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KAUST Solar Center News

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جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology | KAUST SOLAR CENTER

Welcome to our 7th Newsletter!

Frédéric Laquai
Interim Director of KSC
Professor of Applied Physics

It has been a while since the last issue of our Center's Newsletter. We have gone through a period of changes: Our previous Center Director Iain McCulloch has transitioned to a new role at the University of Oxford, and my colleague Stefaan De Wolf and I have assumed the roles of the Center's Interim Associate and Interim Director, respectively.

An important event was the first external review of our Center's past research accomplishments, current research and development projects, educational activities, and Center strategy going forward. I am more than happy to say that it went well, we received a lot of supportive and constructive feedback from our reviewers, and we are now responding with adaptive strategic changes to our Center's research and technology development / translation portfolio, towards our Center's vision:

"To be a leader in research and development of solar energy technologies, translating science into new applications for the benefit of the Kingdom and the world."

Let me now highlight just a few of the Center's most recent activities supporting our Center's mission: "To create new science and technology in the field of solar energy conversion, providing an environment for interdisciplinary research, training and innovation for the benefit of society."

We have recently reported that perovskite solar cells cannot only be very efficient, but also very stable, more precisely, encapsulated perovskite devices passed an industrial stability standard called the damp heat test: less than 5% performance loss over 1000 hours at 85 degrees Celsius and 85% relative humidity. In parallel, the certified efficiencies of our silicon-perovskite tandem solar cells have now gone beyond 28%, an impressive performance achievement. In the area of organic solar cells, we now routinely achieve more than 18%. Our next steps are to progress towards larger area cells and to improve the stability of the devices under real outdoor operating conditions.

A recent highlight of our Center's educational activities was the successful establishment of a joint KSC-SESP (Saudi Electric Services Polytechnic) Photovoltaic (PV) Design School, which equips attendees with the knowledge required to become certified PV designers in the Kingdom upon passing an exam with the Saudi Electric Company (SEC). We are looking forward to the next school in June this year.

Finally, let me welcome Dr. Shadi Fatayer, new faculty in KAUST's Applied Physics program, who has recently joined the KSC. Shadi will work with the Center on the precise determination of energy levels of emerging semiconductors important to understand the processes determining their efficiency, and he adds his expertise of ultra-high resolution scanning tunneling microscopy to the Center's expertise in solid-state physics. Last but not least, we are looking forward to welcoming Professor Martin Heeney to the KSC, who will be joining KAUST and the Chemical Science program in May.

I hope you enjoy reading the 7th edition of our Center's Newsletter!

KSC Principle Investigators

Frédéric Laquai, Interim Director, KSC
Professor of Applied Physics

Stefaan De Wolf, Interim Associate Director, KSC
Associate Professor of Material Science & Physics

Thomas Anthopoulos
Professor of Material Science & Engineering

Derya Baran
Associate Professor of Material Science & Engineering

Shadi Fatayer
Assistant Professor of Applied Physics

Xu Lu
Assistant Professor of Mechanical Engineering

Udo Schwingenschlogl
Professor of Material Science & Engineering

Vincent Tung
Associate Professor of Material Science and Engineering

Iain McCulloch
Adjunct Professor of Chemical Science

Content:
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Cover Image
credit: Eviart from Shutterstock

Second cohort of the KSC-SESP PV Design School: SESP trainer, Muhammad Abbasi, and KSC Interim Director, Frédéric Laquai, (front row, second and third from left respectively) together with participants and members of our lab operations team.

KSC-SESP PV Design School

Saudi Arabia is experiencing vibrant times due to the opportunities afforded by the Kingdom's Vision 2030 which, together with the United Nations Sustainable Development Goals (SDGs), presents a pathway towards a sustainable future for the country. Saudi Arabia aims to reach net-zero emissions by 2060 which is why it is taking strategic measures to ensure access to affordable, reliable, sustainable, and clean energy for all.

Accelarated wide scale use of photovoltaic (PV) technologies for solar energy conversion is at the heart of Vision 2030 and, to achieve the ambitious goals, it is imperative to have a highly skilled and trained workforce that can design, model, optimize, build and analyze photovoltaic systems. KAUST Solar Center (KSC) aims to ensure that the Center's advanced research and technological expertise are shared with the wider regional community, so that the practical implications of this research can be deployed on an industrial scale. Pursuant to this goal, KSC, in collaboration with Saudi Electric Services Polytechnic (SESP), has launched a PV Design School. SESP, an affiliate of the Saudi Electric Company (SEC), is a leading vocational and professional training body within the Kingdom, certified by the King Abdullah City for Atomic and Renewable Energy (KACARE).

The KSC-SESP PV Design School trains early-career Saudi engineers employed in industry and government entities across the Kingdom, qualifying them to work as PV designers in the country's industrial PV sector. This 5-day course, launched in October, on the KAUST campus, facilitated by SESP and KAUST instructors, included classroom lectures combined with hands-on training sessions as well as site and lab tours. In the first session, a total of 20 students received training but, as significant interest was garnered, second and third sessions quickly followed in November and January. The next KSC-SESP PV Design School, scheduled for June, underpins this endeavor as a permanent, successful element of KSC's regional training endeavors.

The course primarily focuses on grid-direct PV systems, the largest and fastest growing segment of the PV industry, but also covers material critical to understanding local standards and regulations. The course is designed to create a fundamental understanding of the core concepts necessary for working with all PV systems, including system components, wiring, site analysis, PV module criteria, mounting solutions,

Course participants receive instruction in KSC's PV Education Laboratory

Saudi Arabia is witnessing vibrant times because of the opportunities bolstered by the Kingdom's Vision 2030.

One of the training sessions during the first KSC-SESP PV Design school being conducted in KAUST's computer training facilities

safety, and commissioning. Students are trained to perform power and energy calculations and load analysis for a grid-direct system, define equipment grounding and system grounding, design grid-connected solar PV (system sizing), describe energy efficiency measures that can be implemented to reduce electricity usage and PV-system size, and identify different types of digital multi-meters and their hazard-free usage. In addition, the course emphasizes how to determine the declination, define azimuth and altitude angle, evaluate the shade-potential for a given site, estimate energy production of a PV-system based on orientation and tilt angle, decipher a balance-of-system equipment specification sheets, and design a residential grid-direct system including the array, inverter, circuit conductors, and over-current protection.

Students' learning is assessed by practical exercises and quizzes which include performing basic Lightning Protection System (LPS) sizing on a grid-direct PV system; PV lab training on how organic, perovskite and silicon solar cells are made; and drafting and submitting project applications and protocols according to Saudi Electric Company standards. The course also includes tours of KAUST Core Labs, where students can observe and experience the state-of-the-art equipment at KAUST, and KAUST's Innovation Hub.

KAUST is a special place that brings together international research talent. In conformity with KSC's vision, the KSC-SESP PV Design School also serves to bring together individuals from diverse educational and professional backgrounds such as electrical engineering, computer engineering, chemical engineering, civil engineering, material sciences, physics, microelectronics, petroleum engineering, and renewable energy systems. The course participants have included graduate students and postdocs from KAUST, current and former students from Effat University, Jeddah; University College London, UK; King Saud University, Riyadh; Virginia Tech University, USA; and University of Colorado, USA. In addition, there were employees affiliated with Energy Care Holding, Jeddah; King Abdulaziz University, Jeddah; Jazlah Water Desalination Company, Al Jubail; and King Abdulaziz City for Science and Technology (KACST), Riyadh.

