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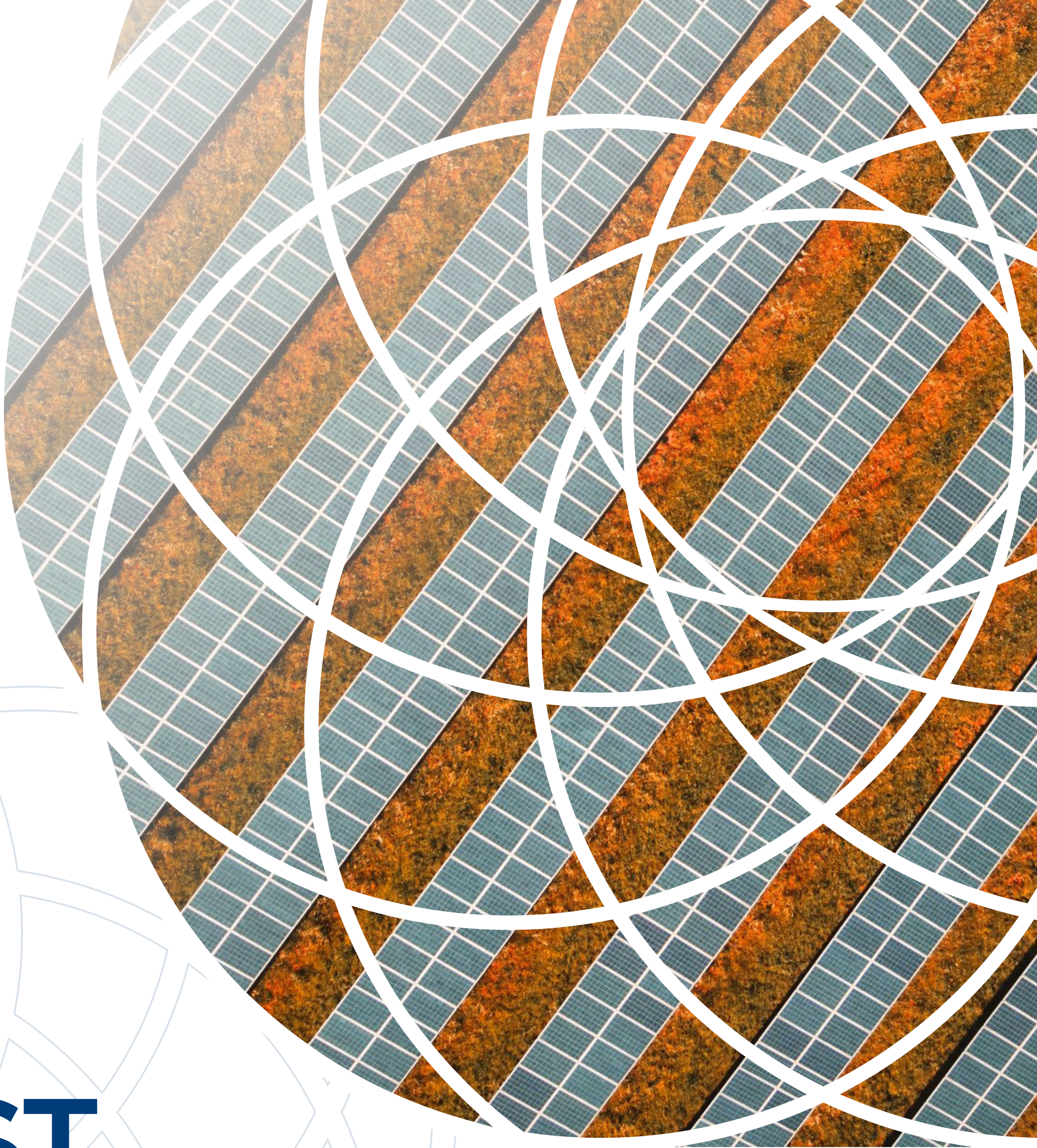

KAUST Solar Center News

Contents:

Message from KSC's Associate Director

A warm welcome to the 6th issue of the KAUST Solar Center's Newsletter!

Frédéric Laquai
Associate Director of KSC
Associate Professor of Material Science & Physics

The past months have been very challenging for all of us. Like many other institutes and universities around the world, KAUST and consequently KSC had to hibernate its labs and all lab work had to cease, a necessary precaution and reaction to the continuing COVID-19 pandemic. From mid-March, we awaited longingly the day the labs would reopen and research would recommence. It turned out to be a long wait though with all labs closed for over three months.

However, we're back: From June 21st KSC's lab operations team initiated the awakening of our labs and equipment and a strict shift plan was implemented, limiting the number of people in each lab to ensure physical distancing. Be assured that the Center management and lab operations team are doing their best to mitigate any risks.

Despite the return to lab work, things are now very different. We are living in a 'new normal', as it is sometimes called, in which face masks, regular disinfection, physical distancing, and limited socializing are our daily companions. I doubt that we will have a chance to go back to 'normal' anytime soon but rather that we will have to adapt to the new situation as this pandemic is going to remain with us for some time.

Yet, despite the partially restricted lab activities, on July 1st we kicked off a new round of our Center-supported research projects. These projects are highly interdisciplinary and translational projects; they run for one year; and make use of the complementary expertise of our Center-affiliated faculty to achieve breakthroughs in core research areas for our Solar Center, such as photovoltaic and photocatalytic solar energy conversion. To be more specific, in the coming 12 months the Center will work on high-efficiency and stable (printed) organic solar cells, perovskite-perovskite tandem solar cells, and new concepts for solar-driven water splitting and conversion of CO_2 into solar fuels. 25 of our Center members are directly funded by the projects, and many more contribute towards achieving the projects' objectives and demonstrating the deliverables. I am confident that within the next 12 months we will not only see a lot of interesting science coming from our projects, but we'll also demonstrate applications and translation of our findings into larger scale demonstrators, in other words, we will see more downstream activities.

Finally, yet importantly, let me thank everyone in the Center for bearing with us in these difficult times. I sincerely thank the lab operations team for their great support in all phases of the lab hibernation and awakening period. Likewise, I thank everyone in the Center for their patience and for adhering to the rules we have implemented since the recommencement of lab work. As we have arrived in the 'new normal', it will take us some time to get used to it, so be patient, the pandemic is not over, but together we can mitigate the risks and can achieve some kind of normality under these still very special circumstances.

Enjoy reading the Newsletter and stay safe!

KSC Principle Investigators

Iain McCulloch, Director, KSC
Professor of Chemical Science

Frédéric Laquai. Associate Director, KSC
Associate Professor of Material Science & Physics

Thomas Anthopoulos
Professor of Material Science & Engineering

Derya Baran
Assistant Professor of Material Science & Engineering

Stefaan De Wolf
Associate Professor of Material Science & Engineering

Udo Schwingenschlogl
Professor of Material Science & Engineering

Vincent Tung
Associate Professor of Material Science & Engineering

Content:
Comments and suggestions regarding contentent can be sent to **ksc@kaust.edu.sa**

