallization and properties of final products. Conventional experiments of antisolvent selections are based on the manual time-consuming trial-error methods, which cannot meet today's increasing demands. In this work, a robot-based method was used to screen the antisolvents for different solvent-perovskite systems in a high-throughput manner to study the influence of interactions among the solvent molecules, cations, metal-halides, and antisolvents, to build an informative database, and to reveal the working mechanism and selection criteria of antisolvents. Besides, simulations based on the screening results provide hundreds of potential antisolvents. Corresponding verification tests evidenced that our predictions are reliable and vital for designing future efficient mixed solvent systems for the fabrication of perovskite optoelectrical materials.

INTRODUCTION

Non-vacuum solution-based fabrication processes receive considerable attention in the photovoltaic area because of their apparent advantages, such as suitability for upscaling, lower process temperature, lower energy consumption, and lower costs. In addition, solvent-based methods can be relatively easily implemented in automatic, high-throughput experiments, allowing for high-throughput screening of materials. The lead halide perovskites feature excellent optoelectronic properties[1–3] and hold continuous attention. The power conversion efficiency of perovskite solar cells has improved from 3.8% in 2009[4] to 25.2% to date.[5] High-quality perovskite solar cells can be fabricated by scalable solvent-based methods, making them competitive with the commercialized thin-film based solar cells. There are many solution-based deposition techniques, such as spin coating,[6] blade coating,[7] spray coating,[8] slot-die coating,[9] and inkjet printing.[10] To obtain high-quality perovskite materials with solution-based processes, it is vital to promote and control the nucleation and growth of crystals. There are some widely used solution systems, where the solvent can be removed rapidly from the perovskite precursor by antisolvent crystallization,[11,12] gas quenching,[9,13] vacuum-assisted drying,[7,14] hot-casting,[15,16] and combinations of these approaches.[17,18] Antisolvent crystallization is frequently adopted to the systems where the choice of an appropriate solvent and antisolvent plays an essential role in generating high-quality perovskite materials.[11,19,20] Herein

Joule 4, 1–17, August 19, 2020

Andrej, Larry and Thomas publish a set of novel material design rules to extend OPV efficiency beyond 20 %



Andrej´s paper on the limitations of organic solar cells just went online in Nature Energy and got advertised in the News & View section of by a very profound comment from Tracey Clarke (thank you Tracey!). Andrej, Thomas and Larry went deep to understand the limiting factors enabling efficient free charge generation in parallel to keeping voltage losses as small as possibly. Not surprisingly, matching the energy levels of the donor and acceptor guarantees to reduce voltage losses. However, at such negligible energetic offset, one would expect that charge generation is breaking down.

In this paper we have shown at the hand of non-fullerene acceptor solar cells how to work around that limitation. As a surprisingly simple design criteria, we could evidence that a long exciton lifetime is key to guaranteeing efficient charge separation even at negligible energy offsets. Of course, there must be limitations. Especially near IR absorbers are known to suffer from the energy gap law, which reduces radiative recombination at the hand of non-radiative relaxation. However, some of the novel NFAs, and especially the Y6 derivatives, seem to be more relaxed from the energy gap law, and we indeed found exciton lifetimes of up to 1 ns. Of course, one has to keep in mind that solid state NFA films are still far away from PLQY of 100 %. As such, small changes in PLQY due to the energy gap law may not be limiting for the current generation of materials. Having understood charge generation at negligible energy offsets has led us to postulate this novel design criteria for the next generation of OPV materials. The focus is on materials that have a particularly long exciton lifetime. Most exciting – measuring the exciton lifetime does not require sophisticated setups. A simple transient photoluminescence measurement is sufficient and opens the venue towards high throughput design and characterization of the next generation of materials. TechXplore, a long time veteran among the pro-science based platforms (see mediabiasfactcheck.com) reporting on science and technology innovations, has featured Andrej´s article.

nature energy

ARTICLES

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The role of exciton lifetime for charge generation in organic solar cells at negligible energy-level offsets

Andrej Classen[1], Christos L. Chochos[2,3], Larry Lüer[1] ✉, Vasilis G. Gregoriou[2,4], Jonas Wortmann[1], Andres Osvet[1], Karen Forberich[1], Iain McCulloch[5,6], Thomas Heumüller[1,7] ✉ and Christoph J. Brabec[1,7,8] ✉

Organic solar cells utilize an energy-level offset to generate free charge carriers. Although a very small energy-level offset increases the open-circuit voltage, it remains unclear how exactly charge generation is affected. Here we investigate organic solar cell blends with highest occupied molecular orbital energy-level offsets (ΔE_{HOMO}) between the donor and acceptor that range from 0 to 300 meV. We demonstrate that exciton quenching at a negligible ΔE_{HOMO} takes place on timescales that approach the exciton lifetime of the pristine materials, which drastically limits the external quantum efficiency. We quantitatively describe this finding via the Boltzmann stationary-state equilibrium between charge-transfer states and excitons and further reveal a long exciton lifetime to be decisive in maintaining an efficient charge generation at a negligible ΔE_{HOMO}. Moreover, the Boltzmann equilibrium quantitatively describes the major reduction in non-radiative voltage losses at a very small ΔE_{HOMO}. Ultimately, highly luminescent near-infrared emitters with very long exciton lifetimes are suggested to enable highly efficient organic solar cells.

With the emergence of non-fullerene acceptors (NFAs), organic solar cells (OSC) reached power conversion efficiencies over 16% (refs [1–3]). Despite this stark increase in power conversion efficiencies, the open-circuit voltages (V_{OC}) still lag behind those of inorganic solar cells, which shows that V_{OC} losses are still substantial[4–6]. An important aspect related to V_{OC} losses is the energy-level offset (E_{offset}) at the donor–acceptor interface which provides the driving force for splitting excitons into free charge carriers[7]. To avoid excessive voltage losses, the offset should be as small as possible. At the same time, though, it is generally believed that an E_{offset} of at least 0.3 eV is necessary to obtain a fast and efficient charge separation[7]. Nevertheless, it was recently shown that by fine-tuning the energy levels in high-performance NFAs to an E_{offset} smaller than 0.2 eV, the bandgap to V_{OC} losses could be lowered from more than 0.8 V to around 0.6 V in highly efficient OSCs[1,2,8,9]. However, it remains unclear how an efficient charge generation can be maintained at such small driving forces for exciton splitting. For instance, very slow charge generations on the order of 20 ps were reported in OSCs based on low E_{offset} systems[10]. Charge generation in these systems is slow compared with the femtosecond charge generation in conventional OSCs, in which a large energy offset affords a strong driving force. This observation thus raises the question of how charge generation in OSCs is affected at a negligible E_{offset} and how this limits the performance of OSCs.

In this work, we address this question by investigating a representative number of OSC blends with offsets between the donor and acceptor highest occupied molecular orbital energies (ΔE_{HOMO}) spanning from 0 to 300 meV. At negligible ΔE_{HOMO}, we detect ultra-slow exciton splitting with lifetimes up to 1,300 ps, which reaches or even exceeds the exciton lifetimes of the pristine material. This drastically limits charge generation and we demonstrate a strong correlation between the exciton splitting efficiency and the external quantum efficiency (EQE). Based on these experimental findings, we postulate a very long exciton lifetime as the key parameter to maintain an efficient device operation at negligible ΔE_{HOMO}. The importance of this design criteria is verified by an analytic model based on the Boltzmann stationary-state equilibrium between the local exciton (LE) and the charge-transfer (CT) state, which quantitatively describes the quantum efficiency for charge generation as a function of two parameters only: energy offsets and singlet exciton lifetime. Moreover, this effective 'two states' model provides striking insights into the experimentally observed steep drop of non-radiative voltage losses ($\Delta V_{OC,non\text{-}rad}$) when zero ΔE_{HOMO} is approached, as this can be quantitatively explained by a shift of the Boltzmann equilibrium from CT states towards exciton states. In particular, the steep drop occurs at a maximum slope of 0.8 V eV^{-1}, which we show to be the expected value if the drop is caused by a Boltzmann equilibrium between two states whose ratio of emissive quantum yields is 0.01.

Donor–acceptor systems with different energy offsets

To analyse the limitations in the device operation of OSCs at a very small E_{offset}, we investigated each combination of four high-performance NFAs with a series of four newly synthesized

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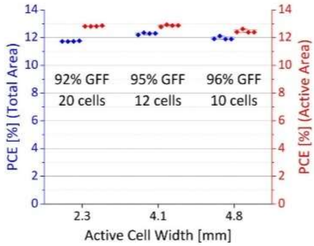
Andi´s work on achieving the world record in organic PV modules gets published in Progress in Photovoltaics



During the last years, the development of new active materials has led to constant improvement in the power conversion efficiency (PCE) of solution-processed organic photovoltaics (OPV) to nowadays record values above 17% on small lab cells. In this work, we show the developments and results of a successful upscaling of such highly efficient OPV systems to the module level on large areas, which yielded two new certified world record efficiencies, namely, 12.6% on a module area of 26 cm2 and 11.7% on a module area of 204 cm2. The decisive developments leading to this achievement include the optimization of the module layout as well as the high resolution short-pulse (nanosecond) laser structuring processes involved in the manufacturing of such modules. By minimizing the inactive areas within the total module area that are used for interconnecting the individual solar cells of the module in series, geometric fill factors of over 95% have been achieved. A production yield of 100% working modules during the manufacturing of these modules and an extremely narrow distribution of the final PCE values underline the excellent process control and reproducibility of the results. We believe that this works lays out the fundamentals how to achieve organic photovoltaic modules with power conversion efficiencies of about 15 % within the next 12 months.

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RESEARCH ARTICLE

PROGRESS IN PHOTOVOLTAICS WILEY

Organic photovoltaic modules with new world record efficiencies

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Abstract

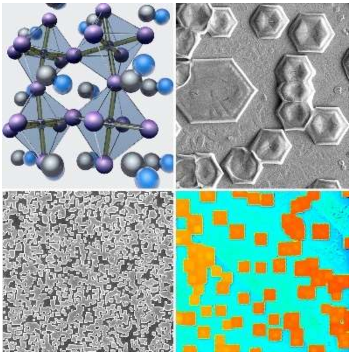
During the last years, the development of new active materials has led to constant improvement in the power conversion efficiency (PCE) of solution-processed organic photovoltaics (OPV) to nowadays record values above 17% on small lab cells. In this work, we show the developments and results of a successful upscaling of such highly efficient OPV systems to the module level on large areas, which yielded two new certified world record efficiencies, namely, 12.6% on a module area of 26 cm^2 and 11.7% on a module area of 204 cm^2. The decisive developments leading to this achievement include the optimization of the module layout as well as the high-resolution short-pulse (nanosecond) laser structuring processes involved in the manufacturing of such modules. By minimizing the inactive areas within the total module area that are used for interconnecting the individual solar cells of the module in series, geometric fill factors of over 95% have been achieved. A production yield of 100% working modules during the manufacturing of these modules and an extremely narrow distribution of the final PCE values underline the excellent process control and reproducibility of the results. The new developments and their implementation into the production process of the record OPV modules are described in detail, along with the challenges that arose during this development. Finally, dark lock-in thermography (DLIT), electroluminescence (EL), and photoluminescence (PL) measurements of the record module are presented.

KEYWORDS
certified power conversion efficiency (PCE), laser patterning, organic photovoltaics (OPV), solar modules, world record

1 | INTRODUCTION

Owing to the advent of nonfullerene acceptors, the efficiencies of polymer-based organic photovoltaics (OPV) have made a big leap forward in the last 3 years, after they had stagnated at around 10% in the seven lean years before 2018.[1] A series of publications has recently appeared, demonstrating solution-processed organic solar cells with efficiencies beyond 15%.[2–5] The present certified record for small area lab cells is at 17.35% efficiency on 0.032 cm^2.[6] Also, stabilities have reached a reasonable level, with lifetimes of several thousand hours being reported for accelerated aging tests.[7,8] What is lacking for commercialization of OPV is the upscaling of lab cells to large-area modules. The world record for large-area OPV modules so far has been held by Toshiba, reaching 9.7% on 26.14 cm^2.[9] The challenges with upscaling are mainly connected to high-quality large-area coating with industrially viable methods and interconnecting cells to modules without losing too much efficiency. The efficiency losses consist of two contributions. On one hand, there are the theoretical losses that arise mainly from the dead area caused by the interconnects and the serial resistances of the electrodes.[10] These losses are intrinsic to the module layout and the materials employed for the electrodes. In the past, we have already presented a study on how to

SOPSEM group overtakes Ultra-High Vacuum Semiconductor Technology with simple Inkjet Printing



Prof. Heiss' group SOPSEM (SOlution-Processed SEMiconductors), in collaboration within the IMEET department and several other FAU WW-s groups, has demonstrated a new approach of metal halide perovskites (MHP) heteroepitaxial crystal growth based on cheap and scalable inkjet printing. The paper is published in Advanced Functional Materials Journal. The developed inkjet printing technology has the potential to impact the whole semiconductor industry. The intrinsic physical properties of MHP, like solubilizing in polar solvents and tolerance to internal defects, make them perfect for processing with printing techniques. The Inkjet printing by itself represents a drop-on-demand digital, additive, and very flexible printing technique utilized for the cost-effective fabrication of different electronic devices. Applying epitaxial deposition principles for inkjet printing may unveil irreproachable device performance, which is only achieved by 1000 times more expensive ultra-high vacuum deposition technologies. SOPSEM studied in detail the boundary conditions like precursor compositions, temperature, environment parameters, and the crystal structures relation of grown material to the substrate for achieving optional selective epitaxial growth starting from separated single crystallites and ending with a full closed single-crystalline compact film. Even though the scope of the study was the development of epitaxial inkjet printing technology of MHP, the SOPSEM group found also that the MHP hetero-epitaxial structures exhibit bright luminescence and extended cubic crystal phase stability due to interfacial lattice anchoring by the substrates. The epitaxial inkjet printing method has the potential to be applied to a large variety of semiconductors for extremely cheap, large-scale, single-crystal electronic device developments and fabrication

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Epitaxial Metal Halide Perovskites by Inkjet-Printing on Various Substrates

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Metal-halide-perovskites revolutionized the field of thin-film semiconductor technology, due to their favorable optoelectronic properties and facile solution processing. Further improvements of perovskite thin-film devices require structural coherence on the atomic scale. Such perfection is achieved by epitaxial growth, a method that is based on the use of high-end deposition chambers. Here epitaxial growth is enabled via a ≈1000 times cheaper device, a single nozzle inkjet printer. By printing, single-crystal micro- and nanostructure arrays and crystalline coherent thin films are obtained on selected substrates. The hetero-epitaxial structures of methylammonium $PbBr_3$ grown on lattice matching substrates exhibit similar luminescence as bulk single crystals, but the crystals phase transitions are shifted to lower temperatures, indicating a structural stabilization due to interfacial lattice anchoring by the substrates. Thus, the inkjet-printing of metal-halide perovskites provides improved material characteristics in a highly economical way, as a future cheap competitor to the high-end semiconductor growth technologies.