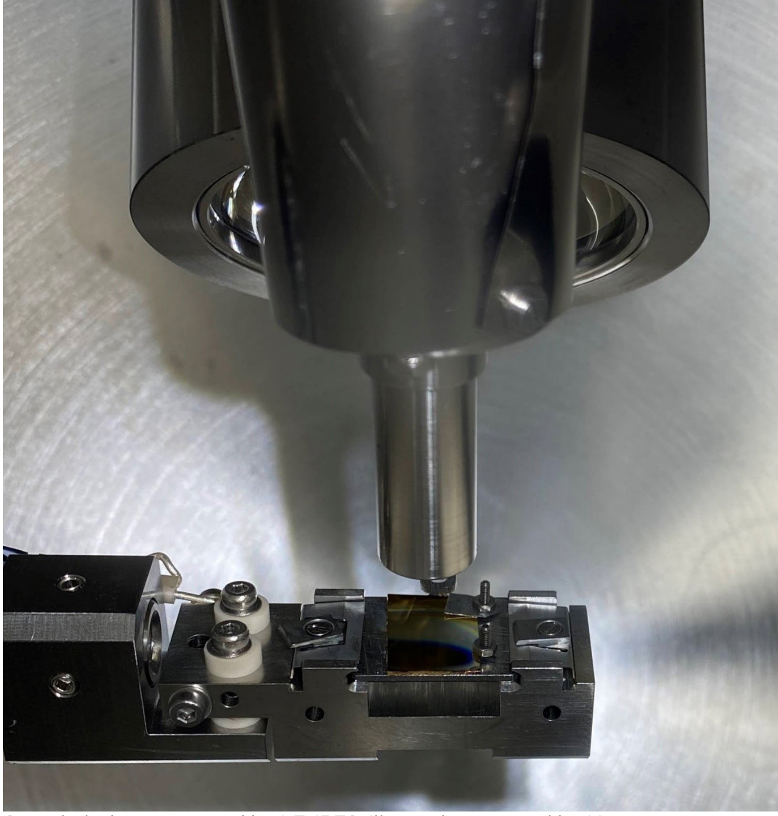
The diverse cohort of participants underscores the significant role that the KSC plays in promoting Kingdom-wide change. Through the development of a multi-disciplinary, highly skilled workforce and knowledge sharing, KSC is proud to support the achievements of Vision 2030 and the United Nations' Sustainable Development Goals.

Course participants from across the Kingdom are contributing towards Vision 2030 and the UN's SDGs for a clean energy future

Feature: KSC Technology

Surface Science Techniques in the KAUST Solar Center

- Craig Combe



Sample being measured by LE-IPES. Illustration created by Heno Hwang (KAUST) and reprinted with permission from DOI:10.1021/acs.chemmater.0c02196.

"Godmadethebulk;thesurfacewas invented by the devil."

(Wolfgang Pauli, Nobel Prize in Physics, 1945)

Recent advances in photovoltaics have produced devices nearing 30% efficiency. This is a result of tandem cell technology, where two solar cells with complementary solar absorption are stacked on top of each other, increasing the amount of the solar spectrum absorbed that can be converted into electricity.

One of the difficulties with tandem solar cells is the high number of layers of different materials that are involved in the stack. Each layer will have its own texture, surface tension, and electrical characteristics that have to align with the neighboring layers to ensure that photo-generated charges can easily flow through the cell. Understanding the many complex interfaces present within the stack is one of the reasons for the efficiency boosts in recent years.

KSC researchers have been developing passivation layers in the form of additives or self-assembled monolayers to improve contact and 'bend' the work function of the layers to improve charge transport. In this case, an accurate analysis of the surface composition and electronic structure/energy levels when the layers are passivated is essential for optimization. Techniques sensitive to the surface (1-10 nm depth) are needed to achieve this. The KSC has an advanced ultra-high vacuum (UHV) cluster where a suite of surface science techniques are used for understanding the layer interactions.
UHV is defined as pressures less than $1.0x10^{-9}$ mbar, with 10^{-10} mbar commonly achieved with a combination of roughing, ion-getter, and turbo pumps. Such high vacuum pressures are required to study material surfaces as the techniques measure surface emitted electrons that would strongly interact and scatter with any gas phase molecules at higher pressure. In addition, surfaces can be prepared in-situ *via* molecular beam epitaxy (MBE) and then maintained without contamination for the duration of the experiment due to the less frequent collision and sticking of molecules in this pressure regime. This is important when the first few nanometers are analyzed, and it can be shown that atmospheric particles quickly deposit on the material forming a carbon over-layer.

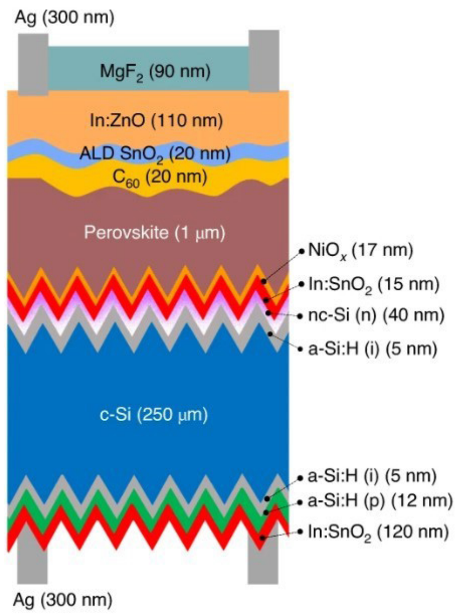


Figure 1. Silicon-Perovskite tandem solar cell stack (de Wolf - Nat Energy 6, 167–175 (2021))

The technique of X-ray photoelectron spectroscopy (XPS) can be employed to analyze the surface chemistry of a material, elemental composition, empirical formula, chemical state and electronic state of the elements within the first 2 – 10 nanometers of a

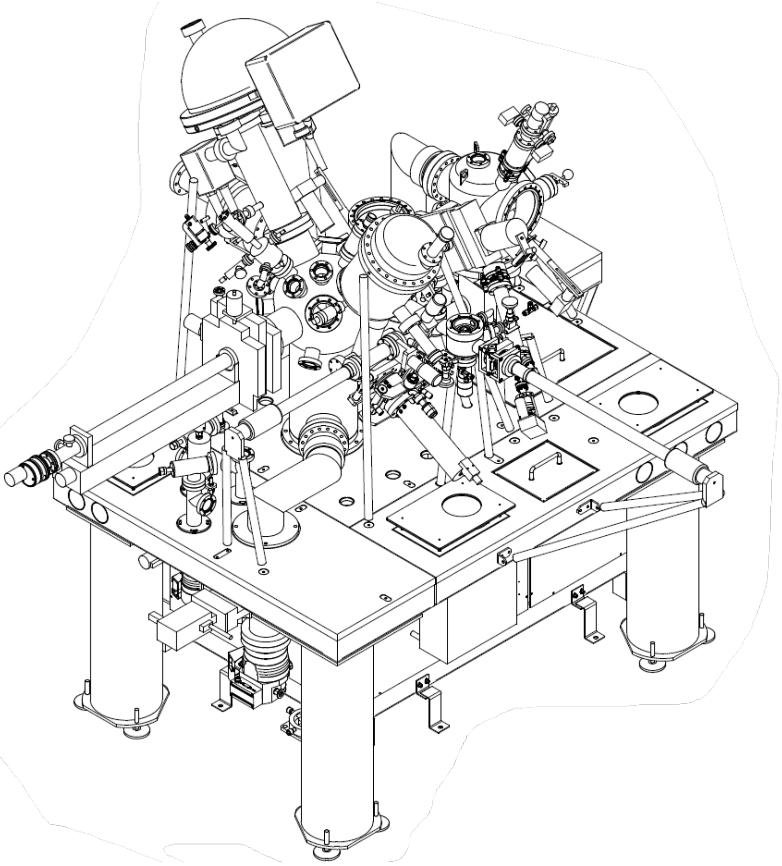


Illustration: Blueprint of the UHV cluster's analytic instrument arrangement

Researchers can use this information to study the electronic effects of their passivation layers and inter-layer energy alignment.

An uncommon capability available on the cluster is low energy inverse photoemission spectroscopy (LE-IPES). This technique operates in the mirror form of those described above; studying the same photoemission process but reversed in time. Whereas the previous techniques excite the material with light and measure the emitted electrons, LE-IPES excites the material with low energy electrons and measures the emitted light. LE-IPES is then used to study the unoccupied electron density from which an edge can be determined and the electron affinity of a material is calculated. A beam of varying, known, and low kinetic energy electrons is directed to the sample and the intensity of the emitted photon as a result of the radiative transition to an unoccupied state is determined. In this energy range the photon emitted in the near-ultraviolet range is detected and the measurement provides a high energy resolution of 0.25 eV, sufficient to map the low-lying, unoccupied molecular orbitals.

material. XPS spectra are obtained by irradiating the surface with a mono-energetic beam of X-ray photons with energies over 1keV while measuring the kinetic energy of electrons that are emitted. These high energy photons are powerful enough to eject the core electrons of an atom. Peaks appear in the spectrum from atoms emitting core electrons of a particular characteristic energy, allowing the surface elements to be identified and quantified from the peaks' energies and intensities. The position of the core level peak is highly sensitive to the chemical bonding environment state of the atom, and, therefore, rich chemical information can be extracted. In addition, the intensity can be quantified and correlated to the atomic percentage of each element and environment present.