Cover Image
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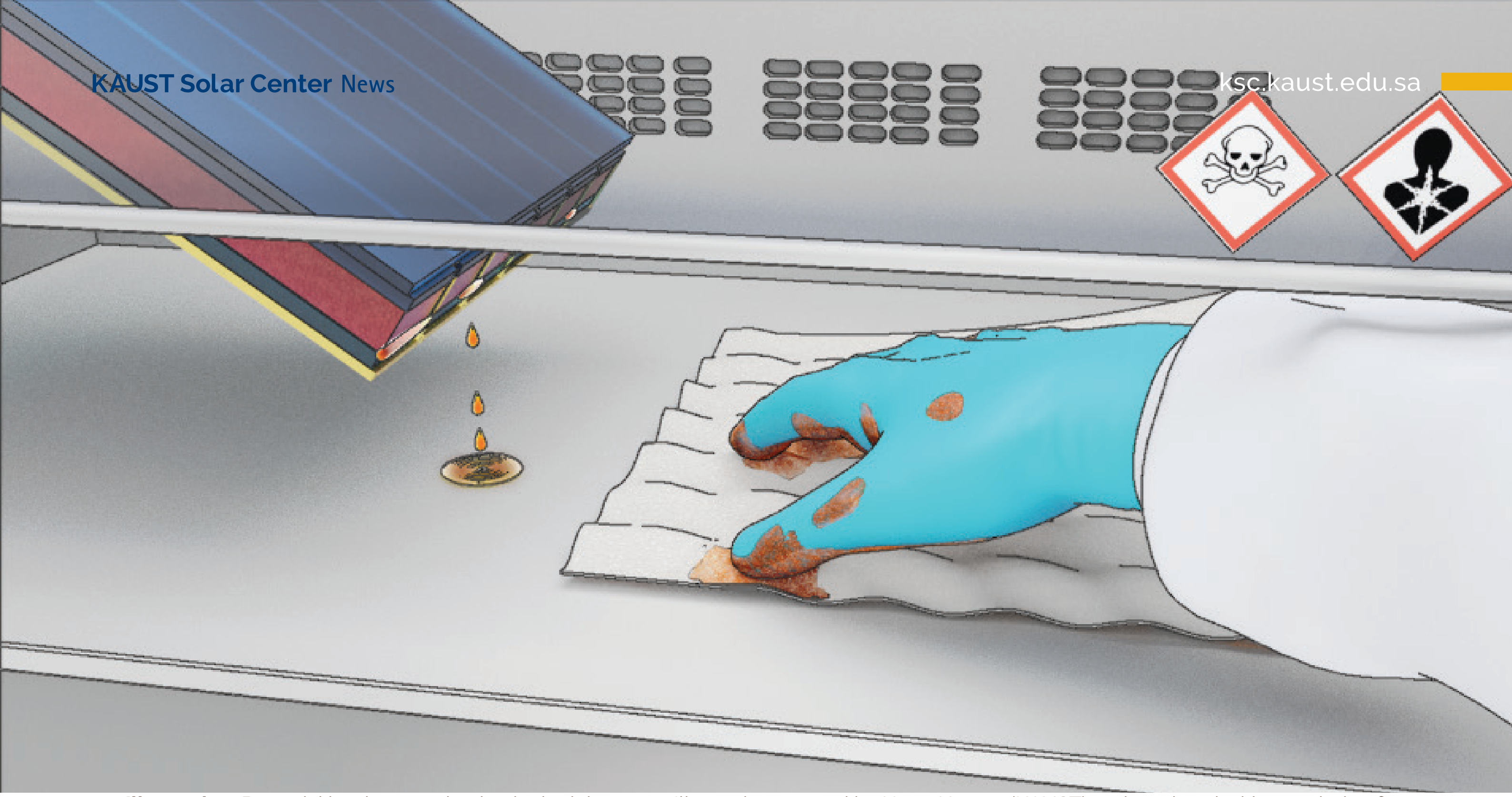

Illustration: Potential lead contamination in the laboratory. Illustration created by Heno Hwang (KAUST) and reprinted with permission from DOI: 10.1021/acs.chemmater.0c02196.

Combating the hidden perils of lead in the lab — Michael Salvador

Perovskite research has evolved into a mainstream research field among academia and industry alike due to the prospect of solar to energy conversion at a substantially lower cost and carbon footprint than currently offered by silicon-based photovoltaics. The downside of perovskite materials from a health, safety and environmental (HSE) perspective is the need for the metal lead. Lead is a toxic metal that can potentially trigger severe long-term health conditions in humans. It can be incorporated into tissue and bone and remain in the body for decades. The toxicity of lead is long known. Yet, recent studies have reported that the toxic activity of lead can occur at levels much lower than previously advised by most health and safety agencies. Notably, a recent cohort study by Lanphear et al. reported an attributable fraction of blood lead levels to all-cause mortality among US adults of 18%.[1]

Agencies such as OSHA (Occupational Health and Safety Administration) are responsible for providing guidance and control mechanisms to avoid exposure to hazards, including toxic materials, in the workplace. We have analyzed guidelines from well-known health and safety agencies like OSHA and others and noticed that those recommendations are either heavily outdated or do not account for lead in scenarios that are predominant in perovskite labs. The Association of Occupational and Environmental Clinics (AOEC) says the following about OSHA: “Although the Federal Occupational Safety and Health Administration’s lead standards have provided guidance that has been beneficial for lead-exposed workers, these regulations have not been substantially changed since the late 1970s and thus are primarily based on health effects studies that are well over three decades old. There is an urgent need to revise them.”[2] We have thus taken the steps to formulate our own recommendations based on several years of experience and discussions with colleagues and HSE professionals. The result is a set of documents that provide practical measures for probing contamination and delineates guidelines for handling and decontaminating lead materials, from small spills to complete labs. The documents include relevant literature, a standard operation procedure, a Powerpoint training tool and a quiz, all developed by KSC in collaboration with KAUST’s HSE department. The material is available from our website.[3]

A manuscript describing our efforts in detail has been accepted for publication in the journal Chemistry of Materials under the title The hidden perils of lead in the lab: Guidelines for containing, monitoring and decontaminating lead in the context of perovskite research.[4]

One way of looking at the problem is to consider the “Hierarchy of Controls” (Figure 1). The measures at the top of the inverted pyramid are considered to be more effective and protective. Elimination would mean giving up perovskite research altogether and substituting lead with other more benign metals is an important research topic among the perovskite community. We focused our efforts on engineering controls, administrative controls and PPE. As part of this endeavor, we first looked at how to probe lead in the lab. We initially opted for lead check swabs offered by 3M. These swabs are used widely across perovskite labs. Through side by side comparisons with quantitative ICP measurements, we quickly realized that the results need to be considered as a very rough orientation only as we observed a significant number of false positives and negatives.

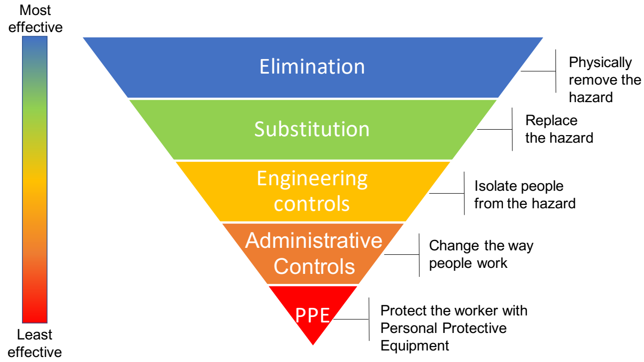

Figure 1. Hierarchy of controls for preventing exposures to occupational hazards. Reproduced from https://www.cdc.gov/niosh/topics/hierarchy/default.html..

When probing our labs for lead, we realized that lead powders can easily become airborne, spread with surprising velocity and throughout large areas. We would like to share the measures that we observed to be most effective:

- Implement a stringent housekeeping plan. This means clean surfaces often and thoroughly after every process involving lead-based materials. Hand soap detergent is effective, and a single cleaning step can significantly reduce the contamination levels. Several cleaning cycles might be necessary to achieve the detection level of ICP.

- Move all work involving lead powders to glove boxes. Antechambers can accumulate lead powder during the venting process and should be cleaned after each use.

- Institute periodic random sampling of lab surfaces using ICP swabs and share results with HSE professionals. Introduce a contamination level of 5ppm, above which immediate cleaning is required.

- Use lab coat, goggles, gloves at all times. In particular, use double gloving, ideally with extended cuff.

- Introduce blood lead level testing. Follow guidelines and reference standards described by NIOSH (National Institute of Occupational Safety and Health) and AOEC.

In summary, our experience has shown that it is possible to control lead exposure. Cleaning frequently is likely the most critical measure to reduce lead contamination. We also believe that creating a high level of awareness among lab users goes a long way in establishing a safe working environment. Our initiative is intended to create the necessary awareness among the perovskite research community, and our expectation is that labs around the world will rely on these guidelines to enhance their safety standards.