1. Introduction

Metal-halide-perovskites (MHPs) are the most promising material system for next-generation photovoltaics,[1,2] which exhibits the fastest annual increase of record power conversion efficiency observed so far.[3,4] This rapid evolution of performance is enabled by numerous research groups, working on improvements in perovskite material compositions, microstructures, morphologies, and interface engineering.[3–9] It is obvious that the performance of solar cells and other electronic devices crucially depends on defects, present in bulk, and increasingly at surfaces and grain boundaries. Hence, single-crystal devices usually outperform polycrystalline and amorphous ones, which is also observed for

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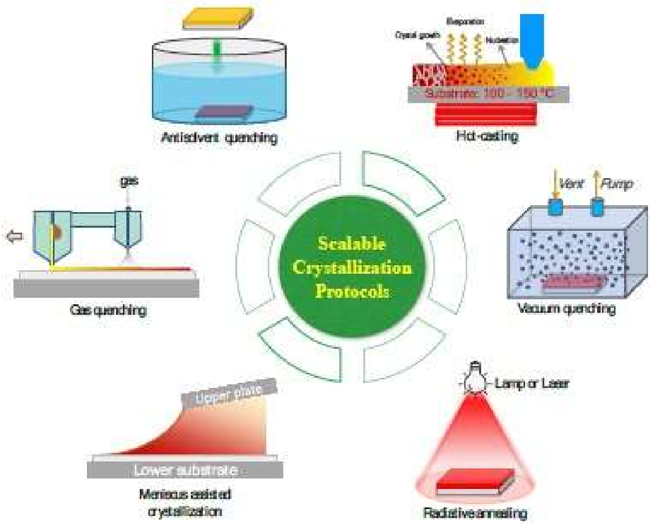
News Feature of Project COSIMA

Can drones be used to assess a utility-scale PV installation comprehensively? Scientists from the Helmholtz-Institut Erlangen-Nürnberg für Erneuerbare Energien (HI-ERN) attempt to show that it can be done in project COSIMA, a collaborative effort between six partners: N-ERGIE – a local utility company, IRCAM – a camera-producing company form Erlangen, Rauschert – a system developer form Thuringia, DHG Engineering – a power-electronics developer and the institute ELSYS from Technischen Hochschule Nürnberg. Allianz Risk Consulting GmbH from Munich is an associated partner.

In a recent feature in PV-Magazine, results from the project were highlighted. “With our advanced analysis methods we can identify anomalies in the operation of PV-systems. We investigate their impact on PV-system durability and explore the efficiency of maintenance procedures for more clean PV-electricity”, says Dr. Claudia Buerhop-Lutz, project-leader from HI-ERN. Utility company N-Ergie, is concerned with a reliable electricity production in the next-decades. Just within its area of operation, there are tens of thousands of PV systems. “For them to reliably produce electricity over the expected 30 year life span, maintenance on a regular basis is important – also because only then will the employed areas be ideally used”, says Rainer Kleedörfer, head of corporate development at N-Ergie.

Until August 2020, 56 PV-systems were assessed using aerial drones in the project. Currently capacities of up to 10 MW can be measured in one day to collect data for the development of automated software to assess the systems’ state. Measurements and software development are ongoing tasks in the project, which lasts until 2021.

Fei´s review on large area coating of perovskite solar cells and modules gets online in Energy & Environmental Science



10 years of research in perovskites semiconductors have provided great insight into the crystallization dynamics of halide based perovskites. Different to their oxide or chalcogenide sisters and brothers, halide perovskites offer a high crystallization enthalpy at very moderate temperatures, requiring utmost precision in timing and in controlling process conditions. In particular, the large efficiency losses associated with upscaling the lab-scale devices to large-area modules are directly correlated with an insufficient understanding but also control of the crystallization process. In this review, the recent advances in understanding crystallization of perovskites when deposited by large-scale deposition methods are critically discussed. One important is the identification of intermediate phases, which, independent of the coating method, to decouple the otherwise overlapping drying process from the crystallization process. Strategies for enhancing the crystal morphology of perovskite films are presented as well, which is vitally important to realize reproducible manufacturing of large-area modules.

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REVIEW

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Controlling the crystallization dynamics of photovoltaic perovskite layers on larger-area coatings

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As perovskite solar cells are highly efficient and already meet the efficiency requirement for renewable power generation, more attention is given to technological barriers such as scalability and stability. In particular, the large efficiency losses associated with upscaling lab-scale devices to large-area modules represents one of the major hurdles for commercialization. Given the essential role of the perovskite films in the device performance, it is of critical importance to develop reliable crystallization protocols to deposit high-quality perovskite layers via scalable methods. This review summarizes recent advances in emerging crystallization protocols for the large-scale deposition of perovskite thin films. The unique merits of the well-developed crystallization strategies, including antisolvent, gas quenching, vacuum quenching, etc., are carefully analyzed and discussed. We highlight that, independent of the coating method, creating intermediate phases to decouple the otherwise overlapped solution coating and crystal growth is essential to realize homogeneous coatings of perovskite thin films. Strategies for enhancing the crystal morphology of perovskite films are presented as well, which is vitally important to realize reproducible manufacturing of large-area modules. This tutorial review assists the screening and development of robust crystallization strategies for scalable deposition of high-quality perovskite films for photovoltaic applications.

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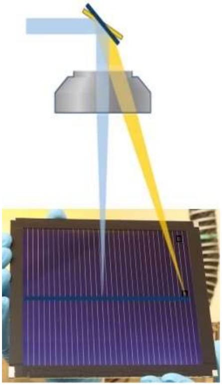
Yaohua Mai

Yaohua Mai received his PhD degree from Nankai University and Forschungszentrum Jülich in 2006. After that he became a post-doctoral researcher at Utrecht University. In 2008, he co-founded Baoding Tianwei Solarfilms Co. Ltd, a thin film silicon PV module manufacturer with an annual production capacity of 75 MW, and served as chief technology officer. He joined Hebei University in 2013 and became full professor. He is now professor and director of the Institute of New Energy Technology (iNET) at Jinan University. He is mainly working on thin film and c-Si based photovoltaic materials and devices.

Fei Guo

Fei Guo received his PhD in materials science from Friedrich-Alexander University Erlangen-Nuremberg in 2015. After a year's postdoctoral training at the group of Prof. Christoph J. Brabec, he joined the Institute of New Energy Technology (iNET) at Jinan University in 2017. His current research interests focus on printed optoelectronic devices of perovskites and organic semiconductors.

i-MEET and Sciprios GmbH have started joint research project PV-IL



Sciprios is a spin-off from FAU, which provides R&D equipment for printed opto-electronics, especially in the field of photovoltaics (PV). The goal of the project is the development of an inline laser system for the monolithic interconnection of organic and perovskite PV modules which enables geometric fill factors of 98% at high throughput and at low cost. This will be achieved by developing a high precision and high-speed roll-to-roll system, based on the long-term experience of i-MEET in laser patterning of organic PV modules.

European project „BOOSTER“has started

The EU-funded project BOOSTER (“Boost Of Organic Solar Technology for European Radiance”) has successfully kicked off. The project has a duration of four years and involves ten academic and industrial partners from eight different countries. Its aim is the development of organic photovoltaic modules with power conversion efficiencies up to 15% and 35 years lifetime. Two building-applied photovoltaics (BAPV) demonstrator installations will be realized within the project to illustrate different BAPV concepts – one of them being installed at FAU in Erlangen!

Congratulations to our colleagues with their PhD defenses

Many i-MEETers have passed their PhD examinations during the 2020 with excellent success and already have made the first step in the professional career. We've shared together this exciting moment that summarized around 4 years of their intensive research and hard work. We cordially congratulate Hermann Bechert (*Flexible und hochsegmentierte organische Leuchtdioden für Fahrzeugrückleuchten-Applikationen*), Chen Xie (*Water/alcohol-based nanoparticle inks for organic photovoltaics)* for successfully finishing their PhD studies.

Hermann Bechert

Chen Xie

Johannes completed his doctoral thesis with an inspiring and rousing defense. His performance was rewarded with Very Good success! Johannes investigated and developed non-destructive imaging methods to analyze material failure in photovoltaic cells and panels. He specifically developed an originary model which allowed him to predict the Voc losses in CIGS modules as a function of the Gallium / Indium gradient (GGI) on the one hand and of the shunt induced power losses on the other hand. Johannes could determine the GGI and shunt induced losses most elegantly with a combination of electroluminescence (scanning) imaging and thermographic imaging. Johannes further developed a thermographic imaging method allowing to directly image water diffusing into a solar cell package. Water ingress is one of the most frequent origins for failure and degradation in thin film modules but could not be directly verified with destroying the module. With Johannes method, it now becomes possible to visualize the amount of water in a package allowing to correlate degradation phenomena with water ingress during inline measurements.

We want to thank Johannes for his marvelous scientific and technical input as well as for his support in managing our numerous projects during the last years. Looking forward to our future projects!.

After three years in Erlangen **Osbel** finished his thesis on the topic of hysteretic effects in perovskite solar cells with excellence. An impressive number of publications, in combination with the development of novel impedance measurement methods and paired with a very strong defense convinced the committee on Osbel´s outstanding performance! Osbel was supervised from two institutions – i-MEET @ FAU on the one side, and from Germa Garcia-Belmonte @ the Univ of Jaume on the other hand. The double supervision as well as the joint thesis defense went exceptional smooth and successful, and I really want to express my gratitude to Germa for co-supervising Osbel. We wish Osbel all the best for his future! I hope he will stay in the community and continue his successful academic career. And of course, we hope to see Osbel sometime soon at a PV conference in Cuba!

Welcome to the family!

We are happy to greet Dr Lee Jihoon, Dr. Luo Junsheng who joined i-MEET in 2020.

Dr. Lee Jihoon

Dr. Junsheng Luo

PhD students

Manuel Daum

Elshaimaa Mostafa Darwish

Tim Freund

Julian Haffner-Schirmer

Huiying Hu

Jonas Ihle

Manuel Kollmuß

Johannes Köhler

Shudi Qiu

Viktor Rehm

Jingjing Tian

Paul Weitz

Zhiqiang Xie

Leonie Brandner have also joined the i-MEET family in 2020.

Leonie Brandner

At the same time Gebi joined the Prof. Maksym Kovalenko's group at ETHZ, Osbel Almora Rodríguez joined Institute of Advanced Materials (INAM) in Spain as postdoc, Iftikhar Channa left, Jack Elia joined the Fraunhofer Institute, Ening Gu, AmirAbbas YousefiAmin, Michael Schöler and Dr. Matthias Schuster left

Osbel Almora Rodríguez

Iftikhar Channa

Jack Elia

Ening Gu

Dr. Dipl.-Ing Gebhard Matt

Michael Schöler

Dr. Matthias Schuster

Chen Xie

YousefiAmin AmirAbbas

Felix Holler joined another department at FAU, Ulrike Knerr retired, and Sandra Wellmann left.

		
Felix Holler	***Ulrike Knerr***	***Sandra Wellmann***

4. Bachelor Theses

Sanna Bind (Forberich)
Synthesis of silver nanowires for transparent electrodes, by investigating the impact of the molecular weight of PVP

Patrick Scharpf (Batentschuk/Sytnyk)
Entwicklung einer Methode zur Herstellung eines quaternären Core-Shell Systems aus den Bestandteilen Zn, In, Ag, S als lumineszierende Nanopartikel für die Beschichtung von Solarzellen

Lena Merz (Egelhaaf)
Druckbare dielektrische Spiegel und ihre Anwendung in der organischen Photovoltaik

Fabian Magerl (Brabec)
Development of a new drop-casting method for high throughput experimentation of organic photovoltaics

Nils Sprengel (Batentschuk)
Degradationsstudie zyklischer mechanischer Belastung von PV-Modulen bei 4-punkt-Befestigung

Leonor Shala (Batentschuk)
Process Development of molten Perovskite-Layers

Janus Thelemann (Batentschuk)
Einfluss von Flourid-Flussmittel und Fluorid-Dotierungen auf die Effizienz

Julius Wiegand (Brabec)
Electrical Characterization of Organic Solar Cells Degradation with and without 1,8-Diiodooctane Influence

Markus Mühlhäußer (Egelhaaf)
Fabrication of perovskite solar cells with carbon electrodes from commercial inks using scalable printing techniques

Christian Schneider (Brabec)
Development of a simulation tool and algorithms for the optimization of automated pipetting processes

Jacqueline Steinhoff (Brabec/Berger)
Evaluierung eines Machine Learning Algorithmus für die autonome Prozessoptimierung in der Hochdurchsatzforschung

Simon Zapf (Brabec/ Egelhaaf)
High throughput measurements: The potential of developing new OPV-cells by means of slot die coating on a roll-to-roll machine

Patrick Lodes (Hoga/ Egelhaaf/ Pflaum)
Development and Evaluation of a Hybrid Power Management System for Airships Intended for Infrared Thermographic Inspection of Photovoltaic Plants

Simon Arnold (Brabec/Wagner)
Development and Implementation of a Fully Automated Spin Coating Setup and Evaluation of the Processes

Pia Ludwig (Heiß/Buerhop-Lutz/Doll/ Winkler)
Investigation of Crack Formation in Monocrystalline Silicon Photovoltaic Modules using Electro- and Photoluminescence measurement

Lena Bayer (Brabec/ Buerhop-Lutz)
Performanceanalyse von 72-Zellen-PV-Modulen unter zyklischer mechanischer Belastung

Max Bibrack (Brabec/Heumüller)
Processing of Organic Photovoltaic Devices via Liquid-Substrate-Transfer-Method

Max Kieker (Batentschuk)
Temporal characterization of femtosecond near-infrared pulses

5. Master Theses

Manuel Daum (Heiß/Sytnyk)
Auf Bismut basierende Halogenide und Perovksite zur direkten Röntgendetektion

Felix Hilpert (Heiß)
Aufbau eines Hallmessplatzes zur Untersuchung von Ladungstransferdotierung in Nanokristallinen Schichten

Fatima Akhundova (Li/Lüer/Brabec)
Optimization of VOC losses in wide-bandgap hybrid organic-inorganic mixed halide perovskite solar cells

Fabian Rau (Heiß)
Entwicklung und Evaluation eines Versuchsaufbaus zur thermischen Impedanzmessung von istungsmodulen mittels Thermographie

Marcel Marquart (Heiß)
Selective doping for high-efficiency solar cells in a high throughput process by using screen-printable pastes in a co-diffusion step

Yazan Jatkar (Brabec/Berger)
Entwicklung und Evaluierung eines Heizsystems für Pipettenspitzen bei automatisiert flüssig prozessierten Schichten

Julian Haffner-Schirmer (Li)
Influence of post processing on microstructures of advanced organic photovoltaic thin films

Max-Pascal Quast (Heiß/Sytnyk)
Infrared solar cells based on PbS quantum dots

Lukas Heinlein (Wellmann/Arzig)
Korrelation von Größe und Richtung von Wachstumsstufen während der Kristallisation von SiC mit Prozessparametern

Jonas Ihle (Wellmann)
Präparation von TaC-Beschichtungen auf Graphit für die Anwendung in der Hochtemperatur-Kristallzüchtung

Michael Kellner (Wellmann)
Untersuchung der Phasenbildung von $BaZrS_3$ *mithilfe der Dynamischen Differenzkalorimetrie und der Thermogravimetrischen Analyse*

Johannes Köhler (Wellmann)
Untersuchung des Einflusses von Stapelfehlern auf den Ladungsträgertransport in kubischen SiC-Halbleiterscheiben

Theresa Nemeth (Wellmann)
Bestimmung der Versetzungsdichte auf SiC-Halbleiterscheiben mithilfe von KOH-Defektätzen und computerbasierter Bildanalyse

David Tran (Wellmann)
Characterization of point defects in 3C-SiC using photoluminescence at low temperatures

Rupert Ullmann (Wellmann)
Untersuchung des Punktdefekt-Haushaltes in nominell undotierten und semi-isolierenden SiC- Halbleiterscheiben

Büsra Yesilbas (Wellmann)
Einfluss des Inertgas-Druckes während des Gasphasenwachstums von 4H-SiC Einkristallen auf die strukturellen Eigenschaften von Halbleiterscheiben