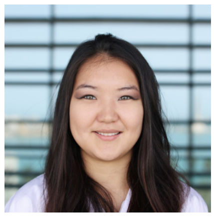
Ultraviolet Photoelectron Spectroscopy (UPS) operates similarly to XPS, the difference being that instead of an X-ray source, it uses the light emitted from a helium plasma discharge in the vacuum ultraviolet range, with photon energies of 21.2 eV. As lower energy photons are used compared to XPS, only valence level electrons can be removed, and hence valence band electronic structure is studied and the surface work function calculated. With an information depth of 1 – 2 nanometers, UPS is a powerful tool for accurately measuring how the work function changes as a result of the surface environment as well as information about chemical bonding at the surface.

The UHV cluster also has an in-situ Scanning Probe Microscopy (SPM) capability so researchers can measure the topography and physical characteristics of their material's surface. Using the same piezo motor, atomic force microscopy (AFM) (qplus) operates by scanning a cantilever over the surface of a material allowing the measurement of size, morphology, texture and roughness. Scanning tunneling microscopy (STM) can also be conducted by means of the measurement of the electron quantum tunneling of an electrical current between the probe tip and the surface. In principal, images can be acquired on an angstrom scale of lateral and vertical resolution in both techniques with a well-defined and suitable surface. This can only be achieved when a sharp termination of a single atom or cluster is present which can drastically alter due to a strong interaction with the surface.

These combined techniques enable KSC researchers to obtain accurate, high quality data to inform their device architecture choices and material design to improve solar cell efficiencies, as well as acquiring basic material and surface knowledge.

Scientists working on the solar cells' fabrication glovebox line in the Photovoltaics Laboratory at the KAUST Solar Center

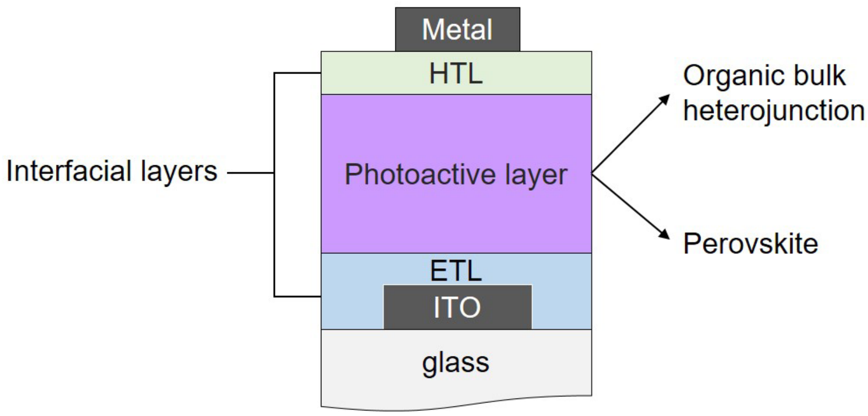
Interface engineering of high-efficiency solar cells — Akmaral Seitkhan


Akmaral Seitkhan

Akmaral Seitkhan has a bachelor's degree in Chemical Engineering from Nazarbayev University, Kazakhstan. In 2021, she obtained her doctoral degree in Materials Science from KAUST Solar Center (KSC) at King Abdullah University of Science and Technology (KAUST) under the supervision of Prof. Thomas Anthopoulos. Currently, she is affiliated with Professor Stefaan De Wolf's research group at the KSC and is working on the up-scaling of silicon/perovskite tandem solar cells.

With the challenges that global warming and increasing world energy demands are bringing into the 21st century, the development and deployment of renewable energy sources are becoming more essential than ever. To date, the most commonly-used and commercialized solar cell technologies (93.6% of the total global market) are silicon-based. Although efficiencies of such solar modules are, at present, only ca. 2% lower than those of the best reported in the laboratories, in 2020, solar energy accounted for only ca. 1% of global energy consumption. With further development and tremendous potential for near-term commercialization, the so-called third-generation photovoltaic technologies, such as organic and perovskite solar cells (OSCs and PSCs, respectively), may provide the much-needed technological solutions in this arena. As compared to various incumbent technologies, both of these emerging ones offer a wide variety of competitive advantages including lightweights, the potential for low production cost due to processing versatility, large-area fabrication, the potential for low environmental impact, and compatibility with inexpensive, flexible, and lightweight substrates. Owing to the extensive research efforts from across the world, reported efficiencies of both these technologies have been improving in recent years at a much faster pace, reaching power conversion efficiencies (PCEs) of 17.6% for organic solar cells and 25.2% for perovskite solar cells. These results have been achieved by simultaneous advancements in organic and perovskite materials' design and synthesis, as well as device and interfacial engineering. As these emerging photovoltaic technologies move closer to commercialization, further improvements in terms of efficiencies and stability of the solar cells are needed. Interfaces in these thin-film solar cells have proven to be of tremendous importance for device performance as well as degradation.

In our research group, considerable efforts are directed towards the development and implementation of innovative functional materials for various optoelectronic applications. One of such applications is the interfacial engineering or the development and



Schematic of the solar cells' architecture

optimization of electron-and hole-transporting layers (ETLs and HTLs, respectively) at the interfaces with the photoactive layer in the emerging photovoltaic devices.

Interfacial layers in both perovskite and organic solar cells serve to play several advantageous roles such as the creation of an Ohmic contact (a non-rectifying electrical junction) at the metal/semiconductor interface, charge selectivity at the respective electrodes, and a physical and/or a chemical barrier between the photoactive materials and electrodes, to name a few. For organic solar cells, optimization of the interfacial layers has been validated as one of the fundamental ways to improve device performance; and in the perovskite photovoltaics field, interfacial processes and their effect on solar cell operation and stability are a topic of rigorous ongoing research. Our research group addresses some of the themes related to interfacial processes in both types of solar cells within the context of cell performance optimization and stability. We explore how careful interface engineering can reduce energy losses in a solar cell thus, boosting its efficiency.

For example, we recently developed a new hybrid electron transporting layer composed of the small molecule Phen-NaDPO and the inorganic molecule tin (II) thiocyanate ($Sn(SCN)_2$). Application of this hybrid ETL to organic solar cells based on the PM6:Y6 active layer was shown to significantly and consistently increase the fill factor (FF) and open-circuit voltage (V_{OC}), culminating in a maximum PCE of 13.5%. It is important to note that the latter value is significantly higher than the maximum PCE of 12.6% measured for control cells based on pristine Phen-NaDPO as the ETL. Combining the hybrid ETL with the best-in-class ternary organic systems and organometal halide perovskite active layers induces similarly impressive PCE enhancements, leading to maximum values of 15.6% and 18.2%, respectively. This remarkable level of improvement was attributed to the reduction of trap-assisted recombination across the photo-active/ETL interface, due to the formation of new energy levels in ETL upon chemical interaction between $Sn(SCN)_2$ and Phen-NaDPO.

In another study, we demonstrated a simple strategy of combining $PC_{60}BM$, aluminum-doped zinc oxide (AZO), and triphenyl-phosphine oxide (TPPO) ETLs to improve perovskite solar cells' performance. Application of this multi-layered ETL was shown to consistently improve all device parameters, reaching a maximum PCE of 19.1% and very high FF of 82% for a methylammonium lead iodide ($MAPI_3$) perovskite solar cells, whilst greatly improving operational stability. We showed that adding AZO and TPPO layers to a fullerene derivative $PC_{60}BM$ results in a more favorable energy alignment in the device owing to the chemical interaction of TPPO with AZO and silver electrodes. This leads to an improvement in the built-in voltage and reduces trap-assisted recombination.

Although organic solar cells and perovskite solar cells have witnessed an impressive rise in efficiency in recent years and show great potential for further improvement, there are still challenges to overcome before they can be successfully commercialized. Interface engineering plays an important role in tackling these challenges; as it can reduce recombination losses and improve the efficiency of both these photovoltaic technologies.

Research Highlight

Designing inks for fully printed solar cells

— Daniel Corzo

Daniel Corzo

Daniel Corzo joined KAUST in September 2017 as a Ph.D. student in the Baran research group. He was already a KAUST alumnus from where he got his Master's degree in Materials Science and Engineering. Before that, he graduated with a Mechanical and Electrical Engineering degree from Tec de Monterrey (ITESM) in Mexico City. His research area focuses on manufacturing engineering of 2D and 3D printed electronics.