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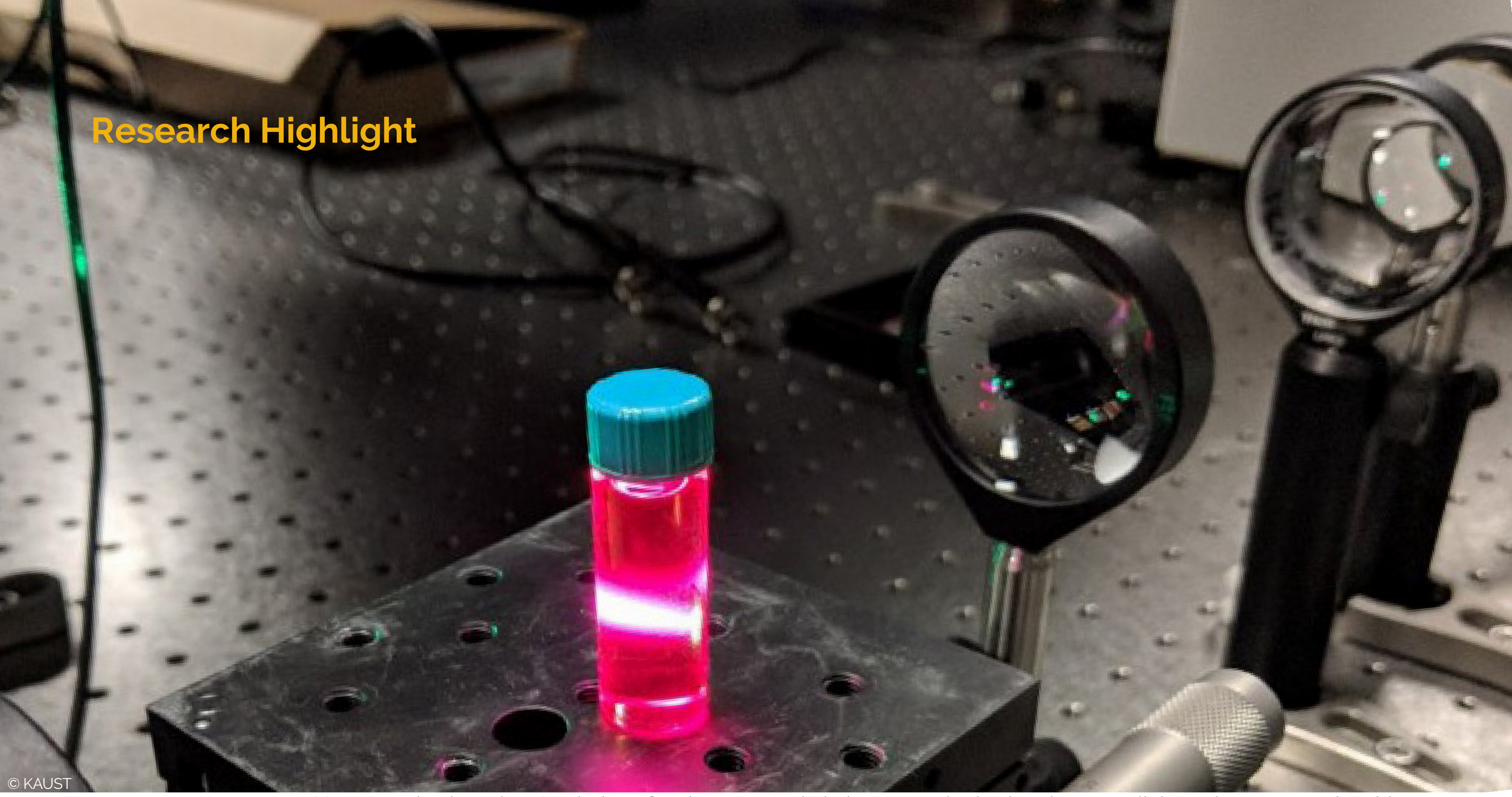
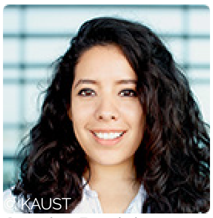


Upconversion in action: A solution of anthracene and platinum-porphyrin absorbs green light and upconverts it to blue.

Up-converting system sensitizes metal oxide nanoparticles for photocatalytic reactions

— Sandra Patricia Gonzalez Lopez



Sandra Patricia Gonzalez Lopez

Sandra Patricia Gonzalez Lopez joined the Ultrafast Dynamics Group lead by Associate Professor Frédéric Laquai in February of 2018. She obtained her master's degree in materials science from King Abdullah University of Science and Technology (KAUST). She graduated magna cum laude in nanotechnology from Universidad de las Americas Puebla (UDLAP).

Photocatalysis, along with other forms of solar energy-conversion such as photovoltaic technologies, has gained a prominent position in potentially tackling and mitigating the energy crisis and environmental pollution by direct conversion of solar energy into chemical feedstock and fuels. The development of efficient semiconductor photocatalysts for converting solar light into fuels or chemical energy has been a continually growing research field ever since the pioneering studies in the 1970s involving mainly bare titania (TiO_2).

Photocatalysts, for instance metal oxide nanoparticles, generate charges through light (photo)excitation for use in redox reactions. Through the absorption of photons of energy equal to or greater than the bandgap energy (Eg) of the semiconductor, electrons from the valence band (VB) are promoted to the conduction band (CB). The excited electron leaves behind a positive charge in its place, known as a hole. Reducing and oxidizing species adsorbed onto the surface of the catalyst can facilitate the separation of the electron and hole pair and their migration to the surface. Once at the catalyst's surface, charges can either directly participate in the photocatalytic reaction or generate active species, which then carry for instance decomposition reactions. However, the efficiency of various photocatalytic processes largely depends on the band alignment of the photocatalyst with respect to the reduction/oxidation potentials of the adsorbed species, the presence of intrinsic and extrinsic defects, and the use of co-catalysts and sacrificial agents.

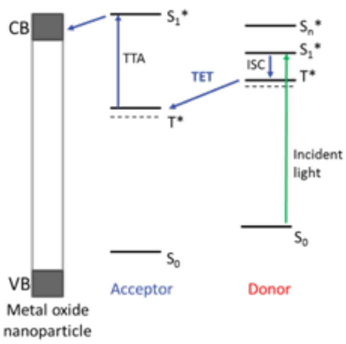


Figure 1. Energy level diagram of a metal oxide nanoparticle sensitized by a triplet-triplet annihilation up-conversion system

Restricted by their (large) bandgap energy, most of the current photocatalytically active metal oxides can only harvest UV photons, which account for not more than 3-5% of the solar spectrum reaching earth. This imposes severe limitations to the maximum achievable solar conversion efficiency and hampers its practical applications. As the rest of the incident solar radiation remains underutilized, strategies to extend the range of harvested photons are continuously researched. in this regard, photon up-conversion is a promising process to apply due to its anti-Stokes emission property, meaning the production of high-energy photons from lower energy incident photons. However, efficient photon up-conversion often requires coherent light and high intensities provided by laser sources, incompatible with incoherent and comparably low intensity solar radiation. This has recently changed due to the development of triplet annihilation-based upconversion systems that use organic dyes and metal-organic compounds.

How does this process work? Triplet-triplet annihilation up-conversion (TTA-UC) requires a system of two molecules; one called sensitizer or (triplet) donor and the other one called annihilator or acceptor. In a typical TTA-UC process, a sensitizer absorbs the incoming low energy photons and successively undergoes intersystem crossing (ISC) to its lowest triplet-excited state. Afterwards, triplet energy transfer (TET) occurs to the triplet excited state of an acceptor via a Dexter-type energy transfer process. When two acceptors in a triplet-excited state collide, triplet-triplet annihilation (TTA) can happen, promoting some of the acceptors to a singlet-excited state. Finally, radiative decay of the acceptor's excited state results in the emission of up-converted fluorescence. In total, two lower-energy photons are transformed into one photon of higher energy.

In the systems we are currently investigating, the acceptor molecules are directly chemically coupled to different metal oxides nanoparticles commonly used as photocatalysts, such as titania, zirconia, and ceria. Once the acceptor molecule is in an excited sinlglet state, a charge transfer to the nanoparticle occurs, allowing subsequent reactions on its surface. To track the energy and electron transfer processes and better understand the dynamics and timescales of these UC photocatalytic systems, we make use of time-resolved photoluminescence (TRPL), photo-induced absorption (PIA), and transient absorption (TA) spectroscopy. These techniques allow us to understand the limitations in the performance of current photocatalytic systems and thereby help to develop new molecules with improved photocatalytic efficency.

Recent Ph.D. Graduates

Congratulations!

Emilie Dauzon

Dr. Emilie Dauzon defended her Ph.D. dissertation entitled 'Flexible and stretchable organic materials and devices for application in emerging optoelectronics' under the supervision of Prof. Thomas Anthopoulos.

Md. Azimul Haque

Dr. Md. Azimul Haque defended his Ph.D. dissertation entitled 'Halide Perovskites: Materials, Properties and Emerging Applications' under the supervision of Assistant Prof. Derya Baran.

Chun Ma

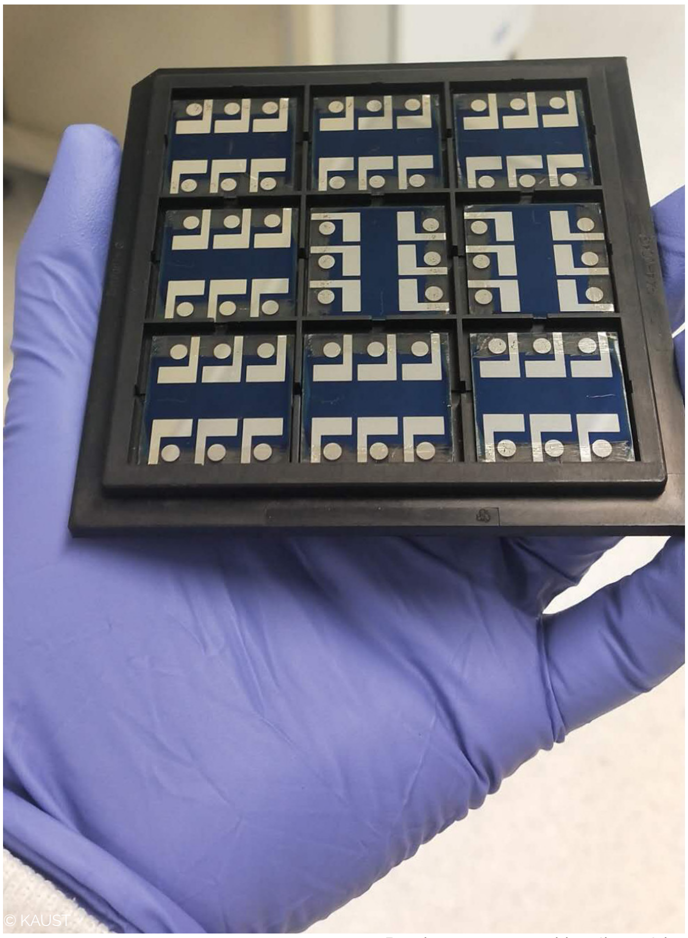
Dr. Chun Ma defended his Ph.D. entitled 'High-performance Optoelectronics Based on Mixed-dimensional Organolead Halide Perovskites' under the supervision of Prof. Thomas Anthopoulos.