6. Doctoral Theses

Doctoral Theses in Preparation

Ali, Amjad (Batentschuk, i-MEET)
Developement of phosphors for light conversion in solar panels

Arzig, Matthias (Wellman, i-MEET)
Untersuchung der Wachstumskinetik von SiC mithilfe der in-situ Computertomographie des Gasphasenkristallisationsprozesses und der Modellierung der Wachstumsbedingungen

Berger, Christian (Brabec, ZAE)
IT systems and infrastructure for the world wide materials genome

Carigiet, Fabian (Brabec, Zürcher Hochschule für Angewandte Wissenschaften)
AC PV-Modul: Kontaktlose Stromübertragung von PV-Modulen ins Stromnetz

Classen, Andrej (Brabec, i-MEET)
Investigation of factors limiting the performance of organic solar cells

Darwish, Elshaimaa (Batentschuk, i-MEET)
Fabrication of perovskite nanostructure for optoelectronic applications

Daum, Manuel (Heumüller / Brabec, i-MEET)
Nanoparticle based processes and structures for organic solar cells

Deumel, Sarah (Heiß, i-MEET)
Metall-organische Perowskite für direktkonvertierende Röntgendetektoren

Doll, Bernd (Brabec/Peters, ZAE)
High Throughput Luminescence Methods for outdoor Photovoltaic characterisation

Dong, Lirong (Egelhaaf, i-MEET)
Interface engineering for the perovskite devices

Elia, Jack (Batentschuk/Brabec, i-MEET)
Liquid Phase Epitaxy of Perovskite-Halides and Garnets

Elsayed, Hany (Heiß, i-MEET)
Lasers based on Organo-Metal-Halide Perovskites

Feroze, Sarmad (Egelhaaf, ZAE)
Building Integrated Organic Photovoltaics

Freund, Tim (Wellmann, i-MEET)
Phase Formation and Synthesis of Chalkogenide Perovskite Thin Films

Garcia Cerrillo, José (Brabec/Egelhaaf, i-MEET)
Fabrication of multication-, mixed halide-perovskite/silicon tandem solar cells by partial processing in air

Haffner-Schirmer, Julian (Egelhaaf, i-MEET)
Development of a pump-probe based inline inspection method for printed photovoltaics

He, Yakun (Li/Brabec, i-MEET)
Stability and photophysics investigation of single component material organic solar cells

Hu, Huiying (Brabec/Osvet, i-MEET)
Engineering robust and stable perovskite based light converting composites as required for large area lighting or display applications

Hübner, Tobias (Brabec, OSRAM Opto Semiconductors GmbH)
Tintenstrahldrucken von Indium-Phosphid basierten Quantepunkt-Leuchtdioden

Ihle, Jonas (Wellmann, i-MEET)
Semi-insulating and high-purity SiC

Jang, DongJu (Egelhaaf, ZAE)
In situ approaching on perovskite crystallization

Kalancha, Violetta (Forberich, i-MEET)
Investigation of Hybrid Silver Nanowire Electrodes

Karl, André (Brabec/Osvet, i-MEET)
Imaging of artificial defects in organic solar cells / Bildgebende Defekterkennung artifiziell eingebrachter Defekte in organischen Solarzellen

Killilea, Niall (Heiß, i-MEET)
Inkjet printed phototransistors

Kollmuß, Manuel (Wellmann, i-MEET)
Sublimationsepitaxie von kubischen Siliziumkarbid "bulk" Material mit 100 mm Durchmesser

Kong, Mengqin (Brabec/ Batentschuk, i-MEET)
Design and fabrication of high-efficiency transparent luminescent solar concentrator for smart window application

Köhler, Johannes (Wellmann, i-MEET)
CVD crystal growth of 3C-SiC thin films for optical waveguides

Kupfer, Christian (Brabec, i-MEET)
Development of a high-throughput-capable method for fabricating, characterizing and processing of novel semiconducting perovskite materials

Langner, Stefan (Stubhan, i-MEET)
Ink formulation and high-throughput experimentation in organic photovoltaics

Liu, Chao (Li/Brabec, i-MEET)
Interfacial engineering for organic solar cells

Mashkov, Oleksandr (Heiß, i-MEET)
Pigment Nanocrystals for Energy and Energy Saving Applications

Meng, Wei (Brabec/Li, i-MEET)
Interface engineering for high-efficiency perovskite solar cells

Mohsun, Mohammed Kasim (Egelhaaf, i-MEET)
Printed barriers for the encapsulation of printed organic

Qiu, Shudi (Egelhaaf, i-MEET)
In-situ monitoring of perovskite film formation

Rehm, Viktor (Heiß, i-MEET)
Solution Procesed Ferroelectrics in Photovoltaic Devices

Schöler, Michael (Wellmann, i-MEET)
Dotierung und Charakterisierung von 3C-SiC

Steiner, Johannes (Wellmann, i-MEET)
Quantitative characterization and prediction of dislocation behavior in high-purity SiC

Steinberger, Marc (Egelhaaf/Distler, ZAE)
Inkjetprinting of Photovoltaic modules

Tam, Kai Cheong (Brabec, ZAE)
Ink-jet printing on organic imaging device

These, Albert (Brabec, i-MEET)
Defect Engineering in Perovskites

Tian, Jingjing (Brabec/Li, i-MEET)
Development of highly efficient and stable wide bandgap inverted all-inorganic perovskite solar cells for tandem applications

Wang, Rong (Brabec/Li, i-MEET)
Efficient bilayer solar cells by spreading transfer on aqueous substrate

Wachsmuth, Josua (Egelhaaf/Distler, ZAE)
Solution-Processed HTL-Layers for NFA-based Organic Solar Cells

Weitz, Paul (Brabec/ Heumüller, ZAE)
Design and characterization of nanoparticle based organic solar cells

Wortmann, Jonas (Brabec, ZAE)
Spectral Imaging in Organic and Perovskite Solar Cells

Xu, Junyi (Brabec/ Heumüller, i-MEET)
Organic nanoparticles as the transport layer for solar cells

Xie, Zhiqiang (Brabec/ Osvet, i-MEET)
Aerosol printed perovskite memristors for neuromorphic computing

YousefiAmir, AminAbbas (Heiß, i-MEET)
Inkjet printed Nanocrystal Detectors

Zhang, Heyi (Brabec/Li/Osvet, i-MEET)
Solution Growth of Crystalline Perovskite Layers for Optoelectronics

Zhang, Jiyun (Brabec/Hauch, i-MEET)
Synthesis of Functional Photovoltaic Materials by a Robot Based High Throughput Approach

Zhang, Kaicheng (Brabec/Li, i-MEET)
Development and Characterization of Novel Interfaces for Organic and Perovskite Solar Cells

7. Doctoral Theses Completed

07.02.2020
Chen Xie (Brabec, i-MEET)
Water/alcohol-based nanoparticle inks for organic photovoltaics

18.05.2020
Hermann Bechert (Brabec, i-MEET)
Flexible and highly segmented OLEDs for automotive applications

19.06.2020
Osbel Almora Rodríguez (Brabec, i-MEET)
Hysteresis and Capacitive Features of Perovskite Solar Cells

21.07.2020
Johannes Hepp (Brabec, i-MEET)
Development of visualization and quantification techniques of local material failures in PV

8. Awards

Congratulations to Ening for winning the Doctoral Prize for the best young female researcher of the Faculty of Technology @ FAU

Just before leaving i-MEET Ening received the great news that she has won the doctoral prize for the best young female researcher of the faculty. Ening investigated in her thesis the fundamentals of solvent complexation of perovskites and resolved a major scientific challenge by a mixed high-throughput and knowledge driven strategy. Her studies revealed the role and functionality of antisolvent during crystallization and were only recently published in Joule this year. Ening is the 2nd i-MEET student receiving this prestigious award after Derya in 2015. In between, Derya is full professor at KAUST. In this spirit I wish Ening a similarly successful scientific career

Congratulations to Yakun on winning the "SAOT Student Award 2020"!

Yakun has won the SAOT Student Award 2020 in the topic "Optical Materials and Systems" for her work "Evidencing Excellent Thermal- and Photostability for Single-Component Organic Solar Cells with Inherently Built-In Microstructure" published in "Advanced Energy Materials".

The article presents a systematical research on the stability of single component organic solar cells. Stability issue is the core restriction for the development and application of organic solar cells (OSCs). The single-component concept, enabled by the covalently-bonded structure with the donor and acceptor in one molecule, presents attractive advantages such as considerable simple and reproducible device fabrication. In this work, we for the first time systematically investigate the stability of single-component organic solar cells (SCOSCs) and the corresponding dynamic mechanisms. Impressively, the SCOSCs remain substantially stable under 160 °C for over 400 hours. Moreover, SCOSCs exhibit almost unchanged performance under 90 °C and light illumination bi-pressure after 1000 hours aging. This is the highest stability reported up to date for OSCs. Due to the exceptional circumstances caused by the ongoing COVID-19 crisis, the SAOT Student and Innovation Awards 2020 were presented online this year.

COMMUNICATION

Organic Solar Cells

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Evidencing Excellent Thermal- and Photostability for Single-Component Organic Solar Cells with Inherently Built-In Microstructure

Yakun He, Thomas Heumüller, Wenbin Lai, Guitao Feng, Andrej Classen, Xiaoyan Du, Chao Liu, Weiwei Li, Ning Li, and Christoph J. Brabec**

Solution-processed organic solar cells (OSCs) are promising low-cost, flexible, portable renewable sources for future energy supply. The state-of-the-art OSCs are typically fabricated from a bulk-heterojunction (BHJ) active layer containing well-mixed donor and acceptor molecules in the nanometer regime. However, BHJ solar cells suffer from stability problems caused by the severe morphological changes upon thermal or illumination stress. In comparison, single-component organic solar cells (SCOSCs) based on a double-cable conjugated polymer with a covalently stabilized microstructure is suggested to be a key strategy for superior long-term stability. Here, the thermal- and photostability of SCOSCs based on a model double-cable polymer is systematically investigated. It is encouraging to find that under 90 °C & 1 sun illumination, the performance of SCOSCs remains substantially stable. Transport measurements show that charge generation and recombination (lifetime and recombination order) hardly change during the aging process. Particularly, the SCOSCs exhibit ultrahigh long-term thermal stability with 100% PCE remaining after heating at temperature up to 160 °C for over 400 h, indicating an excellent candidate for extremely rugged applications.

As one of the most promising renewable energy sources, photovoltaics (PV) is widely deployed for daily use and for industrial applications. It is generally acknowledged that outdoor applications, such as building- and automotive-integrated photovoltaics are very attractive for a future renewable energy scenario. However, these scenarios require solar cells with an exceptional high temperature tolerance, since the surface of a dark-colored car or building wall can easily approach and surpass 90 °C in summer.[1,2] To fulfill these requirements, mounted solar cells need to work sustainably and stably at 90 °C under illumination. Conventional inorganic solar cells, such as silicon or GaAs, can work properly at the required high temperatures.[3] However, the traditional solar cells are not fully compatible with future building- and automotive-integrated applications.

Presently, several research groups have reported power conversion efficiencies (PCEs) of over 14% for lab-scale bulk-heterojunction (BHJ) organic solar cells (OSCs), indicating a significant step toward commercialization.[4–6] The BHJ concept involves interpenetrating networks of donor and acceptor materials forming domains of dimensions commensurate with the exciton diffusion length in the nanometer regime. However, this requires careful and exquisite optimization of the multiple experimental variables involved in material design and device fabrication. For example, relative concentrations of donor and acceptor materials, ink design, film-processing conditions, or the introduction of additives have to be considered for device

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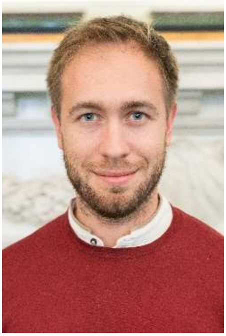
Congratulations to Nicola for being invited to the World Economic Forum Young Scientists class 2020



Nicola finished his PhD at i-MEET in 2017 and we all at i-MEET still have the best memories on him. After working 2 years at KAUST on OPV with Derya, Nicola has joined Imperial College to work on a novel topic – the artificial retina. Just now Nicola has been named World Economic Forum Young Scientists for the class of 2020. Nicola is developing novel technologies to treat severe and incurable vision problems caused by degeneration of the retina, which affects almost 200 million people worldwide.

EU PVSEC 2020 – Bernd Doll wins Student Award

With his contribution "Contactless Outdoor Photoluminescence of Silicon Photovoltaic Modules With Large Area Excitation Source" Bernd Doll, FAU PhD student and guest researcher at HI ERN in the group High Throughput Characterization and Modeling has won one of the Student Awards at the "EU PVSEC 2020"!

During the 5-day online event with 1500 participants from more than 60 countries there were 850 live presentations. With the Outdoor Photoluminescence Setup presented by Bernd Doll it is possible to measure large area photovoltaic modules without contact. This is of particular benefit for reliable energy production of solar parks. The results show that the throughput can be improved compared to electroluminescence by avoiding electrical contact without loss of information.

Daniel Castillo honoured with the award from the Colombian council of chemical engineers

Congratulations to Daniel for winning the national prize for the best post-grad thesis in chemical engineering in Colombia, which was awarded by the national council of chemical engineers. Daniel performed a significant part of his Master thesis in 2019 at i-MEET under the supervision of Thomas (Dr. Thomas Heumüller) This is marvelous news, and I am grateful to Daniel and his supervisor to enable this research sabbatical. I wish Daniel all the best for his future career and hope he will continue the academic career path as successful as he started it!

VII Premio Nacional al Mejor Trabajo de Posgrado en Ingeniería Química 2020

Consejo Profesional de Ingeniería Química de Colombia

El Consejo Profesional de Ingeniería Química de Colombia

otorga el VII Premio Nacional al Mejor Trabajo de Posgrado en Ingeniería Química 2020, al ingeniero

DANIEL CASTILLO BENDECK,

por su trabajo: "Study of the Merged Annealing method to establish a reproducible fabrication protocol for perovskite solar cells with competitive efficiencies"

Según Resolución No. DFP-08-2020

I.Q. Jeffrey León Pulido
Presidente

I.Q. Jackson Fernando Mosos Patiño
Secretario

Se entrega el presente reconocimiento a los veintisiete (27) días del mes de noviembre de 2020
Bogotá D.C., Colombia

For the eighth time in a row Christoph is recognised as Highly Cited Researcher

Each year, Clarivate identifies the world’s most influential researchers ─ the select few who have been most frequently cited by their peers over the last decade. In 2020, fewer than 6,200, or about 0.1%, of the world’s researchers, in 21 research fields and across multiple fields, have earned this exclusive distinction. A nomination for this research award requires the production of multiple highly-cited papers that rank in the top 1% by citations for the respective field and year in Web of Science. 6 researchers from FAU have won this prestigious distinction in 2020, among them two from the department of materials science, Prof Patrik Schmuki and Prof. Christoph J. Brabec, who the awards in the categories “cross field” respectively “materials science”. Both are long time awardees in Clarivate´s list of the “Most Influential Researchers” or “High Cited Researchers” for several years.