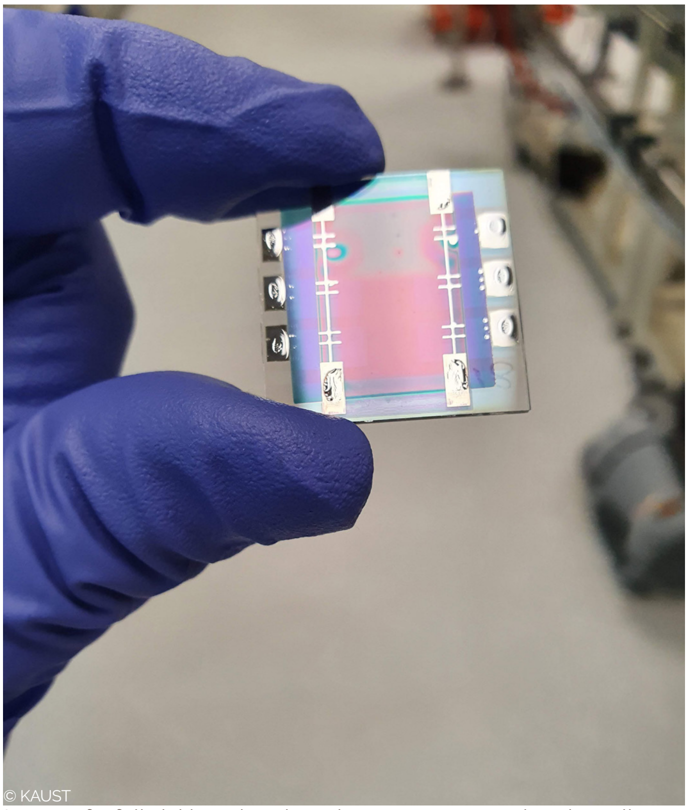


Image of a fully inkjet printed semi transparent organic solar cell based on the PTB7-Th:IEICO-4F blend with an inverted architecture

Organic solar cells (OSCs) have been explored for decades as they offer intrinsic properties such as semitransparency, lightweight, flexibility, and relative ease of processing. [1] They have the potential to be used in building integrated systems, where they can absorb the unwanted UV and NIR wavelengths of light while supporting temperature regulation, improved energy management as well as enhanced plant growth in greenhouse solutions.[2-3] Furthermore, they can also be utilized for microwatt energy harvesting in wearables, lab-on-a-chip devices, and remote -sensing applications, that can take advantage of their flexibility, robustness, and conformability to different substrates.

A significant amount of research work has focused on elevating the performance of OSCs past the 18% mark through the synthesis of novel donor-polymers and non-fullerene acceptor materials (NFAs). These are fundamental studies of film morphology and device physics, and innovations in solution-processed electron and hole transport layers (ETLs & HTLs). [4-5] Nonetheless, a lab-to-fab manufacturing evolution of record-holding photoactive materials from small spin-coated substrates to large area-flexible printed films needs to occur to bridge the gap towards commercialization. There is also an urge to transition the electrodes and transport layers in the solar cell device architecture from difficult-to-scale vacuum deposition techniques, such as thermal evaporation, to solution-based manufacturing, to further reduce the overall production costs.

Inkjet printing is a versatile non-contact technique that can be used for the deposition of the photoactive materials and other functional inks onto desired substrates with full control over the pattern with reduced material consumption. Unlike spin-coating in which the film is defined only by the shear field of the rotation and evaporation of the solvent, the production of high-quality photoactive layers (PALs) and transport

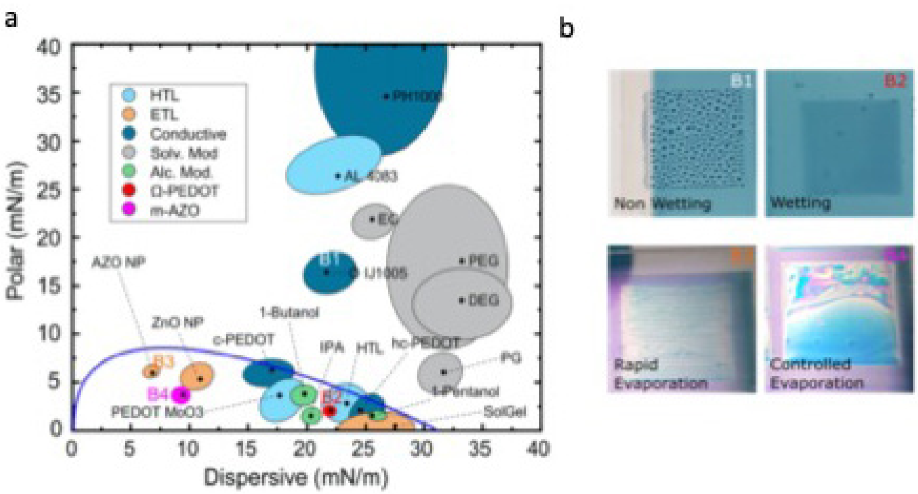


Figure 1.
(a) Wetting envelope of the PTB7-Th:IEICO-4F placed against the surface tension of a few commonly used ETLs and HTLs.
(b) Difference between films made from an ink outside the wetting envelope; within the wetting envelope but with high volatility; and a right formulation with adequate volatility and wetting behavior

layers through printing methodologies depends on the optimization of many factors including viscosity, surface tension, wetting, deposition process parameters, and solvent-drying kinetics.

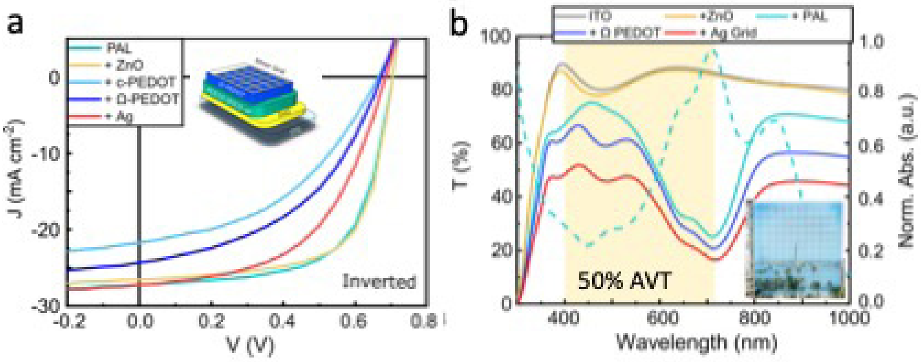


Figure 2. JV curves (a) and UV-Vis NIR transmittance (b) of devices with different numbers of printed layers.

The formation of films through inkjet printing relies on small droplets being ejected from a nozzle, landing at a specific location on a substrate, and then the droplets connecting with each other to form patterns. This can be particularly difficult when dealing with multi-layered devices such as solar cells, especially in connection with transport-layer inks that can coat the highly hydrophobic photoactive layers without damaging them.

Our recent work takes a deeper look at this specific problem from the point of view of formulation of inks and the engineering of surfaces. [6] First, we took advantage of the proven performance of the PTB7-Th: IEICO-4F system and translated it into printable ink by using different solvent combinations that meet the viscosity and volatility specifications for proper jetting. We, then, optimized the printing parameters and fabricated fully working inverted architecture devices with these inks while comparing their performance congruently. The morphology and vertical stratification of the bulk heterojunction (BHJ) are influenced by the solubility of the PAL components in each of the solvents and the way they evaporate after deposition. By measuring the surface energy (SFE) through a contact-angle approach and fingerprinting the polar and dispersive elements of each one of the components, we identified that depending on the ink solvent, the composition at the surface was dominated by the polymer donor in different degrees. Devices made with chloronaphtalene (CN) as an additive demonstrated a more vertically stratified profile which benefited from a favorable charge transport, resulting in higher short circuit current (Jsc) and Fill Factor (FF).

We thus used the SFE approach to build a wetting envelope for the hydrophobic PAL, which served as a guideline to shortlist commonly-used solution-based ETLs and HTLs, and compatible solvent additives that can improve the jetting process and the drying behavior of ink formulations, once deposited. This procedure is key for printing methodologies as proper wetting and optimal volatility can prove to be the difference between discontinuous films with high roughness or uniform functional films.