Esma Ugur

Dr. Esma Ugur defended her Ph.D. entitled 'Photophysical Processes in Lead Halide Perovskite Solar Cells Revealed by Ultrafast Spectroscopy' under the supervision of Prof. Frédéric Laquai

Doping of HTL to improve the performance and stability of perovskite solar cells

— Jiang Liu



Devices prepared by Jiang Liu

Dr. Jiang Liu was born in Hunan, China, and obtained his Ph.D. degree from Tsinghua University, China. He joined Professor De Wolf's research group in October 2018. His research mainly focuses on passivation of perovskite film and high-efficiency perovskite/Si tandem solar cells.

Organic-inorganic hybrid perovskites have attracted extensive attention in recent years and have achieved great success in the fields of solar cells, light-emitting diodes, lasers and others. Thanks to global research efforts, the efficiency of small-area perovskite solar cells (PSCs) has exceeded that of other conventional thin-film technologies. The focus of early research was mainly targeted on methylammonium lead iodide ($MAPbI_3$). After FA (Formamidinium) based perovskites demonstrated better stability and device performance, FA-based perovskites with some mixed cations or mixed anions have become more widely adopted.

Perovskite materials exhibit fascinating features. First, the preparation process of the perovskite films is very simple. Researchers can process perovskite films easily in the lab with simple experimental facilities, including a spin coater and precision balance. This is also an important reason why so many research groups around the world have entered this field. However, fabrication of high-efficiency devices and in-depth understanding of their fundamental working mechanisms still require professional and experienced laboratories. Second, perovskite films exhibit excellent photoelectric properties and bandgap tunability. With the anti-solvent-induced fast crystallization method developed in 2014, a smooth perovskite film with packed grains can be obtained, greatly reducing defects in the perovskite film. Now many groups can reproduce devices with greater than 20% efficiency. Another interesting point is that the perovskite device structure is also adjustable and can be processed into *n-i-p* or *p-i-n* configurations. Which type of device configuration is better is still under investigation: *n-i-p* type perovskite devices commonly have a slightly higher Voc and currently hold record efficiency, while *p-i-n* type devices seem to have the advantages of simple preparation and better thermal stability.

Recently, we demonstrated a hole-transport-layer (HTL) doping method to improve device

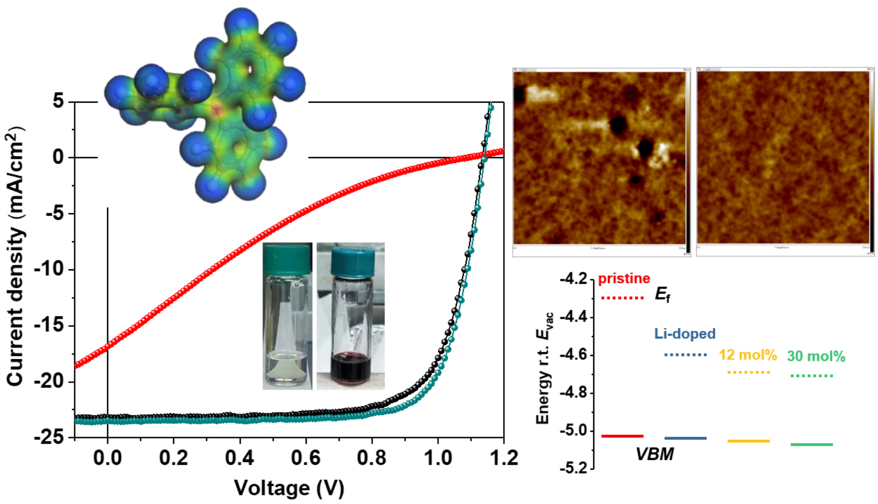


Figure 1. Performance comparison of the Li-doped, undoped, and TPFB-doped spiro-OMeTAD layer.

performance and device stability. For *p-i-n* configuration devices, the HTL used is very thin and usually does not require doping, since the HTL is deposited directly on a very smooth ITO-coated substrate. However, for *n-i-p* configuration devices, *p*-type doping of HTL is fundamental since the widely used and thick organic HTL has low conductivity. Many *n-i-p* devices still use LiTFSI/tBP doping, which causes long-term stability problems. In our work, we utilized tris(pentafluorophenyl) borane (TPFB) dopant to dope spiro-OMeTAD, and systematically investigated the effect of TPFB doping on this HTL and its influence on device performance. Thanks to the TPFB-doping strategy, we achieved dense and pinhole-free films with significantly increased conductivity and improved charge transport. Additionally, we found that TPFB doping improves device stability compared to conventional Li doping.

When TPFB dopant was added into spiro-OMeTAD solution (Figure 1), the resultant solution turns gradually dark red. That may imply some interaction occurs between TPFB and spiro-OMeTAD. Our conductivity measurement shows TPFB doping can increase the conductivity of spiro-OMeTAD by two orders of magnitude. With undoped spiro-OMeTAD, the corresponding J-V curves exhibit an S-shaped feature and very low FF. Our TPFB-doped devices show improved fill factor (FF) compared with that of conventional LiTFSI doping.

To assess the electronic properties of the studied HTL, we performed ultra-violet photoelectron spectroscopy (UPS) on the undoped and doped samples. The Fermi level shifted downward notably when spiro-OMeTAD was doped with Li salt and TPFB, which is also consistent with our Kelvin probe force microscopy (KPFM) results. Lower Fermi level at HTL can help to induce greater interface band bending, thereby improving charge collection.

Jiang Liu

There are always many pinholes in the case of the Li-doped spiro-OMeTAD layer, whereas the TPFB-doped film is smooth and pinhole-free. This structural difference led us to think that the presence of pinholes in the Li-doped film may provide pathways for humidity to permeate into the perovskite layer, thus accelerating the degradation.

In addition, we explored the fluorine-free TPB and boron-free TPFP material molecules as dopants in HTL for the first time. Although the doping effect of TPB and TPFP is not very effective, they can offer excellent contrast, helping to highlight the importance of fluorine atoms on the side and the central boron atom in TPFB. Regarding the doping mechanism, our DFT calculation results provide support for our interpretation. Due to the strong electronegativity of the fluorine atoms on the side of the benzene rings, the entire benzene rings can become large Lewis acid sites, facilitating the formation of Lewis acid-base adducts. We believe that this can provide a criterion for selecting efficient HTL dopants for this type of Lewis-acid doping.

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Overcoming interfacial barriers in perovskite solar cells — Joel Troughton

Marios Neophytou (l) and Joel Troughton (r).

Today's most commonly used perovskite absorber materials are intrinsically tolerant to defects. Unusual in many photovoltaic materials, defect states that form within the perovskite semiconductor tend to be shallow – close to the band edges rather than the band's middle. Such defect states are less prone to non-radiative recombination, allowing perovskite solar cells to maintain their famed high performance despite such imperfections. In recent years, the field has somewhat shifted from producing new perovskite absorbers, and towards tailoring high quality interfaces in contact with the perovskite absorber to extract more and more electrical performance from the solar cell.

The multi-layered nature of perovskite photovoltaics gives researchers a multitude of interfaces to study and optimise: In the most common architectures, charge is transferred from the perovskite semiconductor through charge-selective layers: One to extract electrons on one side of the film, and another to extract holes at the opposite side. KSC researchers have been at the forefront of research on this topic, with recent publications on new deposition techniques, doping routes to enhance electrical performance and enhanced stability.[1–3] At the same time, new self-assembled monolayer (SAM) materials are blurring the definitions of what is required to transfer charge from perovskite absorber to an external circuit: The breakthrough "2PACz" SAM molecule, published by researchers at HZB Berlin, accomplishes the role of hole-extractor with a single monolayer of material adsorbed to an electrode.[4] Besting more conventional polymer and small molecule counterparts which must be made several nanometres in thickness to achieve efficient hole extraction. In a field where every photon parasitically absorbed in photo-inactive materials counts, these new ultra-thin perovskite contacts are likely to surge in popularity in the years to come.