2020 Recipients

	FULL NAME	CATEGORY	PRIMARY AFFILIATION	SECONDARY AFFILIATIONS	
SA	Achenbach, Stephan	Clinical Medicine	University of Erlangen ...	-	View Profile
CB	Brabec, Christoph J.	Materials Science	University of Erlangen ...	-	View Profile
NF	Neurath, Markus F.	Cross-Field	University of Erlangen ...	Johannes Gutenberg ...	Claim profile
SG	Schett, Georg	Clinical Medicine	University of Erlangen ...	-	Claim profile
PS	Schmuki, Patrik	Cross-Field	University of Erlangen ...	King Abdulaziz Univers...	View Profile
RS	Schober, Robert	Computer Science	University of Erlangen ...	-	View Profile

Elshaimaa Darwish received DAAD research grant funding for obtaining PhD degree in 2020 and **Ning Li** was awarded from Journal of Materials Chemistry Emerging Investigators, RSC

9. Publications

(Full Papers and Conference Proceedings)

Full Papers

Osbel Almora, Derya Baran, Guillermo C. Bazan, Christian Berger, Carlos I. Cabrera, Kylie R. Catchpole, Sule Erten-Ela, Fei Guo, Jens Hauch, Anita W. Y. Ho-Baillie, T. Jesper Jacobsson, Rene A. J. Janssen, Thomas Kirchartz, Nikos Kopidakis, Yongfang Li, Maria A. Loi, Richard R. Lunt, Xavier Mathew, Michael D. McGehee, Jie Min, David B. Mitzi, Mohammad K. Nazeeruddin, Jenny Nelson, Ana F. Nogueira, Ulrich W. Paetzold, Nam-Gyu Park, Barry P. Rand, Uwe Rau, Henry J. Snaith, Eva Unger, Lídice Vaillant-Roca, Hin-Lap Yip, and Christoph J. Brabec
Device Performance of Emerging Photovoltaic Materials (Version 1)
Advanced Energy Materials, in press, Article number 2002774, 2020
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Sebastian Lucas, Jochen Kammerer, Martin Pfannmöller, Rasmus R. Schröder, Yakun He, Ning Li, Christoph J. Brabec, Tim Leydecker, Paolo Samorì, Tomasz Marszalek, Wojchiech Pisula, Elena Mena-Osteritz, and Peter Bäuerle
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DOI: 10.1002/solr.202000653

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Unraveling the influence of non-fullerene acceptor molecular packing on photovoltaic performance of organic solar cells
Nature Communications, ***11****, Article number 6005,2020*
DOI: 10.1038/s41467-020-19853-z

Zhengwei Xu, Yicheng Zhao, Jiyun Zhang, Keqiu Chen, Christoph J. Brabec, and Yexin Feng
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Physical Review Materials, ***4(9)****, Article number 95401,2020*
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Andreas Distler, Christoph J. Brabec, Hans-Joachim Egelhaaf
Organic photovoltaic modules with new world record efficiencies
Progress in Photovoltaics: Research and Applications, ***in press****, 2020*
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Tobias Hübner, Christoph J. Brabec, Britta Göötz, Norwin von Malm
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Proceedings of SPIE - The International Society for Optical Engineering, 11365, 2020
DOI: 10.1117/12.2552910

Fu Yang, Lirong Dong, Dongju Jang, Kai Cheong Tam, Kaicheng Zhang, Ning Li, Fei Guo, Cong Li, Charline Arrive, Mélanie Bertrand, Christoph J. Brabec, and Hans-Joachim Egelhaaf
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10. Presentations at Conferences, Workshops, Events

Almora Rodríguez, Osbel

17.09.2020
PEROSEE Helmholtz Workshop, online
Talk: *Reporting Device Performance of Emerging Photovoltaic Materials*

Brabec, Christoph J.

09-14.02.2020
3rd Joint GSMS/SFB953 Winter School, Kirchberg/Tyrol, Austria
Invited talk: *Automated Material Innovation*

27.02.2020
21st International Winterschool on New Developments in Solid State Physics, Mauterndorf, Austria
Invited talk: *Solution processed crystalline perovskites for advanced opto-electronic applications*

29.05.2020
12th Conference on Hybrid and Organic Photovoltaics, HOPV20 Online Conference
Invited talk: *What Limits Efficiency in Organic Solar Cells at Negligible Energy Level Offsets?*

17.07.2020
Solar Innovation 2020 – Advances and Challenges in Perovksite Solar Cells Online Conference
Invited talk: *Towards Stable and Fully Printed Perovskites: Overcoming Remaining Hurdles by High-Throughput Experimentation*

13-17.09.2020
The 6th International Fall School on Organic Electronics (IFSOE) – 2020, Moscow, Russian Federation
Talk: *Resolving long time challenges in emerging photovoltaics with autonomous self-driven labs*

17-18.09.2020
PE-CDT/CPE Annual Symposium
Talk: *Plenary talk*

17-22.10.2020
NanoGe Fall Meeting 2020, Barcelona, Spain
Plenary Talk: *What is OPV missing towards a GW technology*

01-04.11.2020
6th International Conference on Electronic Materials and Nanotechnology for Green Environment (ENGE 2020)
Keynote Talk: *Material Strategies to Accelerate Printed Photovoltaics Towards a GW Technology*

03-05.11.2020
2nd International School on Hybrid, Organic and Perovskite Photovoltaics (HOPE-PV 2020)
Talk: *Amanda line 1: Resolving long time challenges in organic photovoltaics*

27.11-04.12.2020
MRS Meeting 2020
Talk: *Amanda - a platform to accelerate materials discovery*

Carigiet, Fabian

09.2020
37th European Photovoltaic Solar Energy Conference and Exhibition (37th EUPVSEC), online
Poster: *Comparison of Long-Term Indoor and Outdoor Performance Measurement Techniques of Crystalline Silicon PV Modules to Validate Annual Degradation*

Doll, Bernd

10.09.2020
37th European Photovoltaic Solar Energy Conference and Exhibition, 2020
Talk: *Contactless outdoor photoluminescence of silicon photovoltaic modules with large area excitation source*
Talk: *The value of efficiency*

Dong, Lirong

14-18.09.2020
Helmholtz Perovksite Workshop, online, 2020
Talk: *Scalable printing perovskite solar cells based on air flow and vacuum assisted quenching methods*

Feroze, Sarmad

26-27.10.2020
15th Conference on Advanced Building Skins 2020, Bern, Switzerland
Talk: *Printed semi-transparent and multi-colored PV modules for BIPV applications*

10.12.2020
EnCN Jahreskonferenz 2020, online
Talk: *Outdoor Monitoring of OPV Modules*

Heiß, Wolfgang

23.10.2020
NanoGe Fall Meeting – Symposium: Infrared Nanocrystals, online, 2020
Invited talk: *PbS nanocrystal growth and overgrowth by thiourea precursors*

Hübner, Tobias

06-10.04.2020
SPIE Photonics Europe Digital Forum, online, 2020
Talk: *Inkjet printing of multiple layers for large-scale, cadmium-free electroluminescent quantum dot light-emitting diodes*

Kalancha, Violetta

14.05.2020
GRK evening 1896, online
Talk: *Highly conductive and environmentally stable transparent Silver Nanowire electrode*

18.06.2020
GRK 1896, online
Tutorial: *Silver nanowires: Synthesis technologies and growth mechanism*

Li, Ning

28.01.2020
Research School of Engineering, Australian National University, Canberra, Australia
Invited talk: *Innovative architecture design for high performance perovskite-based tandem solar cells*

01.04.2020
School of Materials Science and Engineering, Xi'an Jiaotong University, online
Invited talk: *Stability of Organic Solar Cells: From Fullerene to Non-fullerene Acceptors*

18.08.2020
Graduate International School, Zhengzhou University, online
Invited talk: *Printable Photovoltaic Technology – An Important Part of the Internet of Things Era*

14-18.09.2020
PEROSEED PV-Seminar for Helmholtz Institutions, online
Invited talk: *Developing efficient and stable all-inorganic perovskite solar cells for multi-junction applications*

24.10.2020
Sino-German Young Scholars Forum on Nano Energy and Optoelectronic Technology, online
Invited talk: *Printable organic photovoltaic devices and their stability*

22 – 25.11.2020
The First Young Materials Scientist Forum of Beijing Advanced Forum, online
Talk: *Stability of Organic Solar Cells: From Fullerene to Non-fullerene Acceptors*

Langner, Stefan

16.09.2020
Peroseed Workshop 2020, online
Talk: *Robot-Based Screening of Antisolvents and their Relevance on the Perovskite Formation Process*

Mashkov, Oleksandr

10.12.2020
EnCN Jahreskonferenz 2020, online
Talk: *High-Throughput screening of Prussian Blue water-based inks for electrochromic smart windows*

These, Albert

10.12.2020
PEROSEED PV Seminar, online
Talk: *Additive Manufacturing of Semiconducting Perovskites: the relevance of process induced defects*

Wellmann, Peter

22-26.09.2020
SICE Annual Conference 2020 (SICE 2020), online
Invited Lecture: *The bulk growth of 3C-SiC: different approaches*

27.11 – 04.12.2020
MRS Fall Meeting 2020, online
Invited talk: *Tailoring of defect centers in 3C-SiC for potential application in quantum information in-situ during sublimation epitaxial growth*

Yang, Fu

15.09.2020
PEROSEED PV-Seminar for Helmholtz Institutions, online
Talk: *Fully Printable Highly Efficient Carbon Electrode Planar Perovskite Solar Modules*

09.12.2020
NGSE5 conference, online
Talk: *Fully Printable Highly Efficient Perovskite Devices*

10.12.2020
EnCN Annual Conference, online
Talk: *Fully Printable Highly Efficient Carbon Electrode Planar Perovskite Solar Modules*

11. Seminar Presentations

22.01.2020
Bernd Doll, (annual PhD report)
High throughput outdoor luminescence method for defect detection on large area photovoltaic modules
Patrick Scharpf, (Bachelor Thesis, supervisor PD Dr. Batentschuk/Dr. Sytnyk)
Entwicklung einer Methode zur Herstellung eines quaternären Core-Shell Systems aus den Bestandteilen Zn, In, Ag, S als lumineszierende Nanopartikel für die Beschichtung von Solarzellen

29.01.2020
Lena Merz, (Bachelor Thesis, supervisor Dr. Egelhaaf)
Druckbare dielektrische Spiegel und ihre Anwendung in der organischen Photovoltaik
Fabian Magerl, (Bachelor Thesis, supervisor Dr. Brabec)
Development of a new drop-casting method for high throughput experimentation of organic photovoltaics
Nils Sprengel, (Bachelor Thesis, supervisor PD Dr. Batentschuk)
Degradationsstudie zyklischer mechanischer Belastung von PV-Modulen bei 4-punkt-Befestigung

05.02.2020
Leonor Shala, (Bachelor Thesis, supervisor Dr. Matt, PD Dr. Batentschuk)
Process Development of molten Perovskite-Layers
Manuel Daum, (Master Thesis, supervisor Prof. Dr. Heiß)
Auf Bismut basierende Halogenide und Perovksite zur direkten Röntgendetektion
Janus Thelemann, (Bachelor Thesis, supervisor PD Dr. Batentschuk)
Einfluss von Flourid-Flussmittel und Fluorid-Dotierungen auf die Effizienz

07.02.2020
Chen Xie, (Doctoral examination)
Water/alcohol-based nanoparticle inks for organic photovoltaics

12.02.2020
Felix Hilpert, (Master Thesis, supervisor Prof. Dr. Heiß)
Aufbau eines Hallmessplatzes zur Untersuchung von Ladungstransferdotierung in Nanokristallinen Schichten
Dr. Carolin M. Sutter-Fella, (Guest talk, Chemical Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, California, USA)
Multimodal in situ monitoring of halide perovskite synthesis

26.02.2020
Julius Wiegand, (Bachelor Thesis, supervisor Prof. Dr. Brabec)
Electrical Characterization of Organic Solar Cells Degradation with and without 1,8-Diiodooctane Influence

Lorena Dhamo, (Guest talk, PhD candidate at the Division Biophotonics, Federal Institute for Materials Research and Testing (BAM), Berlin)
$AgInS_2/ZnS$ QDs: Synthesis: Optical Properties and Application as Luminescent Solar Concentrators

<u>22.04.2020</u>
Markus Mühlhäußer, (Bachelor Thesis, supervisor. PD Dr. Egelhaaf)
Fabrication of perovskite solar cells with carbon electrodes from commercial inks using scalable printing techniques
Christian Schneider, (Bachelor Thesis, supervisor. Prof. Dr. Brabec)
Development of a simulation tool and algorithms for the optimization of automated pipetting processes

<u>29.04.2020</u>
Fatima Akhundova, (Master Thesis, supervisor. Prof. Dr. Brabec)
Optimization of V_{OC} losses in wide-bandgap hybrid organic-inorganic mixed halide perovskite solar cells
Fabian Rau, (Master Thesis, supervisor. Prof. Dr. Heiß)
Entwicklung und Evaluation eines Versuchsaufbaus zur thermischen Impedanzmessung von istungsmodulen mittels Thermographie

<u>13.05.2020</u>
Marcel Marquart, (Master Thesis, supervisor. Prof. Dr. Heiß)
Selective doping for high-efficiency solar cells in a high throughput process by using screen-printable pastes in a co-diffusion step

<u>18.05.2020</u>
Hermann Bechert, (Doctoral examination)
Flexibel and highly segmented OLEDs for automotive applications

<u>03.06.2020</u>
Jacqueline Steinhoff, (Bachelor Thesis, supervisor. Prof Dr. Brabec, Berger)
Evaluierung eines Machine Learning Algorithmus für die autonome Prozessoptimierung in der Hochdurchsatzforschung

<u>10.06.2020</u>
Simon Zapf, (Bachelor Thesis, supervisor. Prof Dr. Brabec, PD Dr. Egelhaaf)
High throughput measurements: The potential of developing new OPV-cells by means of slot die coating on a roll-to-roll machine

<u>21.07.2020</u>
Johannes Hepp, (Doctoral examination)
Development of visualization and quantification techniques of local material failures in PV

22.07.2020

Dr. Junsheng Luo, (Guest talk, State Key Laboratory of Electronic Thin Films and Integrated Devices, University of Electronic Science and Technology of China (UESTC))
Research on Key Materials and Properties of Perovskite Solar Cells

29.07.2020

Patrick Lodes, (Bachelor thesis, supervisors: Felix Hoga, PD Dr. Hans-Joachim Egelhaaf, Prof. Dr. Christoph Pflaum)
Development and Evaluation of a Hybrid Power Management System for Airships Intended for Infrared Thermographic Inspection of Photovoltaic Plants

Dr. Jihoon Lee
A study on improving the efficiency of organic solar cells by structural modification of the active layer

05.08.2020

Dr. Mariano Campoy Quiles, (Guest talk, Institut de Ciència de Materials de Barcelona (ICMAB-CSIC), Spain)
High throughput investigations in organic solar cells using material libraries based on gradients

12.08.2020

Tobias Hübner (annual PhD report)
Inkjet printing of Indium Phosphide

Dr. Rachel Kurchin, (Guest talk, Carnegie Mellon Mechanical Engineering and Materials Science)
Accelerating Energy Materials Discovery with Computation

19.08.2020

Yazan Jatkar, (Master Thesis, supervisor. Prof Dr. Brabec, Berger)
Entwicklung und Evaluierung eines Heizsystems für Pipettenspitzen bei automatisiert flüssig prozessierten Schichten

Julian Haffner-Schirmer, (Master Thesis, supervisor. Dr. Li)
Influence of post processing on microstructures of advanced organic photovoltaic thin films

09.09.2020

Dr. Ludmilla Steier, (Guest talk, Imperial College London, UK)
Materials Design for Solar Fuel Production

16.09.2020

Simon Arnold, (Bachelor thesis, supervisors: Jerrit Wagner, Prof. Dr. Brabec)
Development and Implementation of a Fully Automated Spin Coating Setup and Evaluation of the Processes