Based on a performance push-pull strategy, we transitioned each layer of both normal and inverted architectures by optimizing the ink formulation and printing parameters, starting from ZnO and ending with the silver electrode, resulting in fully printed devices with efficiencies over 9.5% (Figure 2). There are many advantages of the ink engineering process, for instance, the higher conductivity of the Ω-PEDOT formulation enabled the production of semitransparent solar cells with Average Visible Transmissivity (AVT) values over 50% and high FF and Jsc values, without the need to fully cover the active area with a silver electrode, which would, otherwise, have damaged the PAL underneath. Lastly, we tested the shelf life of our devices by placing them under normal humidity and temperature. They were able to retain over 90% of their initial performance even after 2 months.

This work is just an example of how the engineering of different printing processes needs to become a fundamental constituent of forefront materials research in order to streamline the production of high-performance devices.

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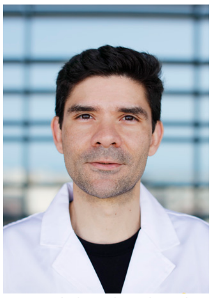
Feature

PV Outdoor Testing in Hot Climates — Michael Salvador

Michael Salvador is the Principal Technology Lead at KAUST Solar Center. He is also the founder and CEO of a KAUST-affiliated startup the Mirai Solar that leverages the synergy between agriculture and photovoltaics for widespread adoption of solar energy. He is currently involved with reliability testing of solar modules in coordination with our industrial and academic partners.



Michael Salvador

Utility-scale solar plants are designed to produce consistent power outputs for over 20-30 years. This imposes very stringent demands on the long-term reliability of materials that form a photovoltaic (PV) module. This is particularly true for hot climates like that of Saudi Arabia, where the potential for solar energy generation is tremendous but at the same time, outdoor conditions are extremely harsh. As such, modules require special resistance in terms of photo-stability, moisture-stability, and corrosion-stability, which is why the encapsulation of photovoltaic modules is so critically important. In a typical solar module, a string of solar cells is protected by barrier materials with ultra-low permeability (usually glass and/or stabilized plastic films), where the encapsulant forms the adhesive that holds the stack together. In addition, sealants are also used to avoid ingress of environmental contaminants from the edges. Failure of any of the components forming the PV module will necessarily impact its operational or financial lifetime. The latter is critically important because it is a determining factor in terms of the levelized cost of electricity (LCOE), among other parameters. Ideally, a module would combine high efficiency with a long lifetime to produce a low LCOE value. In a market as competitive as that of the utility-scale PV technology, any discrepancy from the predicted energy yield will accumulate extra cost which, not rarely, results in litigation scenarios with the principal objective of establishing financial accountability. Understanding and mitigating failure modes under hot climates is, therefore, of extreme relevance.

To showcase the challenges in hot climates, we briefly highlight two examples. In the first example, we recently flew a drone equipped with an IR camera over a rooftop PV installation, recorded IR videos, and identified the many so-called hot spots as exhibited in Figure 1.

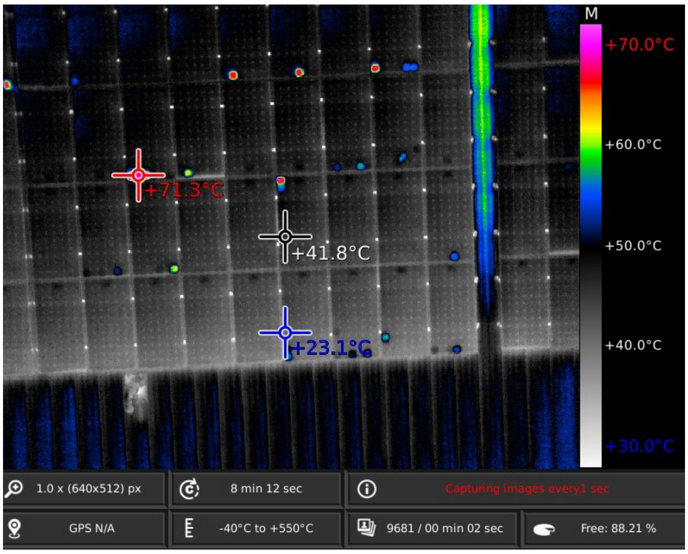


Figure 1. IR image of PV panel array showing several hot spots.

These hot spots are clear indicators of the degradation processes. In fact, several modules had to be replaced after less than 10 years of lifetime, although most modules today have a warranty of usually 25 years. The second example stems from the effect of soiling in desert regions. Figure 2 shows a module that was photographed after 8 days in the field. The soiling problem here is evident. In the past, institutions like TUV have estimated that soiling in desert regions can lead to average drops in the efficiency of up to 0.5% per day. The cost associated with cleaning, therefore, accounts for a significant fraction of the operational cost of a solar plant and has been a major driver of innovation.

An ongoing challenge among the photovoltaic research community is to understand and link the performance decay of photovoltaic technologies to specific failure modes. This is fairly complex to establish as many mechanisms can act in parallel, induced by internal and external stress factors. The most important internal stress factors are electrical currents and potential differences intrinsic to the device, chemical additives and solvents from the encapsu-

Figure 2. Thin-film module after eight days of outdoor exposure in KAUST's outdoor test field.

lant, and metal ions from glass, while external stress factors arise from environmental contaminants, light, temperature, and humidity. To quantify, understand, and mitigate these mechanisms is the reason why the KAUST Solar Center set up an outdoor test field. It is embedded in the KAUST test site, NEO (New Energy Oasis), which comprises an area of about 10,000 m^2 and includes setups from many prominent solar energy companies worldwide. The KSC test field has one area dedicated to commercial technologies and another setup to new generation lab-scale technologies. The test field includes metrology equipment as part of a weather station dedicated to acquiring solar irradiation, temperature, wind, humidity, and precipitation.

Our test site is unique in the sense that it was designed to measure devices ranging from as small as 1 cm^2 upto full-size commercial modules. While some technologies are far from making their way to commercialization, testing outdoors early on has proven extremely valuable as it promotes physical understanding in addition to providing a route towards a more stable device performance. Special efforts are being focussed on perovskite solar cells, silicon/perovskite tandem devices, organic photovoltaics, and crystalline silicon modules. Typically, we track the photovoltaic device parameters and correlate these with solar irradiance and other environmental factors. However, it is important to note that the analysis doesn't end here. A comprehensive picture is only gained after further investigation is conducted in the lab. This may include additional electrical characterization, spectroscopic measurements, or chemical analysis.

Much of the work concerning reliability testing at the KSC is performed with our industrial and academic partners. We have just launched a collaborative outdoor testing initiative with national and international partners. The goal of this collaboration is to study state-of-the-art photovoltaic modules in the context of local climate and acquire insight into the gains of bifacial vs. monofacial modules, the effect of soiling, degradation rates, and mechanisms. The overarching goal here is to use this information to further reduce the LCOE in the region. Another project is being undertaken with a local developer of residential and commercial solar systems to study heat-trapping in rooftop installations. Heat-trapping may cause severe performance drops but also accelerates the degradation. The objective is to quantify the effect of heat-trapping as well as explore mitigation strategies such as spacing and angles between modules and the roof so as to produce best practices for the region.

Reliability remains an important problem for established and emerging photovoltaic technologies, even more so as many countries with the highest solar energy potential in hot climates have just started their quest for cheap renewable energy. It is still not clear how conventional modules can cope with extreme weather conditions. However, by making use of our test field together with our local and international partners, we hope to make solar energy even more reliable and affordable.

News

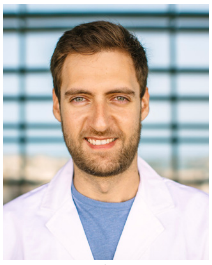
Congratulations: KSC postdocs winners at nanoGe Spring Meeting

Carolina Villamil Franco

The nanoGe Spring Meeting, a multi-symposia based online conference, was held from March 7 – 11, 2022. The conference includes a series of symposia focused on advanced materials science.

KSC had a very visible presence in this conference and our postdocs won big during this event. Carolina Villamil Franco, postdoctoral fellow with the Laquai Research Group, won the prize for the best e-poster valued at 200 € from Fundació Scito. The topic of her e-poster was "Exciton cooling in 2D perovskite nano-platelets: Rationalized carrier-induced stark and phonon bottleneck effects."

Luis A. Lanzetta, another one of our postdoctoral fellows with the Baran Research Group, won the best oral presentation prize given by GDR Hpero. The topic of his presentation was "Degradation mechanism of hybrid tin-based perovskite solar cells and the critical role of tin (IV) iodide."