One often overlooked interface in perovskite solar cells is the junction between charge-selective contact and electrode material. With electrodes typically comprising of metals or semimetals, it is often presumed among device physicists and engineers that making good electrical contact between electrode and semiconductor is trivial. However, there are exceptions where more consideration must be applied before high electrical performance is achieved. One such case is the interface between fullerene n-type semiconductors and many metal electrodes.

Fullerene derivatives form many of the electron-transport materials in so-called "inverted structure" perovskite solar cells, most commonly in the form of evaporated C_{60} or solution-processed $PC_{60}BM$. This layer is typically deposited on top of the perovskite absorber and is consolidated with a thermally evaporated metal electrode of silver, copper or gold. In such a configuration, the mismatch between the fullerene's Fermi level and the work function of the metal electrode serves to form a Schottky barrier at this interface. This barrier leads to an accumulation of electrons within the fullerene which cannot be efficiently transferred to the electrode to perform work. In order to counter this accumulation, researchers have historically employed very thin layers of "cathodic interface material", CIL which shifts the band bending down from fullerene into the electrode, facilitating efficient electron extraction (Figure 1). Many materials have been employed as this CIL, including metal oxides and small molecule organic materials such as BCP and Phen-NaDPO.

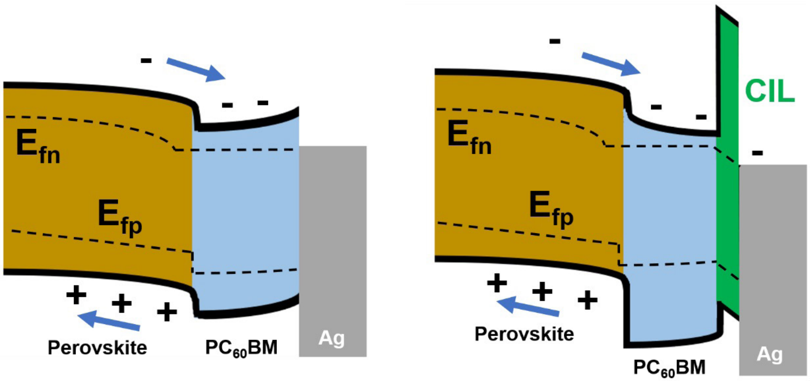

Figure 1. Schematic band diagram of a perovskite solar cell illustrating the electrical barrier formed between Ag electrode and PC60BM semiconductor without a cathodic interfacial layer (CIL)

In 2018, KSC researchers spanning many groups began to investigate the effectiveness of a bi-layered approach to the CIL in perovskite solar cells, augmenting the commonly used materials with doped metal oxides in order to improve performance beyond simply alleviating an electrical barrier. A collaboration with Avantama AG, Switzerland allowed researchers to specify an enhancement to commonly used TiO_2 nanoparticles for use as a CIL. Pristine TiO_2 is prone to surface point defects which act as non-radiative traps in photovoltaics. To overcome this property of the metal oxide, we chose niobium as a dopant, given its similar ionic radius to Ti and extra free electron – This allows for perfect substitution of Ti atoms with Nb, whilst contributing to a passivation of defect states and a higher overall electron mobility. It was found that this Nb-TiO_2 performed slightly better than the control device using the commonly used bathocuproine (BCP). An encouraging result, for sure, but not enough in isolation for an impactful publication.

Being empirical scientists, we were interested to see the effect of combining this new Nb-TiO_2 nanoparticle film with the BCP we intended to replace. This bilayer of inorganic and organic material showed dramatically improved solar cell fill factor compared to either layer when used in isolation (to our surprise!). To confirm our result, and to make sure we weren't kidding ourselves, we sent the materials to the lab of Prof. Henry Snaith at Oxford University, where they observed similar results: The bilayer outperforms the single layer. A detailed explanation for the working mechanism of this bilayer is currently under review in a follow-up article. In short, the work function of metal electrodes, when exposed to BCP, are brought into a more energetically favourable alignment with that of Nb-TiO_2, which itself is an efficient electron extraction material as previously described. The result is a highly ohmic and barrier-free contact between fullerenes and metal electrodes. Aside from better electrical performance, other advantages were observed: With Nb-TiO_2 acting as a barrier to metal diffusion into the perovskite (a cause of performance degradation) and an apparent effect of BCP reacting with, and further arresting the movement of the metal electrode, the operational stability of solar cells employing this bilayer was improved (Figure 2). This work was published in late 2019 in Energy and Environmental Science.[5]

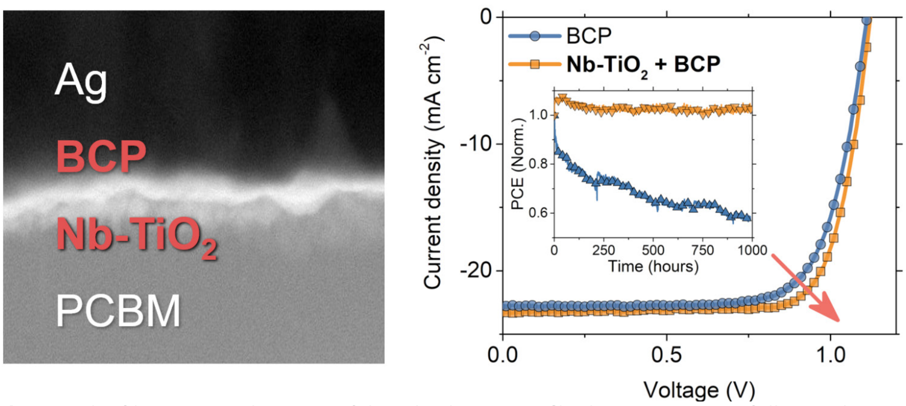

Figure 2. (Left) Cross-section TEM of the Nb-TiO2 + BCP film between PCBM fullerene layer and silver electrode. (Right) Current-voltage curve and stability performance of perovskite solar cells using the novel bilayer.

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Feature

Internships at KSC
Intern Insight — Alessandro Mirabelli

Alessandro Mirabelli studied Physics at the University of Bologna. In his last year and for his master's thesis, he joined KAUST Solar Center within the framework of KAUST's Visiting Student Research Progam (VSRP) - a unique program that offers highly qualified and motivated international students the exciting opportunity to conduct innovative research and gain hands-on research experience within a research group of their choice with faculty mentors. Here Alessandro describes his time with KSC and the highlights from the program:

Alessandro Mirabelli (front row, 3rd from left) together with KSC Prof. De Wolf's KAUST Photovoltaics Laboratory (KPV-LAB) group.

I had the chance to participate in the VSRP program offered by KAUST in the second half of 2019.

"To say that I had a blast would be an understatement."

During my stay, I had the privilege to experience first-hand what it means to conduct top class research. Not only thanks to the state-of-the-art equipment and facilities that KSC provided me with, but also due to the fantastic and knowledgeable members in Professor De Wolf's group from whom I was able to learn more than I could ever imagine. The environment that I found at KSC helped me discover the enjoyment of conducting research and has led me to consider in detail the option of pursuing a Ph.D. after the completion of my master's Degree.

Throughout the 6 months of my stay I was also able to travel to other countries. In December 2019, I was sent to Freiburg, Germany to obtain an important certification for our solar cells and, at the end of January 2020, I had the opportunity to fly to Toronto, Canada where I visited KSC collaboration partner, Professor Ted Sargent's group and conducted outdoor measurements. The crowning event of the internship was the possibility to publish with the group in a high-ranking scientific journal (under review) and together with the collaborative group from University of Toronto: DOI: 10.1126/science.aaz3691

However, my stay at KAUST was not all about work. Without any doubt the main reason I enjoyed my internship was all thanks to the wonderful people that I was able to meet. Not just from the research group that I was in, but also from other groups as well.

Overall, my time spent at KAUST was nothing but full of memorable moments. Looking back, I would definitely repeat this experience and would recommend this adventure to everyone.

KAUST offers talented undergraduate students a number of exciting internship opportunities, particularly via the KAUST Visiting Student Research Program (VSRP). The program offers qualified international students research experience, collaborating with our faculty in world-class facilities.