23.09.2020
Albert These, (annual PhD report),
Defect Engineering in Caesium Lead Tribromide Perovskites
Pia Ludwig, (Bachelor thesis, supervisors: Prof. Dr.Wolfgang Heiß, Dr. Claudia Buerhop-Lutz, Bernd Doll, Thilo Winkler)
Investigation of Crack Formation in Monocrystalline Silicon Photovoltaic Modules using Electro- and Photoluminescence measurement
Dr. Shijing Sun, (Guest talk, MIT Photovoltaics Research Laboratory Materials Science)
Towards Autonomous Design of Next-generation Solar Materials

30.09.2020
Ecem Aydan Alkan, (Guest talk, Middle East Technical University, Turkey)
The impact of [1,2,5]chalcogenazolo[3,4,f]-benzo[1,2,3]triazole structure on the optoelectronic properties of conjugated polymers

07.10.2020
Lena Bayer, (Bachelor thesis, supervisors: Prof. Dr. Christoph Brabec, Dr. Claudia Buerhop-Lutz)
Performanceanalyse von 72-Zellen-PV-Modulen unter zyklischer mechanischer Belastung
Dr. Fei Ye, (Guest talk, University of North Carolina at Chapel Hill, US)
Scalable fabrication of high-quality hybrid perovskite films by solvent-free soft-cover deposition

11.11.2020
Sven Strüber, (Kernfachseminarvortrag)
Highly crystalline organic light emitting diode under high current density operation

18.11.2020
Rong Wang, (annual PhD report),
Exploring the polymer donor aggregation influence on optoelectronic properties on organic bilayer solar cells

25.11.2020
Violetta Kalancha, (annual PhD report),
Highly Conductive and Environmentally Stable Transparent Silver Nanowire Electrodes

02.12.2020
Lilian Vogl, (Guest talk, FAU, WW9),
Correlative in situ microscopy: A nanowire study

16.12.2020
Christian Kupfer, (annual PhD report),
Towards high-throughput characterization of lead-free perovskites
Max-Pascal Quast, (Master thesis, supervisor: Prof. Dr.Wolfgang Heiß)
Infrared solar cells based on PbS quantum dots

23.12.2020

Max Bibrack, (Bachelor thesis, supervisors: Prof. Dr. Christoph Brabec, Dr. Thomas Heumüller)

Processing of Organic Photovoltaic Devices via Liquid-Substrate-Transfer-Method

Guest Talks 2020

12.02.2020
Dr. Carolin M. Sutter-Fella, (Chemical Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, California, USA)
Multimodal in situ monitoring of halide perovskite synthesis

26.02.2020
Lorena Dhamo, (PhD candidate at the Division Biophotonics, Federal Institute for Materials Research and Testing (BAM), Berlin)
$AgInS_2$/ZnS QDs: Synthesis: Optical Properties and Application as Luminescent Solar Concentrators

22.07.2020
Dr. Junsheng Luo, (State Key Laboratory of Electronic Thin Films and Integrated Devices, University of Electronic Science and Technology of China (UESTC))
Research on Key Materials and Properties of Perovskite Solar Cells

05.08.2020
Dr. Mariano Campoy Quiles, (Institut de Ciència de Materials de Barcelona (ICMAB-CSIC), Spain)
High throughput investigations in organic solar cells using material libraries based on gradients

12.08.2020
Dr. Rachel Kurchin, (Carnegie Mellon Mechanical Engineering and Materials Science)
Accelerating Energy Materials Discovery with Computation

09.09.2020
Dr. Ludmilla Steier, (Imperial College London, UK)
Materials Design for Solar Fuel Production

23.09.2020
Dr. Shijing Sun, (MIT Photovoltaics Research Laboratory Materials Science)
Towards Autonomous Design of Next-generation Solar Materials

30.09.2020
Ecem Aydan Alkan, (Middle East Technical University, Turkey)
The impact of [1,2,5]chalcogenazolo[3,4,f]-benzo[1,2,3]triazole structure on the optoelectronic properties of conjugated polymers

07.10.2020
Dr. Fei Ye, (University of North Carolina at Chapel Hill, US)
Scalable fabrication of high-quality hybrid perovskite films by solvent-free soft-cover deposition

02.12.2020
Lilian Vogl, (FAU, WW9),
Correlative in situ microscopy: A nanowire study

12. Conferences organized by Members of the Institute

Brabec, Christoph

20.07.2020
Mini Symposium on Charge Transport in Disordered Semicondcutors (at the occasion of Dr. Matt´s farewell)
Location: Erlangen

7-9.12.2020
Conference (Full name): The 5th International Conference on Next Generation Solar Energy (NGSE5)
Location: online conference

Li, Ning

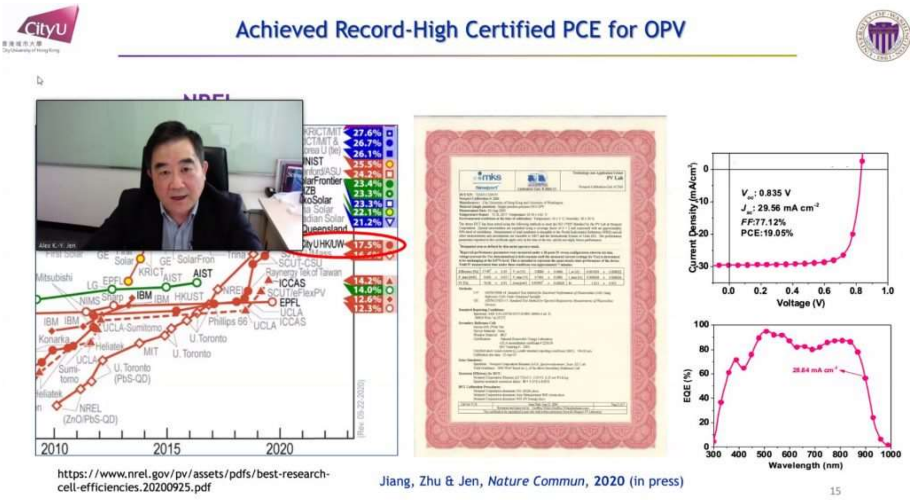
7-9.12.2020
Conference (Full name): The 5th International Conference on Next Generation Solar Energy (NGSE5)
Location: online conference

The 5th International Conference on Next Generation Solar Energy (NGSE5)

Opening-slide NGSE5

The 5th International Conference on Next Generation Solar Energy (NGSE5) was held from 7th – 9th of December 2020 in close collaboration between the Friedrich-Alexander University Erlangen-Nuremberg (FAU), the Helmholtz Institute Erlangen-Nuremberg for Renewable Energies (HI ERN), the South China University of Technology (SCUT), the Erlangen Graduate School of Excellence in Optical Technologies (SAOT) and the International Research Training Group "Energy Conversion Systems: From Materials to Devices" (IGK 2495). The conference was "hybrid" – with both digital participation via video conferencing and with on-site presence. The conference concept introduced the topic "Next Generation Solar Energy" with a series of 50 min tutorials. A series of 15 min long impulse lectures on current results and trends complemented the concept. The NGSE5 was kicked off with a short greeting by Prof. Brabec. The first day featured two great Tutorials with an average of ca. 210 participants

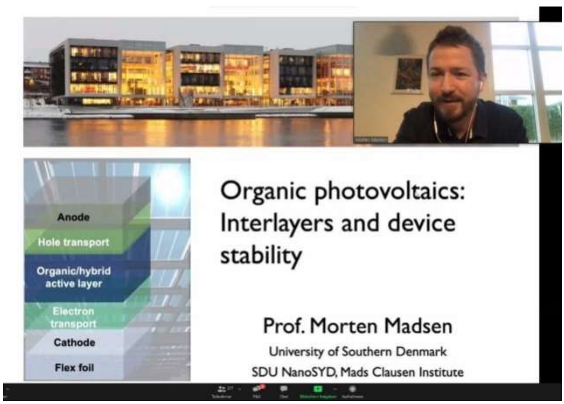
The second tutorial session of the NGSE5 was started out by Prof. Alex K.-Y. Jen from the City University of Hongkong. Prof. Jen is a pioneer in the design of Donor-Acceptor Molecules which helped pushing OPV efficiencies in the past few years. In his tutorial he gave an introduction into materials design & engineering for emerging PV technologies.

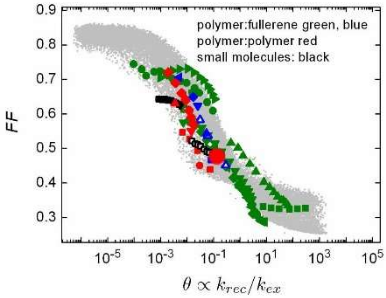


Prof. Jen showing OPV device with initial Efficiency of 19.05%

In his session Prof. Jen showed first device data for an OPV cell with an initial efficiency of 19.05% (certified at 17.45%)! According to Prof. Jen 20% is within reach! In the second part of his lecture Prof. Jen focussed on advances in interface materials for Perovskites. Particular attention is paid to Metal organic frameworks with the ability to significantly stabilize Perovskite solar cells by trapping lead ions.

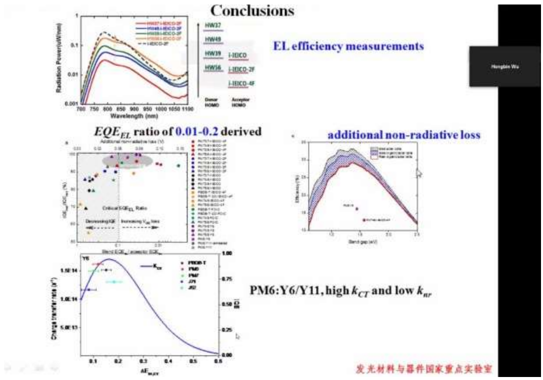
After Prof. Jen's inspiring talk on materials design Prof. Morten Madsen from the Mads Clausen Institute at the University of Southern Denmark gave a great review on stability of organic solar cells by detailing various aging mechanisms of all layers in OPV. Surprising results presented for example was the stabilization of the burn-in by adding β-Carotine (yes – you find it in carrots) as an additive, since it is able to quench singlest Oxygen.

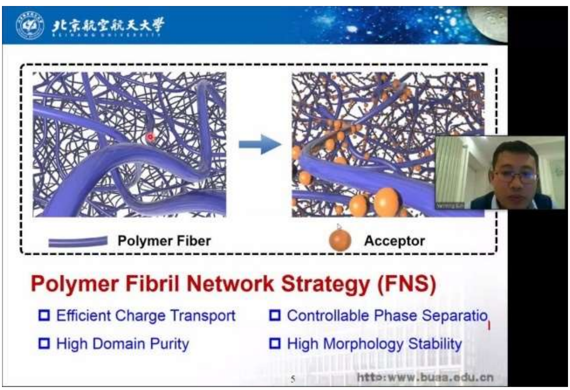




The third tutorial of the morning was given by Prof. Jan Anton Koster from the University of Groningen on simulation and modelling in OPV and Perovskite solar cells. Prof. Koster gave a great introduction into the background and the challenges of simulating these somewhat complicated devices. Prof. Koster shared many insights into the difficulties of comparing simulation and experiments from the simulation point of view. His lecture made it quite clear how both disciplines benefit from each other!

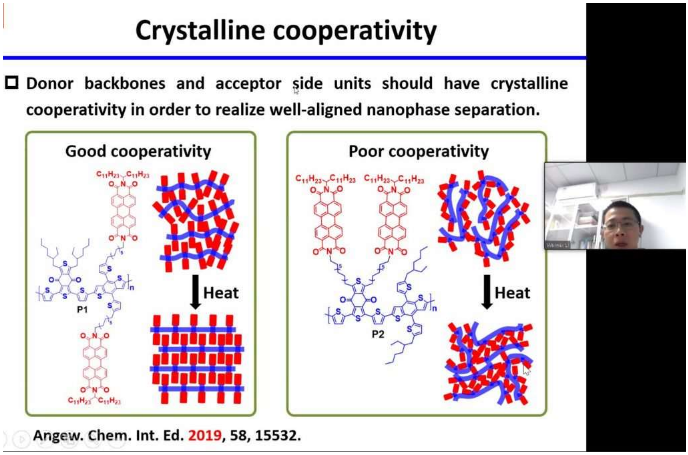
Hongbin Wun reported on loss mechanisms in high performance polymer solar cells, demonstrating the advances that have been made with modern non-fullerene acceptors and donor-acceptor molecules in his presentation titled "Assessing efficiency of photoinduced charge separation between electron donor/acceptor interface in organic solar cells by quantifying radiative proportion method"



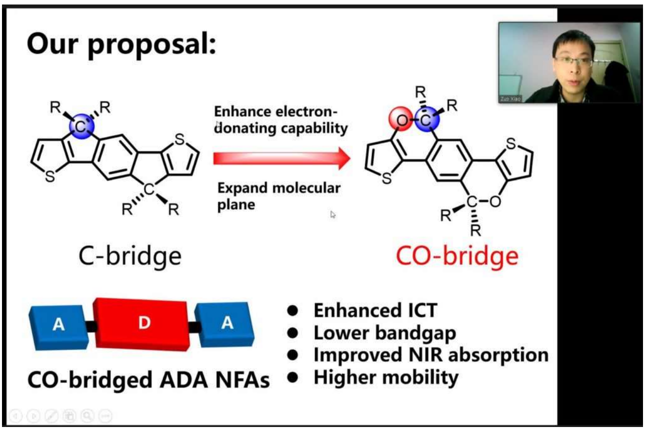


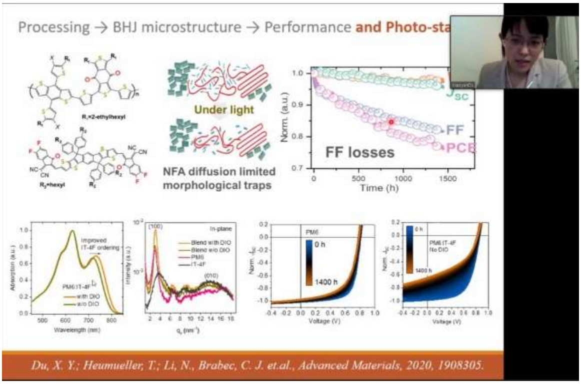
In his contribution Yanming Sun presented detailed analysis of the morphology of polymer fibrils for high efficiency solar cells. Prof. Sun demonstrated nicely the role that Fibril morphology plays in achieving super high Fill Factors of up to 80.5% in OPV.

Prof. Weiwei Li reported on his achievements in improving single material solar cells made with double-cable conjugated polymers. Good cooperativity, achieved with both highly coordinating side units as well as backbones is very important to achieve good performance up to 8.4%.

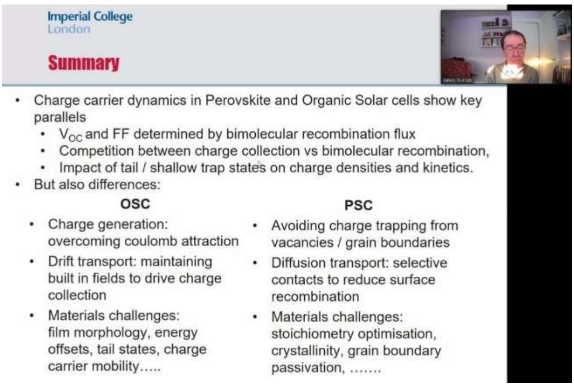


In the first talk of the second Hot Topics Session Prof. Zuo Xiao reviewed the development of non-fullerene acceptors and polymer donors towards the current certified record OPV cells with efficiencies >18% in a single junction. For the donors the most promising materials are fused ring polymers. With D18:Y6 the efficiency could be pushed beyond 18% with <87% EQE in the maximum.