Luis Lanzetta

Faculty Focus

Interview with Professor Xu Lu

Dr. Lu Xu was hired by KAUST in 2020 but due to COVID-19 physically joined the university in March 2021. He is currently an Assistant Professor of Mechanical Engineering and affiliated with Clean Combustion Research Center (CCRC) and Solar Center (KSC). He obtained his B.S. and Ph.D. degrees from the Department of Mechanical Engineering, the University of Hong Kong in 2012 and 2017, respectively. He was then trained as a postdoctoral fellow in the Department of Chemistry, Yale University. His lab (the LECS-Lab, lecs.kaust.edu.sa), currently with 6 postdocs, three Ph.D. students, and one Master's student, focuses on reactor and material engineering for electrochemical CO2 conversion and energy storage. So far, he has 2 U.S. provisional patents and 27 peer-reviewed publications (14 first-authored, 2 communication authored) in *JACS, Angewandte Chemie, Nature, Joule, ACS Energy Letters, Journal of Power Sources, Applied Energy, Renewable Energy, etc..*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Can you briefly describe the subject of your Ph.D. research?

My Ph.D. research topic was essentially along the same lines as what I am working on now: electrochemically converting CO_2 into usable fuels. With interdisciplinary expertise in mechanical engineering and fundamental chemistry, I have collectively worked across complex multiphase thermofluid networks at the system scale to hybrid catalyst nanostructures at the molecular scale to make electrochemical CO_2 reduction processes more commercially viable.

What led you to enter academia?

A low-carbon economy is a goal set by authorities worldwide. This ambition has motivated and aligned me with the knowledge base and holistic view to complement the existing CO_2 value chain. I realized that to develop a transformative technology towards this goal, academia provides the best environment for me to think and create freely.

When and how did you first become involved with KAUST?

I heard a lot about KAUST from social media and KAUST alumni when I was a Ph.D. student. That is part of the reason why I submitted my résumé to seek a job here without hesitation. My first contact with KAUST happened during my job interview in early 2020, luckily right before the COVID breakout. I still remember very clearly how I was impressed by the talented faculty members and students, top-tier facilities, and campus infrastructures.

Please tell us about your current research interests.

Along with my enthusiasm for CO_2 valorization, my lab (the LECS-Lab) focuses on reactor and material engineering for electrochemical CO_2 conversion and energy storage. Our target is to develop novel electrochemical CO_2-to-fuel conversion platforms (alternatively known as Power-to-Liquid) that could support high-performance catalysts, enhance energy and carbon efficiencies, and eventually arrive at eco-attractive fuel production in industry-relevant scenarios.

You are currently working within KSC on collaborative projects. What is the role of your research group in these projects?

Recently my team has been working closely with other KSC groups to develop a low-cost and robust solar-to-hydrogen conversion device. Simply put, we are integrating our customized water electrolyzer, which is designed to possess some thermodynamic merits, with low-cost solar cells to enable efficient photochemical water electrolysis. Conventionally, this is not possible because the bandgap energy of solar cells is lower than the water electrolysis onset potential. Our proposed device, with a thermodynamically narrowed potential window, could bypass this limitation and realize a direct solar-to-hydrogen conversion route.

What external collaborations are you involved in?

Currently, I am working with Prof. Joseph Francisco at the University of Pennsylvania, who has been providing calculation support for my new catalyst developmental projects. Prof. Udo Schwarz at Yale University has been offering my team great support with single crystal material fabrication. Prof. Dan Brett at University College London and Prof. Guanjie He at the University of Lincoln are my collaborators in seawater electrolysis, adsorption, devices, and more. I also collaborate with Prof. Neil McKeown at the University of Edinburgh in integrating his polymers with my catalytic system for direct flue gas utilization. Beyond academia, my team is working closely with our industrial partners such as ACWA Power, etc.

How does your position at KAUST support your short- and long-term research goals?

My position at KAUST supports my out-of-the-box thinking, allows me to keep track of up-to-date research in other fields, and brainstorm the possibility of cooperatively aiding in the engineering of better catalysis and enhanced energy and carbon efficiencies. The world-class talents and infrastructure at KAUST provide the foundation for my short-term career goal of advancing electrochemical energy technologies towards higher industrial readiness levels and eventually will facilitate my long-term research goal to develop technologies that drive the direct valorization of waste CO_2 by overspilling renewable energy.

What research would you still like to accomplish in the future?

So far, studies in electrochemical CO_2 utilization have been relying on high-purity CO_2 feed gas, operated in ideally conditioned small apparatus. The throughputs and costs could not fulfill the low-carbon economy roadmap set out by authorities. To deliver realistic CO_2 value chain enabling technologies, my primary research focuses are 1. to harness flue gases to clean fuels; 2. to drive or even intensify this electrochemical process by overspilling renewable electricity; and 3. to optimize and up-scale the undertaking devices so that they could be readily used at the industrial level, where we can foresee great engineering challenges but also opportunities.

From a higher-level perspective, this research will address a large-scale scenario question: what will a carbon-neutral society look like? Answering this will require expertise and collaborations across several academic disciplines, to which I will be fully dedicated.

What advice do you have for young scientists?

My words to young scientists are simple: 1. Work hard but also work smartly. 2. Keep your perseverance and do not be scared by failures. 3. Keep exercising. Your health is not only important to your career but also important to you and your family.

Recent Ph.D Graduates

Congratulations!

Dr. Akmaral Seitkhan defended her Ph.D. dissertation entitled 'Interface engineering of high performance organic and perovskite solar cells' under the supervision of Prof. Stefaan De Wolf.

Dr. Yuanbao Lin defended his Ph.D. dissertation entitled 'Performance enhancement of organic solar cells by interface layering engineering' under the supervision of Prof. Thomas Anthopoulos.

Dr. Areej A. Alzahrani defended her Ph.D. dissertation entitled 'Poly-silicon passivating contacts for crystalline silicon solar cells' under the supervision of Prof. Stefaan De Wolf.

Dr. Areej Aljarb, defended her Ph.D. dissertation entitled 'Orientation and dimensionality control of two-dimensional transition metal dichalcogenides' under the supervision of Prof. Vincent C. Tung.

Dr. Xuan Wei defended her Ph.D. dissertation entitled 'Printable 3D MoS2 Architected Foam with Multiscale Structural Hierarchies for High-rate, High-capacity and High-mass-loading Energy Storage' under the supervision of Prof. Vincent C. Tung.

Dr. Yi Wan defended her Ph.D. dissertation entitled 'Toward controlled growth of two-dimensional transition metal dichalcogenides: Chemical vapor deposition approaches' under the supervision of Prof. Vincent C. Tung.

Dr. Jui-Han Fu defended her Ph.D. dissertation entitled 'From 3D Macroscopic Printing to Wafer-Scale Atomic Epitaxy of 2D Materials' under the supervision of Prof. Vincent C. Tung.

Dr. Wandi Wahyudi defended his Ph.D. dissertation entitled 'Unraveling the Microstructure of Organic Electrolytes for Applications in Lithium-Sulfur Batteries' under the supervision of Prof. Thomas Anthopoulos.

Dr. Guillermo Tostado-Blázquez defended his Ph.D. dissertation entitled 'Green Solvent-additive ink formulations based on Hansen Solubility Parameters for up-scaling of organic solar cells' under the supervision of Prof. Derya Baran.

KSC Senior Technical Specialist Semen Shikin explaining the spectrometer to school children during Science on the Spine

KAUST Research Open Week

King Abdullah University of Science and Technology (KAUST) held its inaugural KAUST Research Open Week from November 28–December 2, 2021. Sponsored by the Office of the Vice President for Research, the theme was "Sustainability: Science for the Future." KAUST has reaffirmed its adherence to sustainability by endorsing the United Nations Sustainable Development Goals (SDGs) for 2030 which is also consistent with the Kingdom of Saudi Arabia's Vision 2030 for a clean and sustainable energy future.