In addition to hosting VSRP students, KSC runs a one week intensive summer school comprising lectures from international experts and introductory laboratory sessions covering device fabrication and characterization techniques. After completing the KSC Summer School, participants can put their skills to use during an extended stay as an intern with a summer research project in the world-class KSC laboratories. Successful applicants will be awarded one of 15 stipends to cover travel, accommodation and living expenses. Enquiries: ksc@kaust.edu.sa

Faculty Focus

Interview with Professor Vincent Tung

Vincent Tung earned his bachelor and master degrees in Chemistry at the National Tsing-Hua University, Taiwan in 2006. Next, he joined the University of California, Los Angeles (UCLA) for Materials Chemistry and received his Ph.D. degree in Materials Science and Chemistry in 2010 with honor. He continued his research and became an Initiative for Sustainability and Energy at Northwestern (ISEN) postdoctoral research fellow at Northwestern University in 2011. In 2013, he joined the University of California, Merced (the newest UC campus opened in 2010) as Assistant Professor and held a joint appointment at the Molecular Foundry Division, Lawrence Berkeley National Lab. He is the recipient of an America Chemical Society Petroleum Fund New Doctoral Investigator Award, NSF CAREER Award, and the Research Excellence Early Career Investigator Award from the Graduate Council at the University of California. In 2018, he joined KAUST as Associate Professor of Materials Science and Engineering and became affiliated with the KAUST Solar Center in 2019.

Can you briefly describe the subject of your Ph.D. research?

My Ph.D. dissertation was about solid-state and surface chemistry of organic-inorganic hybrid composite for energy harvesting applications. In fact, the topic deviates significantly from my current research; that is, the epitaxy growth of atomically thin semiconductors for electronics and optoelectronics applications.

What lead you to enter academia?

Honestly speaking, I did not make up my mind until studying for my Ph.D. in Chemistry at UCLA. I dreamt about becoming an architect and am always fascinated by the timeless classic designs of Charles Eames' works; that is, arranging building blocks with a chosen sequence to afford sleek outlines and extended functionalities for the final products. This design principle was later manifested in the seminal discovery of self-assembly of functional nanostructures pioneered by Prof. George Whiteside. Specifically, these assemblies that are only held by the non-covalent intermolecular forces bear a close resemblance to the architectural design by Mr. Eames. I thus become immensely intrigued by the chemistry and applications of self-assembly of building blocks with different dimensionalities. These building blocks can be further tethered chemically, engineered systematically and combined synergistically to afford functional assembly with artistically subtle arrangement in a way that architecture cannot capture, and I found it fascinating. Under the guidance of Prof. Richard Kaner and Yang Yang, I was given free rein to explore self-assembly with the emerging graphene during my Ph.D. and realized academia is my aspiration. UCLA at that time offered perhaps the best solid-state chemistry and self-assembly of 2D layered materials in the country, paving the solid foundation for my later pursuits in academia.

When and how did you first become involved with KAUST?

It was a series of serendipities!! I first met the former VPR Prof. Jean M. J. Fréchet during my Ph.D. presentation at the Molecular Foundry Division, Lawrence Berkeley National Lab. I was told that he was about to leave UC Berkeley for KAUST. Even during our short conversation, I was intrigued by his witty explanation about joining KAUST where everything will be built from scratch (ground zero!). This was my first but very vague impression about KAUST. After joining the MSE department at Northwestern University as a postdoctoral research fellow, I came across VPR Fréchet again during an invited talk. This time, I was deeply impressed with the clear vision, scientific mission and groundbreaking research of KAUST even though I did not apply for a faculty position at that time. Finally, upon getting my tenure as Associate Professor at the University of California and Molecular Foundry Division, I was invited to talk in KAUST's MSE program by the former colleague, Director Lain-Jong (Lance) Li and again in front of VPR Fréchet along with the higher management team. I guess the third time was a charm! I was offered a position as Associate Professor to succeed to Lance's lab as he took over the director position of corporate research at the Taiwan Semiconductor Manufacturing Company.

Please tell us about your current research interests?

My current research focuses on exploring the novel epitaxy growth mechanism for wafer-scale synthesis of single crystalline, non-silicon monolayer 2D Materials with ultra-high mobility. The holy grail of next-generation electronics is to identify viable alternatives for non-Silicon electronics with synthetic scalability, industry compatible processability, crystallinity, and most importantly, ultra-high mobility. Chemical vapor deposition (CVD) provides an enabling platform to stitch dissimilar atoms into functional molecules where the periodic and repeated arrangement of lattices is perfect and extend throughout the entirety of the specimen without interruption. The result is the wafer-scale uniformity, and unparalleled electronic properties on par with the mechanically exfoliated benchmarks. Current projects straddle across (a) lattice orientations; (b) heterogeneous junctions; (c) dopants; (d) metal contacts; and (e) device integration, respectively. Notable applications include but are not limited to the internet of things (IoT), flexible electronics, and next-generation semiconductors.

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

Since joining KSC in 2019, we have participated in a Center Applied Research Funding (CARF) project. This project consists of different activities focusing on the investigation of new material systems and concepts for photocatalytic energy conversion. Of particular importance is the integration of the complementary strengths among KSC faculty members to explore a new class of highly efficient and corrosion-free silicon-based photoelectrochemical (PEC) though physical lamination of the multifunctional graphene coated van der Waals heterostructures. The main contribution from our group is the exploration of the recent discovery of catalytic transparency and corrosion-resilience of graphene coated van der Waals heterostructures as the electrolysis component for highly efficient silicon-based PEC cells. We aim at creating an atomically thin stack of highly efficient and electrochemically functional materials to complement the silicon-based photovoltaic cells to achieve self-sustainable water splitting.

What external collaborations are you involved in?

Thus far, my group maintains close ties with Lawrence Berkeley National Lab and Sandia National Lab through the awarded energy innovation initiatives funded by the Department of Energy (DoE), USA. The research project focuses on synthesizing next generation transition metal catalysts for clean fuels. Meanwhile, we started collaboration with Prof. Jeehwan Kim, Prof. Jing Kong and Prof. Tomas Palacios at MIT on transition metal dichalcogenide (TMD) based catalysis in 2017 and on TMD (opto)electronics in 2019 based on common interests. These groups have mutual understanding and had well-defined coordination for several projects in the past. We have reported the selective growth of vdW 3D/3D heterostructures, large area epitaxial growth of single crystal TMD nanoribbons, inverters and MoS_2-enabled flexible rectenna for Wi-Fi-band wireless energy harvesting. The collaboration with Director Lain-Jong (Lance) Li adds a unique perspective, both as a scientist and as a director of corporate research at Taiwan Semiconductor Manufacturing Company (TSMC), to the group. His strong connections in the semiconductor fields will grow and strengthen our ties with leading semiconductor companies as well as helping provide technical advice and evaluate the technological readiness and response through the possible technology transfer.

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

Being Associate Professor at KAUST allows you to establish a lab of world-class, high-impact fundamental research that is advancing the forefronts of nanoscience with full support! Specifically, the CoreLab and Solar Center provide researchers with access to expert staff and leading-edge, often one-of-a-kind, instrumentation to enable the understanding and control of matter at atomic scale in a multidisciplinary, collaborative environment. In parallel, by collaborating with the KAUST faculty's broad spectrum of core capabilities and expertise, principal investigators here increase the scope, technical depth, and impact of their research. Bold ideas, new capabilities and ambitious goals often emerge during a cup of coffee with your colleagues. As an inorganic chemist and materials science engineer, I have the privilege of working with a group of bright faculty members. Synthesis of atomically thin, two-dimensional (2D) materials can be guided through the density function theory (DFT) and characterized by the advanced imaging and spectroscopic characterizations, thus forming a solid feedback loop. More amazingly, the above mentioned capabilities are readily available within a 10-minute walking distance!

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

At a time of volatility in the cost of raw materials, I am eyeing additive manufacturing of metals with immense interest. By significantly slashing production costs and lead times for a wide variety of metal parts, additive manufacturing has the potential to transform the value chain in metal production and reshape the industry's power dynamics. However, before the technology matures and adoption spreads, there are significant challenges ahead. The key growth limitations are the availability of material, material science know-how, and low temperature processing. In parallel, hardware for driving Artificial Intelligence (AI) through atomically thin circuit will be on the targeted list.

What advice do you have for young scientists?

Failure is the fertile ground for success! Don't be afraid of committing mistakes but thinking bold and beyond, and never stop challenging yourself! Stay curious, and observant will help turn failure and crisis into success and opportunity. Last but not least, your time is limited, so don't be trapped by dogma. Having the courage to follow your heart, knowledge and intuition along the path toward research excellence.

What do you like to do beyond research?

I enjoy watching baseball in Fenway Park at Boston when I was still an Assistant Professor in the US. I am also very much into architecture design and mid-century furniture. Notable architect and designers include but are not limited to Charles Eames, Zaha Hadid, and Kengo Kuma. When I am not reading, I enjoy taking my Audi RS5 to drive along the Pacific Highway 1 in California.

What was your motivation to join KAUST?