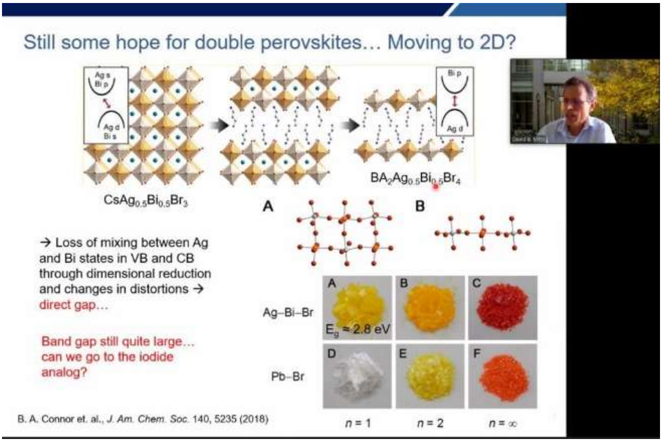




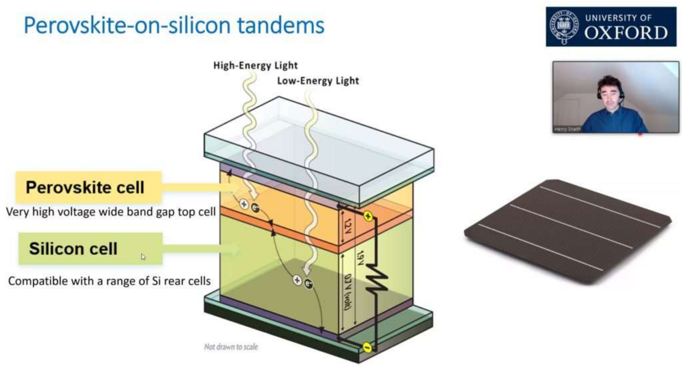
Dr. Xiaoyan Du from the Helmholtz Institute Erlangen-Nuremberg reported on her work combining Automation together with Machine learning in order to investigate the effect of molecular engineering on photostability in her talk titled “Elucidating the full potential of OPV materials with AMANDA and machine learning”. To do this she investigated a large number of cell variations based on PM6:Y6 and analyzed their performance in efficiency and stability with Gaussian Process Regression.



In the last contribution of the session Prof. James Durrant compared the charge carrier dynamics between OPV and Perovskite solar cells. He finds a number of similarities, while also pointing out key differences.

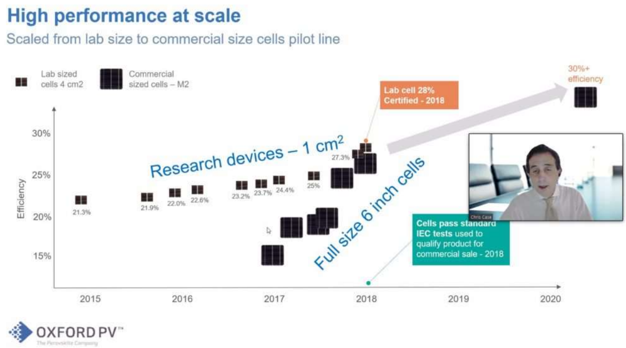


The next session started out by Prof. David Mitzi from Duke University with a detailed review of the Perovskite structure, its properties and means of manipulating them by changing the composition and manufacturing methods. With his detailed investigations Prof. Mitzi showed the amazing spectrum of properties that can be imprinted and engineered in this astonishing family of compounds.



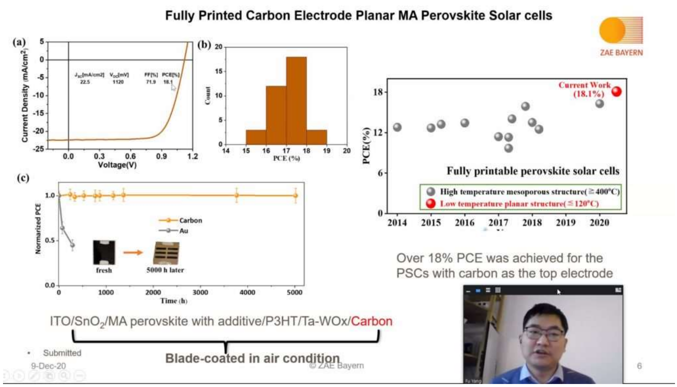
The fourth tutorial session at the NGSE4 was kicked off by Henri Snaith from the University of Oxford with a great introductory lecture. Prof. Snaith lectured on the basics and the development of Perovskite materials for PV-applications leading up to the design of Si/PSK-Tandem Solar cells, ending with insights into the mechanisms for degradation and stability for perovskites. In the end Prof. Snaith shared some new results of imaging Perovskite with TEM with surprising detail.

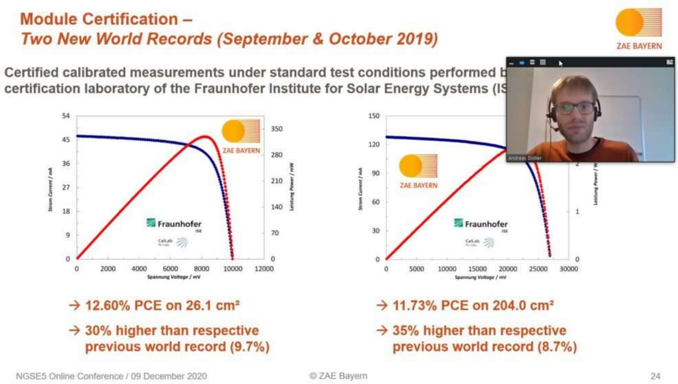
Dr. Chris Case, CTO of Oxford PV, followed the lecture by Prof. Snaith with a great overview on the challenges of upscaling a new technology like Si/PSK Tandems to a commercial scale, as well as the string of achievements Oxford PV has made towards this goal. By focusing on adding an additional layer of perovskite on a standard Si-Wafer they have been able to scale up very fast by using much existing technology.



A further talk on upscaling perovskite production was provided by Bin Fan from GCL Nano. Bin Fan began his talk by pointing out the amazing progress in PSk-Stability that has been achieved. He also pointed out, that a pure PSK-module actually contains less lead than a Si-module. An advantage of scaling PSK is that it is more like scaling a display production, rather than scaling a Si-production. Currently GCL Nano is preparing a 100 MWp line working on 1m by 2m modules. Bin Fan presents calculations showing that a GW-facility for PSK will be more than 3x cheaper than an equivalent facility for Si-modules and 8x cheaper than a CIGS facility. Bin Fan also believes that there are interesting opportunities for voltage matched Si/PSK tandems, as well as pure PSK tandems from a cost perspective.

Dr. Fu Yang from ZAE Bayern presented the upscaling developments for fully printed perovskites for production on Roll-to-Roll equipment. With printed Electrods made from Carbon so far more than 18% efficiency could be achieved in cells with good efficiency. The technology was also scaled to modules with 16.9% efficiency.



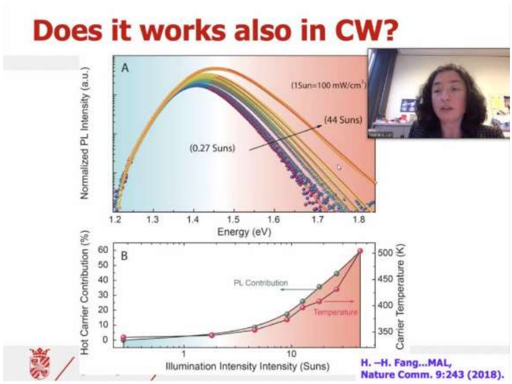


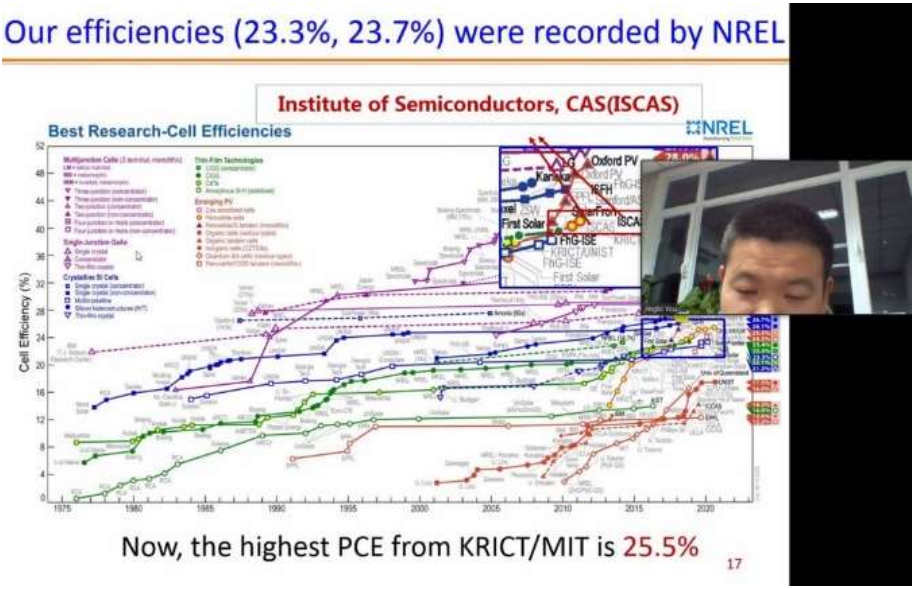
Dr. Andreas Distler followed by describing the results of the production group for OPV modules at ZAE Bayern. In his presentation he started in by pointing out how losses accumulate when going from lab-to-fab for a flexible module. The largest share of the losses comes from a change of substrate. Beyond that Dr. Distler detailed the process for making a record OPV-Module with 12.6%.

In the next Tutorial of the session Jonas Bergquist from Epishine was outlining their approach to the market for applications of OPV. Epishine is focussing on indoor IOT products, mainly for wireless connected sensors. Epishine has developed a custom production process for OPV based on lamination in order to make the parallel resistance as large as possible to achieve best possible indoor performance. The final presentation in the tutorial sessions was given by Gang Bao the CTO of Advanced Solar Tech. He gave an introduction to the use of CdTe in BIPV applications. Advanced Solar Tech is a manufacturer of CdTe Modules and is capable of manufacturing both opaque and semitransparent ones. Gang Bao presents an impressive portfolio of buildings which utilize their modules to achieve stunning architecture while still producing energy from seamlessly integrated, semitransparent of colored modules.

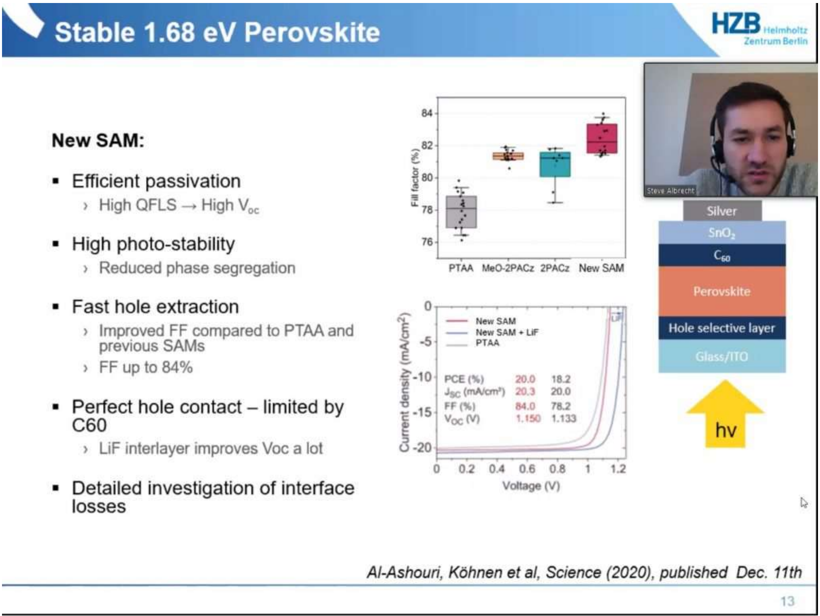
Example of Building Integration of CdTe by Advanced Solar Power

The first contribution in Hot Topics Session 3 session was from Maria Antonietta Loi, Professor of Photophysics and Optoelectronics at Groningen University with a talk on "Sn-based perovskites from hot electrons to device performances". Hot electrons are an intriguing idea for exceeding the Shockley-Queisser limit. In her work she has been able to identify hot-carriers in Sn-based PSKs and finds that the lifetime is extremely long.



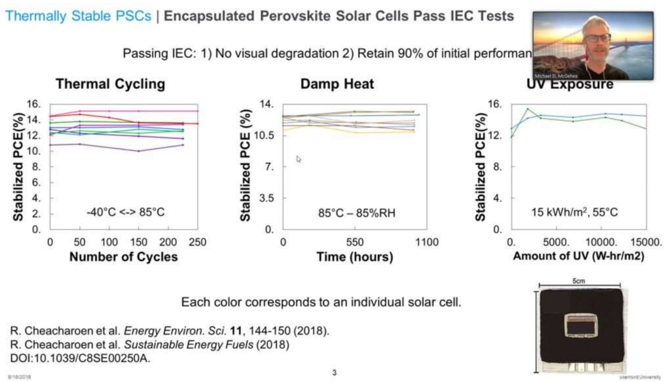


Prof. Jingbi You from the the Institute of semiconductors of the chinese academy of sciences have shown efficient perovskite solar cells with various bandgaps. In his work Prof. You has found that organic salts have big impact in preventing recombination at the surface of the PSK-layer. This has helped to push the Efficiencies of single junction narrow bandgab PSKs beyond 23%. In wide bandgap PSKs even more than 25% have been achieved. For inorganic PSKs >20% have been achieved.



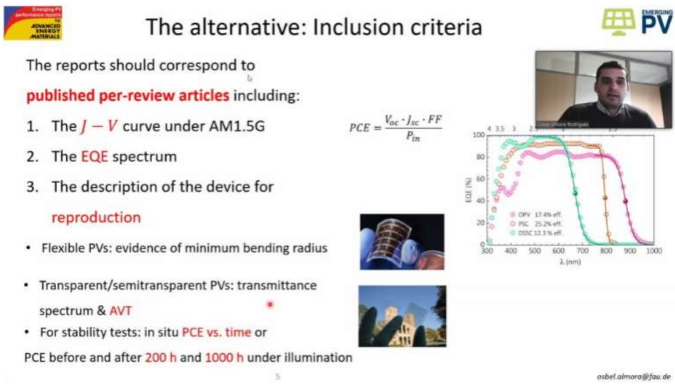
Steve Albrecht on the effect of a novel SAM

Steve Albrecht, head of a young investigator group at the Helmholtz Center Berlin reported on Perovskite-based tandem solar cells: towards 30% efficiency. The breakeven point of Perovskites with Si has been reached. PSK cells are more efficient than the best Si-cells. Prof. Albrecht reports on the work towards the 29.1% record Si/PSK Tandem cells. Also in this work passivation of the PSK Surface played a large role. Here self assembled monolayers were used that were not further specified, but was published on Dec. 11th.