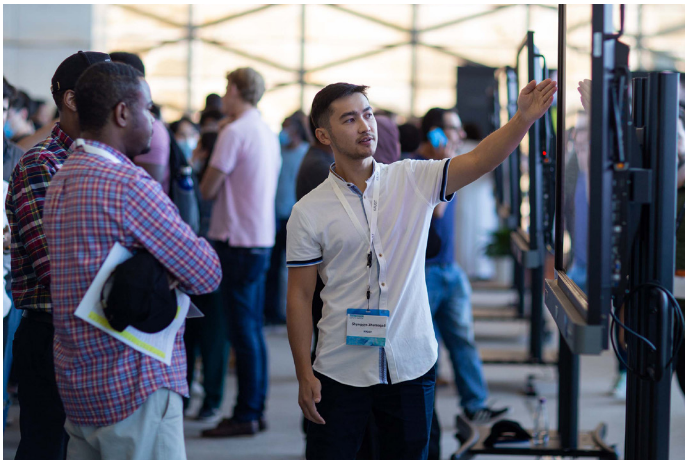
The open week was a showcase comprised of demonstrations, talks and discussions at the cutting-edge of scientific research being undertaken at the KAUST. The event attracted 16 international keynote speakers and over 1150 guests from across the world, including the Formula 1 racing driver Lando Noris, thanks to KAUST's research collaboration with the McLaren team. The multitude of events and activities which were part of this showcase included an exhibition of the scientific demonstrations, a start-up space, poster session, scientific talks, "science on the spine", and open door events.

KAUST Solar Center (KSC) actively participated in all these activities. Throughout the week, the exhibition featured a booth from KSC Prof. Stefaan De Wolf's research group showcasing tandem solar cells and another from KSC Prof. Thomas Anthopoulos's group highlighting their semiconductor research. Simultaneously in the start-up space, "Mirai Solar," a project initiated by KSC's Principal Technology Lead, Michael Salvador with support from KAUST Innovation Ventures, showcased applied solar energy research in a demonstration of their innovative agri-photovoltaic technology for greenhouses.

Visitors, ranged from KAUST community members and students from local schools and colleges, to industry leaders, stakeholders, foreign dignitaries, and investors. Participants were thrilled to become part of the discussion on the latest KSC technologies such as slot-die coated perovskites, hybrid perovskite/silicon tandem, solution perovskite/silicon tandem, silicon heterojunction, advanced functional materials and devices and agri-photovoltaics.

Wednesday, December 1, 2021 was Energy Day in line with one of KAUST's five research thrusts and KSC, one of the world's largest and best equipped academic centers for solar energy research and technology and supporting a broad research portfolio of collaborative projects, was at the heart of the action.

KSC Professor Thomas Anthopoulos & his team with visitors to their semiconductor booth



KSC Ph.D. student Shynggys Zhumagali won the Best Poster award on Energy Day during the KAUST Research Open Week

The poster session involved scientists and researchers presenting their latest work on digital screens to visitors. This event proved to be an excellent opportunity for the KSC scientists to have stimulating scientific discussions and to network with fellow researchers. During the poster session, two KSC members from Prof. Stefaaan De Wolf's group, postdoc Furkan H. Isikgor and Ph.D. student Shynggys Zhumagali presented their work. Shynggys Zhumagali's poster, "Linked nickel oxide/perovskite interface passivation for high-performance textured monolithic tandem solar cells" was awarded Best Poster on Energy Day.

Energy Day: in line with one of KAUST's research thrusts with KSC at the heart of action.

KSC scientists and researchers contributed to the Science Talks, presenting an expansive range of research topics. Afnan AlBatati, KSC Ph.D. student from Prof. Thomas Anthopoulos's research group, presented her work in a talk on "Nanostructured Electrodes for Efficient Energy Harvesting and Green Hydrogen Production" and Luis Lanzetta, KSC postdoc with Prof. Derya Baran's research group, gave a talk entitled "Degradation mechanism of hybrid tin perovskite solar cells: reasons for their instability and solutions towards stable photovoltaics." The conclusion of each talk was marked by an intense question

KSC Ph.D. student Afnan AlBatati presenting during the KAUST Research Open Week

and answer session. The discussion focused not only on how and why the scientists arrived at their research conclusions but also on what the future research implications of their work are. KSC scientists ensured that their talks encouraged participants to reason with evidence with an inclination towards risk-taking in scientific research. These presenters from the KSC won first and second place respectively.

The Kingdom of Saudi Arabia's Vision 2030 has set up ambitious objectives of molding the country's economy in a manner that offsets the impact of fossil fuels and simultaneously works towards enhancing its use of clean energy sources. In line with this objective, KSC strongly believes that inspiring young people with its innovative research is pivotal. Hands on exhibits during the Science on the Spine session were, therefore, a crucial part of introducing community mem-

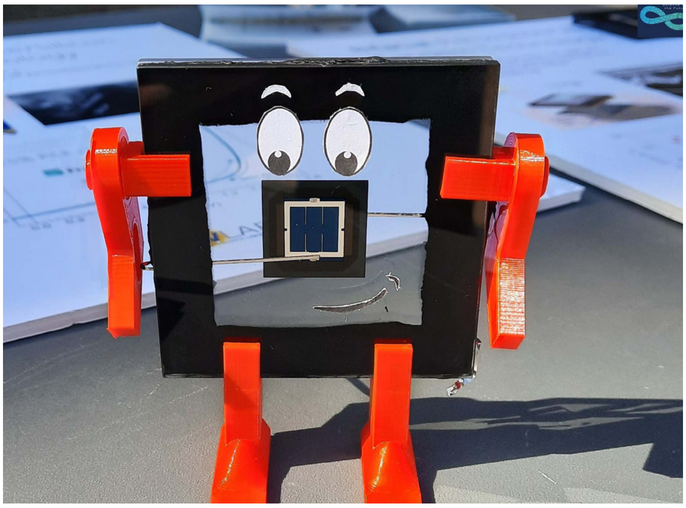
KAUST Research Open Week's theme was "Sustainability: Science for the Future" in line with the UN Sustainable Development Goals and the Kingdom's Vision 2030

bers to the value of solar energy research and recognizing the scientific research excellence at the KSC.

... inspiring the next generation of young scientists and engineers.

Although open to everyone, this session was specifically targeted at a younger audience, not only from KAUST but from various regional schools. KSC was proud to extend this opportunity to the next generation of prospective scientists where they not only got up close and personal with our team of scientists but also participated firsthand in a variety of creative learning experiments.

Esma Ugur, a KSC postdoc with Prof. Stefaan De Wolf's research group enthused our young guests with tandem solar cells, information sheets and small toys operational with sunlight, with the children reading the voltage output from tandem solar cells by themselves. At the end, her event's mascot, unanimously named "Wolfi" by a twitter poll, was introduced as a surprise new member of the KSC KPV Lab.



Wolfi - The new mascot of the KSC Photovoltaics Lab

The KSC lab operations team who ensure that our scientists are provided with the best research facilities, were also front and center during this event. Senior Technical Specialist, Semen Shikin set up a spectrometer on the Spine to measure the solar light spectrum. Excited future scientists witnessed how the power of the whole spectrum or any of its chosen parts varies when white light is observed through a shadow, UV protection (sunglasses), or a special UV protection fabric.

Senior Technical Specialist, Bright Wadja designed the creative demo "Human vs Solar" wherein participants got to check whether the power generated by them while cycling a spinning bicycle can beat that of a solar panel.

The "Human vs Solar",challenge: Participants try generating as much energy on an exercise bicycle as from a solar panel.

Owing to its highly experienced and diverse faculty, KSC possesses a distinctive set of research expertise. For the KAUST Research Open Doors event, KSC rolled out the red carpet for visitors to its labs so that they could discern for themselves what actually goes on behind closed doors to identify modern-day scientific solutions for transitioning to a clean energy economy. Our staff scientists Atteq ur Rehman, Abdulrahman El Labban and Craig Combe were at the ready to host our guests and answer any questions that they had. Over two hours a total of 91 guests, from inside and outside KAUST, were welcomed into our labs and were given interactive presentations and demonstrations of our work with detailed question-answer sessions.

Abdulrahman El Labban , KSC Lab Staff Scientist giving a demonstration to the visitors during Open Doors event

The KAUST Research Open Week inspired KSC members Catherine de Castro and Daniel Corzo to take to social media with both winning prizes for their contributions. The week was rounded of by a presentation on solar energy technology given by KSC's Dr. Faisal Wali at the KAUST School. The interest from the 7th graders was tangible from their questions.

The excitement generated by the KAUST Research Open Week was tangible on campus throughout the week. KSC was delighted to support the event, showcasing our research, informing the wider community regarding the potential of solar energy for a clean energy future and inspiring the next generation of young scientists and engineers.

Christopher Petoukhoff is among the first cohort of awardees of the KAUST Global Fellowship Program (KGFP)

KAUST Global Fellowship awarded to Christopher Petoukhoff

The KAUST Global Fellowship Program (KGFP) for postdoctoral fellows focuses on excellence with impact and attitude to support emerging, exceptional research talent from across the globe on the pathway to a fully independent career. KAUST Vice President for Research, Professor Donal Bradley has described the opportunities afforded researchers through this prestigious program:

"Those selected will be asked to play a key role in helping to address the major challenges of our time and we will provide them with a stepping stone opportunity to launch their careers within a dynamic and fast-paced environment."