The diverse and inclusive culture of KAUST, e.g., the source of innovative ideas and research excellence, has been the major driving force for me to leave California for KAUST. Diversity can refer to the variety of personal experiences, values, and worldviews that arise from differences of culture and circumstance. It is such differences that drive innovations and spark discoveries beyond the barriers of race, ethnicity, gender, age, religion, language, abilities/disabilities, socioeconomic status, and geographic region, and more. In parallel, I was very fascinated with and impressed by the missions of the Solar Center that strive at providing innovative solutions to address pressing energy challenges. Thus, it was a no-brainer for me to join KAUST when opportunity emerged. I also embrace the idea of one-campus-for-all, where you live, study, research and enjoy recreation in this enormous college town! Last but not least, it is important to emphasize that KAUST is one of only a handful places in the world where clear visions and shared expertise, inclusiveness and diversity converge to pursue the research excellence.

Please tell us about your five year scientific vision.

The path from breakthrough discovery to transformational industry applications can be a long, circuitous one. Often the first rush of possibility is followed by decades of development, refinement and ultimately deployment. The precedent may gloom the prospect of 2D layered electronics and optoelectronics. However, building up on the rich research and widespread experimentation of silicon semiconductors, in the next five years, we may witness the next wave of innovation in both materials and manufacturing for next generation non-silicon electronics and optoelectronics. Importantly, this does not necessarily mean that the emerging 2D layered materials will make silicon obsolete. Yet, the scalable implementation of 2D layered materials will complement but not supplant silicon technology to further transcend the innate limitation of Moore's Law.

What do you see as significant challenges and how will you address them?

Development of new-generation hardware to drive artificial intelligence (AI) through machine learning; material innovation in synthesis and recycle to negate the scarcity in natural resources; Water desalination through more efficient renewable energy resources; Starshot breakthrough with audacious goals of sending spacecraft beyond our Solar System to a neighboring star; Nuclear fusion for the ultimate solution to addressing the ever-increasing and pressing energy needs. These are the immediate challenges surfacing in my mind, but these items are definitely just the tip of the iceberg. To take up these challenges, a concerted, joined-up and forward-thinking efforts from academia, businesses and government can deliver the positive disruption for which the Kingdom of Saudi Arabia and KAUST are relatively well positioned. This will forge a link between cutting-edge research and commercial success to drive innovation. In parallel, investing in new and existing talent through establishing the recruitment pipeline will be critical, too.

The Solar Landscape in the Kingdom of Saudi Arabia — Faisal Wali

Sakaka solar project with the capacity of 300MW is the first mega solar power project in Saudi Arabi"(image courtesy of ACWA power)

Saudi Arabia is considered to be one of the world's largest oil producing countries but at the same time it has a rapidly growing population putting increasing pressure on the country's non-renewable hydrocarbon resources. Therefore, the Kingdom has decided to find alternative yet sustainable and reliable sources of energy to generate electricity and produce desalinated water, reducing the consumption of the nation's fossil fuel reserves. A balanced mix of alternative and conventional energy was also found to be strategically important to long-term prosperity, energy security and Saudi Arabia's leading position in the global energy market. Therefore, in 2010, the Kingdom of Saudi Arabia established King Abdullah City of Atomic and Renewable Energy (KACARE) with the fundamental aim of building a sustainable energy solution. KACARE was given the task to introduce alternative resources using both nuclear and renewable energy, while offering numerous opportunities for national and international private sector companies to grow their business in the Kingdom, and Saudi citizens to improve their knowledge and skills. In 2013, KAPSARC (King Abdullah Petroleum Studies and Research Center) was founded as a non-profit institution for research into global energy economics. KAPSARC mainly develops economic frameworks to help achieve effective alignment between energy policy objectives and outcomes for the Kingdom.

In 2016, the Kingdom of Saudi Arabia announced ambitious and inspiring plans to develop all sectors by introducing "Vision 2030". In 2017, under the umbrella of Vision 2030, a comprehensive program; the National Industrial Development and Logistic Program (NIDLP) was announced to transform the Kingdom of Saudi Arabia into a leading industrial powerhouse and a global logistics hub. This program focuses on four major areas including industry, mining, energy and logistics. In the energy sector, NIDLP aims to enhance power supplies, improve the electricity sector in general, and increase the share of the renewable energy sector. To focus further on the renewable energy sector, the National Renewable Energy Program (NREP) was initiated in 2017. NREP aims to substantially increase the share of renewable energy in the total energy mix, targeting the generation of 9.5GW by 2023.

To achieve NREP goals, within the Ministry of Energy the Renewable Energy Project Development Office (REPDO) was established in 2017. REPDO was assigned the task of collaborating with the Kingdom's existing energy sector stakeholders, including KACARE, KAPSARC, The Electricity and Cogeneration Regulatory Authority (ECRA), and the Saudi Electricity Company (SEC). REPDO brought more unified leadership to the Kingdom's capabilities in renewable energy research, measurement, data acquisition, regulation, pre-development and, primarily, tendering for all the new projects. Saudi Arabia awarded its first NREP solar PV project of 300MW in February 2018. ACWA Power (a local Saudi company) won the bidding with the price of 2.36 $ cents per kilowatt hour and has recently completed the project. In 2019, Saudi Arabia awarded its second NREP project which was a wind energy project of 400MW and it has broken a new world record achieving the lowest LCOE (levelized cost of energy) for onshore wind power, closing at 1.99 $ cents per kilowatt hour. In April 2020, REPDO invited bidding for its third round under NREP, comprising four Solar PV projects with a combined generation capacity of 1,200 megawatts (MW). The projects, which are located on four sites in the central region of the Kingdom, will be:

Category A (smaller) projects: Wadi Ad Dawasir 120 MW Solar PV and Layla 80 MW Solar PV.

Category B (larger) projects: Ar-Rass 700 MW Solar PV and the Saad 300 MW Solar PV.

To meet the growing demand for solar energy in the Kingdom, the government has launched a number of other initiatives in parallel. This includes the establishment of the National Industrial Clusters Development Program (NICDP) which is being led by the "Industrial Clusters" team, working under the direction of the Ministry of Energy. The NICDP program is mainly focusing on creating new industries to diversify the economy to meet Vision 2030 ambitions. Considering the growth in the PV sector, Industrial Clusters is keenly exploring opportunities to localize the renewable energy sectors. Desert Technology (located at Jeddah) is one of the first and most advanced PV module manufacturers in the Kingdom of Saudi Arabia with a state-of-the-art automated assembly line with 110 MW/year capacity. It is important to mention that the REPDO bidding process provides an advantage to those industries that promote and benefit from the local resources. Furthermore, the GCC Electrical Testing Laboratory has been established which aims to provide global leadership in testing, inspection, calibration, certification and innovation for the Power Sector in general. King Salman Energy Park (SPARK) is also being developed to capture the full economic value from energy-related goods and services in Saudi Arabia and throughout the region. SPARK is attracting industrial investors in five strategic sectors: Upstream, Downstream, Petrochemicals, Power, Water and Wastewater. SPARK will provide the supply chain facilities to the investors in these sectors to fill the massive gap for locally produced goods and gain a lasting competitive advantage. Last but not least, NEOM is being built on the Red Sea in northwest Saudi Arabia as a New Future city with the ideation of "a place on earth like nothing on earth". One of the most interesting aspects of NEOM is that it will build a 100% renewable energy system based on solar and wind power. NEOM also aims to build new industries and drive the next wave of the energy transition by producing green hydrogen.

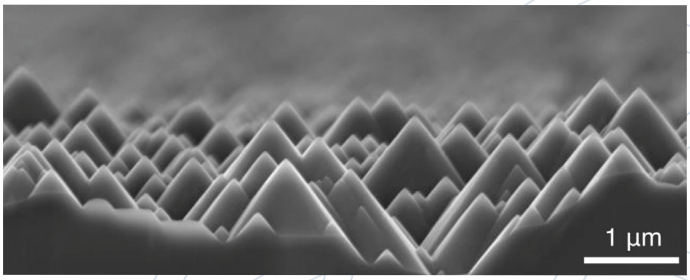
These exciting advancements in the Kingdom's renewable energy sector emphasize the significance of the role KSC has to play in Saudi Arabia. The Center engages with the above mentioned government, semi-government and private entities to understand their major challenges. These challenges include knowledge development, developing energy policy, establishing PV standards for the Middle East, setting new testing norms for specialized PV products, supporting the growth of local PV industries, aiding the selection of the right PV technology for the region, and more importantly researching and developing new technologies to achieve the ambitions of Vision 2030.

KSC Highlight Paper

"Growing perovskites on textured silicon: a new path towards commercialization of perovskite/silicon tandems" — Erkan Aydin & Michele De Bastiani

Perovskite/silicon tandem solar cells are an emerging photovoltaic technology that promise power conversion efficiencies beyond the single-junction limits of silicon solar cells, at competitive prices. Conventional solar cells employ one semiconductor to convert sunlight into electricity. The theoretical efficiency limit of this type of power conversion is 33%. By stacking two semiconductors in a "tandem" solar cell (for instance using halide perovskites onto silicon), this power conversion efficiency limit can be pushed to 44%.