In the plenary Prof. McGehee reports on his progress in making metal halide perovskite solar cells stable. In his labs his group has been able to pass the industry standard ALT tests with Perovskites in a device architecture based on a layer stack of Perovskite/Fullerene/ALD SnO/Sputtered ITO. In his view especially the ALD layer is very important to achieve stability. A second issue Prof. McGeehee was addressing was the reverse biasing of Perovskites, a state that commonly occurs in applications when there is partial shading. Reverse bias is very harmful to PSKs. Part of the reason for this is that PSKs are a form of electrochemical cell, that will lead to reduction of materials and subsequently breakdown. The McGeehee group has developed quite a bit of understanding of the underlying processes of this breakdown, in part through a custom Drift-Diffusion model that accounts for ion mobility.

Osbel Almora Rodriguez introduced the concept of the "Emerging PV Initiative". The goal of the initiative is to compile a database of research cell performance data that is accessible, interactive and up-to-date.



The database is supposed to reflect the status of development of new technologies by putting the performance data together with device details into a database that is continuously updated by the research community.

The new database will offer much more detail than the existing NREL-Efficiency Chart or the PIP-Tables by Martin Green. Also there is no need to have a certified cell, it is sufficient if the cell is published. This means there will be significantly more data. The best cells from the database will be periodically published and summarized in Advanced Energy Materials.

In addition to the publication there is a database accessible online and can be interactively visualized with a variety of plots. The database is available at emerging-pv.org. Some of the data is viewable without logging in. However more sophisticated features are available to contributors that log in with their ORCID ID, and who submit data to the database as Christian Berger from the Helmholtz Institute Erlangen-Nuremberg demonstrates. This feature is open to anyone with an ORCID ID. There is no requirement that the cells that are reported are your own cells. It is also possible to contribute cells from other publications.

Screenshot from the emerging-pv.org website

13. Cooperation in Committees

Batentschuk, Miroslaw

Internship Committee of the Material Department, Friedrich-Alexander University Erlangen-Nürnberg

Study Commission of the Department of Material Science, Friedrich-Alexander University Erlangen-Nürnberg

Brabec, Christoph J.

Activities for the Friedrich-Alexander University Erlangen - Nürnberg (FAU):

Member of the Material Science Department´s Steering Committee

Spokesman of the Material Science Courses, Friedrich-Alexander University Erlangen-Nürnberg

Representative of the Material Science Department in the Faculty´s Commission of Studying

National Activities:

Scientific Director Department Renewable Energies, ZAE Bayern, Erlangen

Member of the EnCN Science Board (Energy Campus Nürnberg)

International Activities:

Honorary Professor at the University of Groningen

Director at the Forschungszentrum Jülich (FZJ) for Highthroughput Methods in Photovoltaics – Helmholtz Institute Erlangen-Nürnberg (HI-ErN)

Member of Scientific Board of the PE graduate school, Imperial College, London

Member of the Scientific Advising Board, CRANN AMBER, Trinity College Dublin, Ireland

Member of the Scientific Board of the International Conference on Organic Electronics (ICOE)

Head of the Organization Board of the Next Generation Solar Energy Conference (NGSE)

Member of two European INFRAIA consortia

Member of the Management Committee Member of 3 GPV School

Services to the Community:

Serving as expert referee for European Community - European Research Council (ERC Awards)

Chairman of the Editorial Board "Advanced Energy Materials", Wiley VCH

Member of the Editorial Board of "Progress in Photovoltaics", Wiley VCH

Member of the Editorial Board of "Emerging Materials Research", ICE publishing

Serving as referee for several funding organizations, among them the Austrian Science Fund (FWF), for the German Research Foundation (DFG), the Baden-

Württemberg Stiftung, and for more than 15 top ranked journals in the field of materials, semiconductors and energy (Nature Family, EES, Advanced Family)

Kalancha, Violetta

Center for Nanoanalysis and Electron Microscopy, GRK1896

Li, Ning

Organizing committee for the 5th NGSE conference, Guangzhou, China & Nürnberg, Germany.
Member of the Editorial Board of "Journal of Semiconductors", IOPscience

Wellmann, Peter

President EMRS
Organizer: Europa-Afrika Zusammenarbeit Materialwissenschaft
Nanosmat Satellite Symposium: Big leaps with nano steps | The European-African Materials Research Exchange (EAMARE) 2019
International Union of Materials Research Societies: Member of the Meetings Commission
Treasurer of Deutsche Gesellschaft für Kristallzüchtung und Kristallwachstum (DGKK e.V.)
Reviewer for Journal of Crystal Growth, Journal of Crystal Growth & Design, Journal of Crystal Research and Technology und Journal of Thin Solid Films.
Member Editorial board Nature Applied Sciences by Springer

14. Research Projects

Deutsche Forschungsgemeinschaft DFG: MA 6617/1-1
18.06.2018 – 30.06.2021
Bleifreie Perovskite für die Röntendetektion

PV-ZUM – DynaSol, Zentrales Innovationsprogramm Mittelstand
bis 31.07.2020
Transientes Photoelektronisches Messverfahren

China Scholarship Council (China)

CSC grant No. 201206130055
Design and Fabrication of organic solar cells based on solution-processed small molecules (Ke, Lili)

CSC grant:
Gu, Ening
He, Yakun
Liu, Chao
Xie, Chen

Deutsche Forschungsgemeinschaft DFG WE 2107/12-1 (Germany)
01.04.2016 – 31.03.2020
Analyse der Wachstumskinetik während der Hochtemperatur-Kristallzüchtung von SiC unter Anwendung der Computertomographie zur in-situ 3D Visualisierung der Wachstumsphasengrenze

EnCN2 (Germany)
01.01.2017 – 31.12.2021
Erneuerbare EnergieträgerTechnologien im urbanen Umfeld (EET)
Speicher A

EU CHALLENGE 720827
01.01.2017 – 31.12.2020
3C-SiC Hetero-epitaxiALLy grown on silicon compliancE substrates and 3C-SiC substrates for sustaiNable wide-band-Gap powEr devices

Projektträger Jülich 0324154D (Germany)
01.11.2017 – 30.09.2020
Verbundvorhaben: MYCIGS - Energieertragsoptimierte Cu (In,Ga)(S,Se)$_2$-Dünnschichtsolarmodule durch gezielte Steuerung der Ertragsparameter; Teilvorhaben: Materialwissenschaftliche Charakterisierung

PV-ZUM DynoSol (BMWi) (Germany)
01.05.2017 – 30.04.2020

SFB 953 B01 (Germany)
Synthetic Carbon Allotropes

Deutsche Forschungsgemeinschaft DFG (Germany)
2017 –2021
Smarte und Schaltbare Fenster, in collaboration with EnCN

International Research and Training Group GRK 2495, DFG (Germany)
2020 –2025
Solution Processed Ferroelectrics in Photovoltaic Devices

GRK 1896, DFG (Germany)
In situ microscopy with electrons, X-rays and scanning probes

Deutsche Forschungsgemeinschaft DFG-EIN-SBH: AOBJ: 670990 (Germany)
01.10.2020–30.09.2022
Analyse der Wachstumskinetik während der Kristallzüchtung von SiC auf großen Kristalldurchmessern unter Anwendung der µ-Computer-Laminographie zur in-situ 3D Visualisierung der Wachstumsphasengrenze

EU, 8. Rahmenprogramm Horizon 2020, Teilprojekt (899679)
01.10.2020- 30.09.2023
CMOS compatible and ultra broadband on-chip SiC frequency comb (SiComb)

Deutsche Forschungsgemeinschaft DFG: Teilprojekt (399073171) (Germany)
01.01.2020-31.12.2022
IGK 2495: Energy conversion systems: From Materials to Devices, Teilprojekt I: Growth of Single Crystal Transition Metal Perovskite Chalcogenides

Deutsche Forschungsgemeinschaft DFG-EIN-SBH: AOBJ: 646355 (Germany)
01.01.2018-31.12.2021
Quantitative Charakterisierung und Vorhersage von Versetzungsverhalten in hochreinem SiC

Bundesministerium für Wirtschaft und Technologie (BMWi), (ZF4506004RE8) (Germany)
20.12.2018-30.06.2021
Entwicklung eines Wachstumsprozesses für SiC-Wafer mit Durchmessern größer 10cm unter Anwendung der neuen SiC-Quellenmaterialien

Bundesministerium für Wirtschaft und Technologie (BMWi), (0324154D) (Germany)
01.10.2017-30.06.2021
MYCIGS: Energieertragsoptimierte Cu(In,Ga)(S,Se)2-Dünnschichtsolarmodule durch gezielte Steuerung der Ertragsparameter Materialwissenschaftliche Charakterisierung

Leadership in Enabling & Industrial Technologies (LEIT), Teilprojekt (720827)
01.01.2017-30.06.2021
CHALLENGE: 3C-SiC Hetero-epitaxiALLy grown on silicon compliancE substrates and 3C-SiC substrates for sustaiNable wide-band-Gap powEr devices

EU Project 952911 "Booster"
2020-2024
Boost Of Organic Solar Technology for European Radiance

i-PEN Project (EU and Israel)
Photonic Education in Nanotechnology

Deutsche Forschungsgemeinschaft DFG, BR4031/20-1 (Germany)
09.2020 –08.2023
Prozess-Struktur Relationen für die lösungsmittel-basierte organische Photovoltaik

Deutsche Forschungsgemeinschaft DFG, BR4031/20-1 (Germany)
09.2020 –08.2023
Prozess-Struktur Relationen für die lösungsmittel-basierte organische Photovoltaik

European Union's Horizon 2020 research and innovation programme, CITYSOLAR, 101007084
08.2020 –07.2023
Energy harvesting in cities with transparent and highly efficient windowintegratedmulti-junction solar cells

Bundesministerium für Wirtschaft und Technologie (BMWi), (PIASOL, ZF4506012DB9) (Germany)
01.11.2019 –31.10.2021
Integration eines Ladungsträgerlebensdauermessgeräts in eine R2R-Produktionsanlage zur Inline-Qualitätskontrolle für gedruckte Halbleiter

Bundesministerium für Wirtschaft und Technologie (BMWi), (PV-IL, ZF4506011DF9) (Germany)
01.04.2020 –31.03.2022
Entwicklung der Laserparameter für die Inline-Strukturierung von gedruckten Solarmodulen

Bayerisches Staatsministerium für Wissenschaft und Kunst (D7-F5121.3.6.3.4), (Germany)
Solar Technologies go Hybrid (SolTech)

Bayerisches Staatsministerium für Wissenschaft und Kunst (iPV4.0), (Germany)
08.2018 –07.2021
Laboranalyse von Degradationsmechanismen unter beschleunigter Alterung und Entwicklung geeigneter feldtauglicher bildgebender Detektionsverfahren und Entwicklung und Evaluation eines Algorithmus zur Fehlerdetektion und Prognostizierung der Ausfallwahrscheinlichkeit (iPV4.0)

Bayerisches Staatsministerium für Wissenschaft und Kunst (EB1022), (Germany)
01.08.2018 –31.07.2022
Modulanalytik und Fehlerauswertung (optiCIGS_II)

Bundesministerium für Wirtschaft und Technologie (BMWi), (CESSY) (Germany)
01.2018 –06.2020
Entwicklung eines High-End-Solarkollektors mit bisher unerreichtem erhöhtem nutzbarem Temperaturniveau für maximalen Nutzungsgrad der Energie aus dem Sonnenlicht; Auswahl PV-fähiger Materialien, Validierung diverser Befestigungsmöglichkeiten, Fixierung variabler Werte für die Testläufe, Lastfallsimulationen, Prototypenbau (CESSY)

Bundesministerium für Wirtschaft und Technologie (BMWi), (Low Haze Schichten R2R auf Folie) (Germany)
01.2019 –06.2020
Herstellung von Silbernanodrähten mit reduziertem Durchmesser und deren Verwendung in Formulierungen zur Rolle-zu-Rolle Beschichtung von Folien mit den Funktionalitäten transparent, leitfähig und niedrigem Haze (Low Haze Schichten R2R auf Folie)

Bayerisches Staatsministerium für Wissenschaft und Kunst (EnCN EET TP2), (Germany)
2017 –2021
Erneuerbare Energieträger-Technologien "Zerstörungsfreie und bildgebende Analyse" (EnCN EET_TP2)

15. Teaching

Winter Term 2019/2020

Lectures (VORL)

Grundlagen der Halbleiterphysik [GHl], *W. Heiß*

Grundlagen des Kristallwachstums und der Halbleitertechnologie, *P. Wellmann*

Materialien der Elektronik und der Energietechnik [MEET-V], *P. Wellmann*

Materialien und Bauelemente für die Optoelektronik und Energietechnologie: Grundlagen [OpEt-G], *Ch. J. Brabec, G. Matt*
Nano-Bauelemente-Sensoren, MEMS, Micromachining [(NanoDev)], *G. Matt*

Nanospektroskopie [NanoSpek], *W. Heiß, M. Batentschuk*

Photo Physics and Electronic Transport [PhPhys], *H.-J. Egelhaaf*

Photo Physics and Electronic Transport (Extention) [PhPhys_ext], *H.-J. Egelhaaf*

Technische Grundlagen medizinischer Diagnostikverfahren [TGmD], *M. Thoms*

Werkstoffe und Verfahren der medizinischen Diagnostik I [WVmDI], *M. Thoms*

Werkstoffkunde für Studierende der Elektrotechnik (EEI) [Werkstoffk.(ET)], *P. Wellmann*

Exercises and laboratory courses (PR, PJS, SL, UE)

Kernfachpraktikum i-MEET Grundlagen [KFP_G], *M. Batentschuk, A. Osvet*

Lab Work Organic Electronics [OE-Pra-MWT], *Th. Heumüller*

Lab Work Organic Electronics NT [OE-Pra-NT], *N.N.*

Praktikum Materialien der Elektronik und der Energietechnologie (5. Sem.) [PR2-ET], *P. Wellmann*

Nano-Bauelemente-Sensoren, MEMS, Micromachining [(NanoDev)], *G. Matt*

Praktikum Funktionswerkstoffe in der Energietechnologie [FEt-Pra], *P. Wellmann*

Praktikum Nanotechnologie 2 (Master) [NT2-Pra], *W. Heiß, E. Spiecker*

Praktikum Transporteigenschaften in HL [TrEHl-Pra], *A. Osvet*

Praktikum Wahlfach Crystal Growth [WCrGr-Pra], *P. Wellmann*

Praktikum Werkstoffe 2 [PW 2], *M. Batentschuk*

Projektarbeit - Arbeitsgemeinschaft Kristallisation von SiC und CIS [AGK-Sem1], *P. Wellmann*

Projektarbeit -Arbeitsgemeinschaft Organische Photovoltaik [OPV-AG-Sem], *Ch. J. Brabec*

Projektarbeit –Arbeitsgemeinschaft Solution Processed Semiconductors [SPS_AG-Sem], *W. Heiß*

Übung Nano Devices [(ÜbNanoDev)], *N.N.*

Vorbesprechung Masterstudium i-MEET WS 18/19, *M. Batentschuk, Ch. J. Brabec*

Seminars (AWA, SEM, TUT)

Anleitung zur wissenschaftlichen Arbeit [AnwA-F], *K. Forberich*

Anleitung zur wissenschaftlichen Arbeit-E [AnwA], *H.-J. Egelhaaf*

Anleitung zur wissenschaftlichen Arbeit-GM [AnwA], *G. Matt*

eTutorial - Materialien der Elektronik und Energietechnik [eTUT-WET], *P. Wellmann*

eTutorial Werkstoffkunde für EEI [eTUT-WW-EEI], *P. Wellmann*

Kern-/ Nebenfachseminar i-MEET [KF/NF-iMEET-Sem], *Ch. J. Brabec*

Neuere Fragen zu Werkstoffen der Elektronik und Energietechnologie (Lehrstuhl-Seminar) [iMEET-Sem], *Ch. J. Brabec, M. Batentschuk, K. Forberich*