Recipients undertake a 3-year research project at KAUST. Their research topic may be related to a major global challenge in line with KAUST's research pillars, or green hydrogen technologies and storage solutions.

Christopher Petoukhoff is among the first cohort of awardees of the KGFP. He will conduct his research at the KAUST Solar Center (KSC) under the supervision of KSC Interim Director, Professor Frédéric Laquai. Christopher obtained his Ph.D. in 2017, in Materials Science & Engineering from Rutgers University, USA. Before joining KAUST, he conducted postdoctoral research at the Okinawa Institute of Science and Technology (OIST), Japan and also spent 6 months as a visiting researcher at the Tata Institute of Fundamental Research (TIFR), India. During his Ph.D. and first postdoc, Christopher investigated methods of enhancing organic photovoltaic (OPV) efficiencies using nanomaterials and nanophotonic structures. He combined multi-scale materials characterization approaches, coupled with photo-physics measurements, to determine the impact of two-dimensional materials and plasmonic metasurfaces on organic active layer films. This, combined with electromagnetic, optical, and electrical simulations, aids in predicting methods of improving OPV efficiencies.

"I chose to come to KAUST to participate in cutting-edge research in solar energy at the KSC, and to be part of Saudi Arabia's revolutionary goal of achieving 50% renewable energy by 2030", said Christopher.

For his KGFP research project, Christopher will investigate the impact of 2D semiconductors as multifunctional hole-transport-layers (HTLs) in high-efficiency OPV devices. He described the opportunity, "Through this fellowship, I look forward to leading my independent project, partaking in the various traineeship and leadership opportunities offered by the Office of Postdoc and Research Affairs, and preparing to kick-start my career as a future research professor."

In addition to the opportunity to become a global research leader in renewable energy, campus life provides additional attractive benefits: "I enjoy cycling, hiking, snorkeling, and stand-up paddle-boarding, and I'm looking forward to exploring the desert and the Red Sea. I intend to seek out opportunities for science outreach and education while conducting the KGFP fellowship."

News

CONGRATULATIONS

Luis Lanzetta invited to the Lindau Nobel Laureate Meeting 2022

Luis A. Lanzetta, a postdoctoral fellow with the Baran Research Group in the KSC has been selected to participate in the 71st edition of the prestigious Lindau Nobel Laureate Meeting (Chemistry), as a nominee of the Global Young Academy. The event is scheduled to take place from June 26, 2022 – July 1, 2022, in Lindau.

These meetings – initiated in 1951 – provide an opportunity to young scientists from across the world for an exchange with Nobel laureates; paving the way for establishing a globally sustainable scientific community – a network of excellence. The meetings specifically target young scientists who, after undergoing a meticulous and grueling selection process, epitomize the next generation of scientific greatness. This platform is not just restricted to a week's worth of scientific discussions but serves to foster lifelong associations as alumni of Lindau Nobel Laureate Meetings stay interconnected over the course of their scientific careers. This select group of participants are envoys of the scientific discourse fomented by these meetings.

Luis is one of the 600 highly qualified young scientists who will get to experience and contribute to this distinctive platform. He is looking forward to "avail this incredible opportunity to network with other young scientists and interacting with the laureates." Luis is anxiously waiting to have an in-depth analysis of the "laureates' insightful views on current global challenges" that will also serve to provide his own research a broader perspective.

"I am most curious to discuss about the pressing need of transitioning from fossil fuels to clean, affordable sources of energy and how we, as chemists, can make a difference. I am really looking forward to discussing topics outside of my current research area to gain a broader view of cutting-edge chemistry."

Luis is keeping his fingers crossed to get a chance to talk to Prof. Akira Yoshino, the famous Japanese chemist and one of the 2019 Nobel laureates in chemistry, who developed lithium-ion batteries, and ask him about his views on the future of energy storage systems.

"I feel extremely privileged to take part in this event; this is a once-in-a-lifetime experience and I am sure it will have a long-lasting impact on me in both personal and professional capacities."

Luis A. Lanzetta has been selected to participate in the 71st edition of the Lindau Nobel Laureate Meeting (Chemistry), as a nominee of the Global Young Academy.

Ph.D. Profile

Nisreen Alshehri

Nisreen Alshehri

Nisreen Ahmad Alshehri, from Saudi Arabia, is pursuing her PhD in Applied Physics at the KAUST Solar Center, King Abdullah University of Science and Technology (KAUST) under the supervision of Professor Frédéric Laquai. Nisreen received her Master's degree in Materials Science and Engineering from KAUST. Prior to that, she completed her B.Sc. in Physics and Astronomy at King Saud University where she is currently employed as a Lecturer. Her current research focuses on charge transport in organic materials for photovoltaic applications.

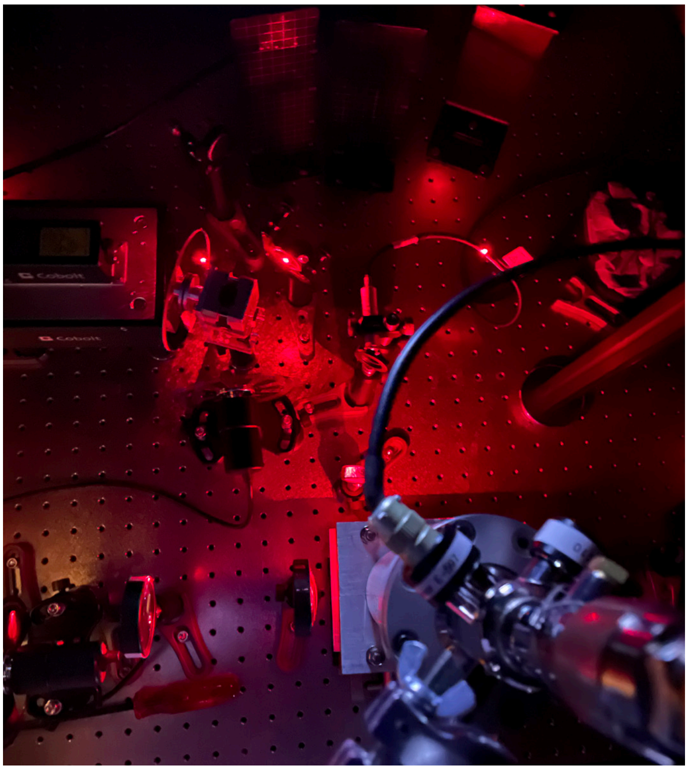
For her Master's thesis, which focused on building mathematical models to predict spin transport through antiferromagnetic materials, she worked on theoretical spintronic. While working on these systems, i.e. normal metal\antiferromagnetic interfaces, she observed an interesting phenomenon due to their broken symmetry. This work provided her with a robust experience that ultimately motivated her to pursue theoretical research, particularly in condensed matter physics and quantum mechanics.

"In order to appreciate and sense the mathematical models, I needed to experimentally observe the physical phenomena. My inquisitiveness drove me even further to inquire about what would happen in terms of quantum transport when systems got complicated. Therefore, after taking a class on Photophysics of Organic Semiconductor with Prof. Laquai, I knew, then and there, that this kind of a system would feed my curiosity."

Organic materials, classified as "soft condensed matter", although way more complex than the "hard condensed matter" that Nisreen used to work on were more intriguing to her. "In fact, at this level of complexity, new properties appear due to intermolecular interactions... that need more investigative research to better understand them."

During the first year of her Ph.D., Nisreen worked on organic thin films where she investigated the generation of quantum states such as Charge Transfer, Singlet, and Triplets, using several laser-based spectroscopy techniques. The first step of this technique involved fabrication of non-fullerene acceptors and donors' thin films. Then, upon exposure to light, light-matter interactions, in particular absorption and photoluminescence emission, were observed. Their spectra, in fact, contain valuable information about the molecular structure and evidence of quantum states in such systems.

"Indeed, what makes this field even more interesting is its interdisciplinary aspect, which means I get to work with chemists, physical chemists, experimental and theoretical physicists. The supportive environment at KAUST excellently employs Richard Feynman's saying, "Nature is not interested in our separations, and many of the interesting phenomena bridge the gaps between fields."



An overview of the laser setup