Seminar "Organic Electronics" [OE-Sem2], *A. Osvet*

Seminar on Solar Energy [SolSem], *Ch. J. Brabec, J. Hauch, Ch. Pflaum*

Seminar über "Solution Processed Semiconductors" [SoPS-Sem], *W. Heiß*

Seminar über Bachelor- und Masterarbeiten [BMBr-Sem], *Ch. J. Brabec*

Seminar über Bachelor-, Master und Doktorarbeiten – Crystal Growth [BMD-CG-Sem], *P. Wellmann*

Summer Term 2020

Lectures (VORL)

Devices, *Ch.J. Brabec, Th. Heumüller*

Elektrische, magnetische und optische Eigenschaften - Energietechnik, *W. Heiß*

Elektrische, magnetische, optische Eigenschaften [EMO], *Ch.J. Brabec, M. Batentschuk , W. Heiß*

Elektronische Bauelemente und Materialfragen (Technologie II), *P. Wellmann*

Halbleiter großer Bandlücke, *P. Wellmann*

Halbleitercharakterisierung, *W. Heiß*

Kolloidale Nanokristalle [KNKr], *W. Heiß*

Leuchtstoffe/Phosphors, *M. Batentschuk, A. Winnacker*

Materialien und Bauelemente für die Optoelektronik und Energietechnologie: Anwendung [WET II], *Ch. J. Brabec* , *G. Matt*

Numerische Modellierung des Kristallwachstums mithilfe des Programmpakets COMSOL Multi-Physics [CGL-Comsol], *P. Wellmann*

Thin films: processing, characterization and functionalities, *H.-J. Egelhaaf*

Thin films: processing, characterization and functionalities (Extension), *H.-J. Egelhaaf*

Werkstoffe der Elektronik in der Medizin [WEM-V/Ü], *M. Batentschuk, A. Winnacker*

Werkstoffe und Verfahren der medizinischen Diagnostik II [WVmD II], *M. Thoms*

Exercises and laboratory courses (EX, PJS, PR, UE)

Devices, *Ch.J. Brabec, Th. Heumüller*

Exkursionen, *P. Wellmann*

Kernfachpraktikum I, Werkstoffe der Elektronik und Energietechnologie, *M. Batentschuk*

Kernfachpraktikum II, Wahlfach Organic Electronics, *N.N.*

Lab Work Organic Electronics, *N.N.*

Lab Work Organic Electronics, [OE-Pra-MWT], *K. Forberich, Th. Heumüller*

Materialien und Bauelemente für die Optoelektronik und Energietechnologie: Anwendung [WET II], *Ch. J. Brabec* , *G. Matt*

Numerische Modellierung des Kristallwachstums mithilfe des Programmpakets COMSOL Multi-Physics [CGL-Comsol], *P. Wellmann*

Praktikum Eigenschaften von Leuchtstoffen [PREgsLs], *M. Batentschuk*

Praktikum Wahlfach Crystal Growth [CGr-Pra], *P. Wellmann*

Projektarbeit - Arbeitsgemeinschaft Halbleiter-Prozessierung und gedruckte Elektronik [AG-HL-Solar-Druck], *H.-J. Egelhaaf*

Projektarbeit - Arbeitsgemeinschaft Halbleiterelemente und Solarenergie [AG-HL-Solar], *Ch. J. Brabec, N. Li, A. Osvet*

Projektarbeit - Arbeitsgemeinschaft Kristallisation von SiC und chalkogenen Perowskiten [AG-Kristallisation], *P. Wellmann*

Projektarbeit - Arbeitsgemeinschaft Lösungsprozessierte Halbleiter [AG LP-HL], *W. Heiß*

Projektarbeit - Arbeitsgemeinschaft optische Spektroskopie, Leuchtstoffe, Lichtkonversion und Displays [AG Licht], *A. Osvet, M. Batentschuk*

Seminars (SEM, SL)

Anleitung zur wissenschaftlichen Arbeit - Accelerated lifetime testing of materials and devices [AnwA - Lifetime-Test], *Ch.J. Brabec, Th. Heumüller*

Anleitung zur wissenschaftlichen Arbeit - Devices [AnwA - Dev] [AnwA], *Ch.J. Brabec, N. Li*

Anleitung zur wissenschaftlichen Arbeit - High Throughput Characterisation and Modelling [AnwA - HT-Ch-Mod], *Ch.J. Brabec, M. Peters*

Anleitung zur wissenschaftlichen Arbeit - High Throughput Material and device Research for photovoltaics [AnwA - HT-Mat-Res], *Ch.J. Brabec, J. Hauch*

Anleitung zur wissenschaftlichen Arbeit - Materials for Optoelectronics [AnwA - Materials], *A. Osvet,Ch. J. Brabec, M. Batentschuk*

Anleitung zur wissenschaftlichen Arbeit - Solution Processing of Semiconductors [AnwA-SolPro-SC], *H.-J. Egelhaaf*

Anleitung zur wissenschaftlichen Arbeit- Solution-Processed-Semiconductor-Materials [AnwA- SOPSEM], *W. Heiß*

How to start a company, *Ch. J. Brabec, J. Hauch*

Kernfachseminar, *Ch. J. Brabec, A. Osvet*

Neuere Fragen zu Werkstoffen der Elektronik und Energietechnologie (Lehrstuhl-Seminar) [iMEET-Sem], *Ch. J. Brabec*, *M. Batentschuk, A. Osvet*

Seminar on Solar Energy [SolSem], *Ch. J. Brabec, J. Hauch*

Seminar über Bachelor- und Masterarbeiten, *Ch. J. Brabec*

Seminar über Bachelor- und Masterarbeiten, *W. Heiß*

Seminar über Bachelor- und Masterarbeiten, *P. Wellmann*

Vorbesprechung zum Masterstudium am i-MEET [iMEET-Vb-Ma], *M. Batentschuk, Ch. J. Brabec*, *W. Heiß*, *P. Wellmann*, *H.-J. Egelhaaf*

Winter Term 2020/21

<u>Lectures</u> <u>(VORL)</u>

Advanced Semiconductor Materials - Excited States and Charge Transport in Organic Semiconductors [ASM-ES-ChT-OE], *H.-J. Egelhaaf*, *Ch. J. Brabec*

Advanced Semiconductor Technologies - Materials for Organic Electronics [AST-MatOE], *M. Halik*

Advanced Semiconductors Introduction: Devices & Applications [ASI - D&A], *Ch. J. Brabec*

Advanced Semiconductors Introduction: Fundamentals [ASI - F], *W. Heiß*

Crystal Growth 1 - Fundamentals of Crystal Growth and Semiconductor Technology [CG-1], *P. Wellmann*

Grundlagen der Halbleiterphysik [GHl], *W. Heiß*

Materialien der Elektronik und der Energietechnik [MEET-V], *P. Wellmann*

Materialien und Bauelemente für die Optoelektronik und Energietechnologie: Grundlagen [OpEt-G], *Ch. J. Brabec*

Nanospektroskopie [NanoSpek], *W. Heiß, M. Batentschuk*

Phosphors for Light Conversion in Photovoltaic Devices and LEDs [Ph-PV-LED], *M. Batentschuk*

Photo Physics and Electronic Transport [PhPhys], *H.-J. Egelhaaf*

Photo Physics and Electronic Transport (Extension) [PhPhys_ext], *H.-J. Egelhaaf*

Technische Grundlagen medizinischer Diagnostikverfahren [TGmD], *M. Thoms*

Werkstoffe und Verfahren der medizinischen Diagnostik I [WVmDI], *M. Thoms*

Werkstoffkunde für Studierende der Elektrotechnik (EEI) [Werkstoffk.(ET)], *P. Wellmann*

<u>Exercises and laboratory courses</u> <u>(PR, PJS, SL, UE)</u>

Advanced Semiconductor Technologies - Characterization and Advanced Defect Imaging of PV Modules and Systems [AST-DefIm-PR], *Ch. J. Brabec, J. Hauch*

Advanced Semiconductor Technologies - Manufactoring and Characterization of Phosphors and Dielectric Mirrors [AST-PhosMirr-PR], *M. Batentschuk*

Advanced Semiconductor Technologies - Photovoltaic Systems for Power Generation - Design Implementation and Characterization [AST-PVS-Design], *Ch. J. Brabec, J. Hauch*

Advanced Semiconductor Technologies - Synthesis of Carbon Quantum Dots [AST-QD], *W. Heiß*

Crystal Growth - Lab Work 1 Crystal Growth, *P. Wellmann*

Crystal Growth - Lab Work 2 Semiconductor Technology, *P. Wellmann*

Lab Work Characterization and Advanced Defect Imaging of PV Modules and Systems [LW - Ch&Im], *A. Osvet, J. Hauch*

Lab Work Organic Electronics [OE-Pra-MWT], *Th. Heumüller*

Lab Work Organic Electronics NT [OE-Pra-NT], *N.N.*

Lab Work Solution Processed Electronics [LW-SP-El], *A. Osvet*

Praktikum Materialien der Elektronik und der Energietechnologie (5.Sem.) [PR2-ET], *P. Wellmann*

Nano-Bauelemente-Sensoren, MEMS, Micromachining [(NanoDev)], *O. Kasian*

Praktikum Funktionswerkstoffe in der Energietechnologie [FEt-Pra], *P. Wellmann*

Praktikum Nanotechnologie 2 (Master) [NT2-Pra], *W. Heiß, E. Spiecker*

Praktikum Transporteigenschaften in HL [TrEHl-Pra], *A. Osvet*

Praktikum Wahlfach Crystal Growth [WCrGr-Pra], *P. Wellmann*

Praktikum Werkstoffe 2 [PW 2], *M. Batentschuk*

Projektarbeit - Arbeitsgemeinschaft Kristallisation von SiC und CIS [AGK-Sem1], *P. Wellmann*

Projektarbeit -Arbeitsgemeinschaft Organische Photovoltaik [OPV-AG-Sem], *Ch. J. Brabec*

Projektarbeit –Arbeitsgemeinschaft Solution Processed Semiconductors [SPS_AG-Sem],
W. Heiß

Übung Nano Devices [(ÜbNanoDev)], *N.N.*

Vorbesprechung Masterstudium i-MEET WS 20/21, *Ch. J. Brabec, M. Batentschuk, W. Heiß*, *P. Wellmann*, *H.-J. Egelhaaf, A. Osvet*

Seminars (AWA, SEM, TUT)

Advanced Semiconductor Technologies - Solution Processed Semiconductor Materials [AST-SPS-PR], *W. Heiß*

Anleitung zur wissenschaftlichen Arbeit - Accelerated lifetime testing of materials and devices [AnwA - Lifetime-Test], *Ch.J. Brabec, Th. Heumüller*

Anleitung zur wissenschaftlichen Arbeit - Devices [AnwA - Dev], *Ch.J. Brabec, N. Li*

Anleitung zur wissenschaftlichen Arbeit - High Throughput Characterisation and Modelling [AnwA - HT-Ch-Mod], *Ch.J. Brabec,M. Peters*

Anleitung zur wissenschaftlichen Arbeit - High Throughput Material and device Research for photovoltaics [AnwA - HT-Mat-Res], *Ch.J. Brabec, J. Hauch*

Anleitung zur wissenschaftlichen Arbeit - Materials for Optoelectronics [AnwA - Materials], *A. Osvet, Ch.J. Brabec, M. Batentschuk*

Anleitung zur wissenschaftlichen Arbeit - Solution Processing of Semiconductors [AnwA-SolPro-SC], *H.-J. Egelhaaf*

Anleitung zur wissenschaftlichen Arbeit- Solution-Processed-Semiconductor-Materials [AnwA- SOPSEM], *W. Heiß*

Electronic Materials – Tutorium [EM - Tut], *N. Li, Ch.J. Brabec*

eTutorial - Materialien der Elektronik und Energietechnik (5. Sem) [eTUT-WET], *P. Wellmann*

eTutorial Werkstoffkunde für EEI (1. Sem) [eTUT-WW-EEI], *P. Wellmann*

Kern-/ Nebenfachseminar i-MEET [KF/NF-iMEET-Sem], *Ch. J. Brabec*

Neuere Fragen zu Werkstoffen der Elektronik und Energietechnologie (Lehrstuhl-Seminar) [iMEET-Sem], *Ch. J. Brabec, M. Batentschuk, K. Forberich*

Seminar "Organic Electronics" [OE-Sem2], *A. Osvet.*

Seminar and Conference Participation on Solar Energy [Sem&Conf_SE], *Ch. J. Brabec, N. Li, J. Hauch*

Seminar über "Solution Processed Semiconductors" [SoPS-Sem], *W. Heiß*

Seminar über Bachelor- und Masterarbeiten [BMBr-Sem], *Ch. J. Brabec*

Seminar über Bachelor-, Master und Doktorarbeiten – Crystal Growth [BMD-CG-Sem], *P. Wellmann*

16. Addresses and Maps

Department of Materials Science & Engineering
Materials for Electronics and Energy Technology
Friedrich-Alexander University of Erlangen-Nürnberg
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Highway A3 exit **Tennenlohe**; direction to Erlangen (B4). Follow the signs "**Universität Südgelände".** After junction **"Technische Fakultät"** please follow the map.

By train:
Railway station **Erlangen.**
Bus line No. 287 direction **"Sebaldussiedlung"**. Bus stop **"Technische Fakultät".** 50 meters to a layout plan; search for **"Insitut für Werkstoffwissenschaften"**.

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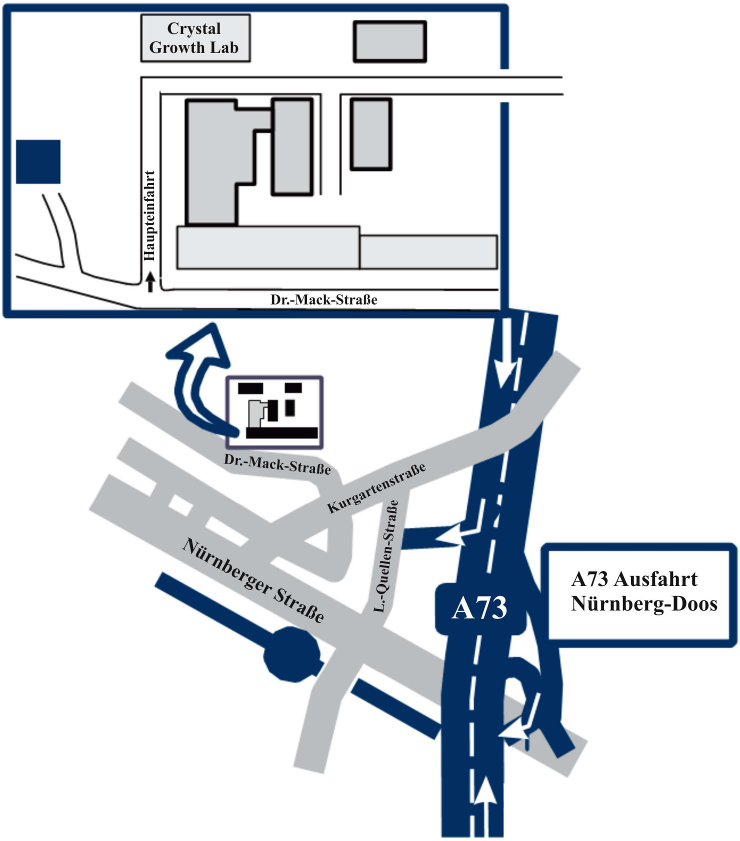
Internet: http://crystals.tf.fau.de



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