Nowadays, several academic groups have reported tandems with power conversion efficiencies >25% for lab-scale devices (~1cm^2), and for several years Oxford PV has developed such solar cells, aiming at large-scale deployment of this technology. However, so far, mostly front side flat devices are preferred due to the ease of transferring documented perovskite-processing knowledge onto planar glass substrates.



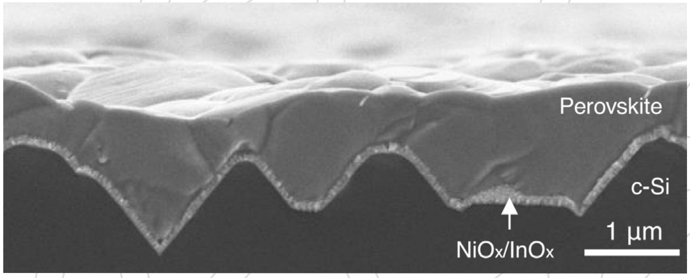


Figure 1: Cross section scanning electron microscope images of the textured silicon bottom cells before (top) and after (bottom) perovskite coverage.

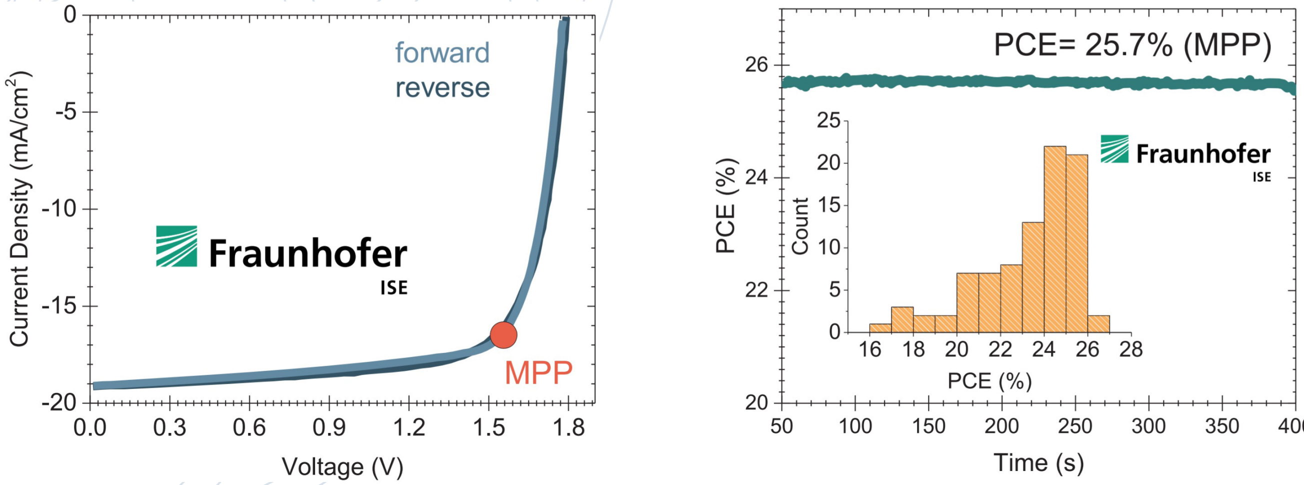


Figure 2: Certified power conversion efficiency results for the perovskite/silicon tandem solar cells. .

Utilizing textured-silicon wafers improves light-capturing in the silicon bottom cells by increasing the near-infrared response, and enables efficient charge extraction.[1] In addition, textured bottom cells bring industrial relevance to perovskite/silicon tandem solar cells since they simplify the overall process, reduce the wafer preparation cost, and do not require high-cost equipment investment. However, well-established solution-based material systems often fail on textured substrates. The main issue with solution processing is the lack of conformal coverage on the rough surfaces. In the recent publication in Science Magazine, KAUST Photovoltaics Laboratory (KPV-LAB) at KSC, in a collaboration with the Sargent Group at the University of Toronto, developed a unique solution, achieving end-to-end coverage of the pyramidal textures. With this study, for the first time in literature, the team grew the perovskite layers on textured silicon bottom cells using the solution-based spin-coating technique. The team envisage that this breakthrough will accelerate perovskite/silicon tandem research significantly, since the spin-coating technique is readily available in several solar cell research labs and there is a rich library for high degree control of the properties of the perovskite absorbers.

In addition to the novel perovskite processing technique reported here, the research team explored self-anchored 1-buthanethiol passivation on the perovskite surfaces, to enhance the diffusion length and further suppress phase segregation. The team also found that a micrometer-thick perovskite covering on pyramids enhances the charge collection in these thick films through improved drift and diffusion of photogenerated carriers. These combined enhancements enabled an independently certified power conversion efficiency of 25.7%. These devices exhibited negligible performance loss after a 400-hour thermal stability test at 85°C and also after 400 hours under maximum power point tracking at 40°C.

Currently, within the scope of the KAUST funded near-term grand challenge project titled as SCOPES - Scaled Monolithic Perovskite / Silicon Tandem Solar Cells, KPV-LAB is working on the scale-up of perovskite deposition technology to meet the current industrial size standards for the devices, first as a proof of concept, and then to pilot-line scale at a later stage.

(l-r) Erkan Aydin (KSC), Yi Hou (University of Toronto) & Michele De Bastiani (KSC) are part of an international team that has designed a new tandem solar cell, combining industry standard silicon manufacturing with new perovskite technology. (Photo: KAUST)

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This year's conference coincided with "International Day of Women in Science". Pictured are just some of the women in science who are making an impact in the field of solar energy research around the globe and who we were proud to host.

KAUST Research Conferences provide a unique platform for scientific exchange

From February 10-12, KSC hosted the 'KAUST Research Conference: Emerging Concepts in Solar Energy Conversion – from Computation to Implementation' chaired by Professors Frédéric Laquai and Udo Schwingenschloegl. As the COVID-19 pandemic spread, we had to rapidly adapt the event due to various global travel restrictions. Nonetheless, we were delighted to welcome 38 speakers to KAUST from across the Kingdom of Saudi Arabia and around the globe and our thanks go out to them for their willingness to travel during such unprecedented times.

KSC is dedicated to bringing together faculty to work on joint multidisciplinary projects. In particular, the center gives funding support to the combined efforts of research groups working on silicon-perovskite tandem solar cells and high-efficiency and stable organic solar cells within the framework of its CCF funded programs. The conference enabled us to bring together additional international experts from academia and industry to contribute to discussions in these strategic areas and spark new collaborative ideas.

Computational approaches in PV material design, aligned with the Center's and KAUST efforts to include machine learning and AI in the development of novel materials for PV applications, as well as photocatalytic carbon dioxide reduction and water splitting, provided additional conference focus topics.

This year's event also placed particular emphasis on in-Kingdom activities in renewable energy generation, in line with KSC's efforts to establish new and strengthen existing links with Saudi Arabian researchers and institutions to jointly address the Kingdom's needs in the area of photovoltaic energy generation within the framework of the country's Vision 2030 strategy. In particular, large-scale PV deployment and PV stability, an important topic for the Kingdom given its particular environment (illumination, temperature and dust), were featured. In this regard, we were delighted to bring together delegates from Ministry of Energy, KACST, ACWA Power, KA-Care, KFUPM, REPDO, University of Jeddah, Taibah University and King Abdulaziz University.

KSC organized conferences always place emphasis on providing a platform for young scientists to enter into dialogue with established scientists and engineers and for them to gain exposure by presenting their work to a global audience. This year was no exception. During dedicated young speaker sessions, a jury comprised of international faculty was impressed by the talented presenters, awarding Taylor Moot from the National Renewable Energy Laboratory, USA, (NREL, postdoctoral fellow) this year's RSC Materials Horizons Young Scientist Presentation Award. We also had a great turn out at the poster session where attendees were presented with over 30 research posters from young scientists. RSC Journal of Materials Chemistry A Poster Prizes were awarded to Areej Al-Zahrani (KAUST / Al Baha University, Ph.D. student), Jules Bertrandie (KAUST, Ph.D. student) and Sean Dunfield (NREL, postdoctoral fellow).

Eight international young scientists were awarded travel scholarships to attend the conference and students from universities within the region were invited to attend.

The sessions dedicated to young scientists were rounded off with a career development panel discussion during which Prof. Elizabeth von Hauff (VU Amesterdam), Dr. Nancy M. Haegel (Center Director for the Materials Science Center, NREL) and Dr. William Tumas (Assoc. Laboratory Director, NREL) joined KSC Professors Iain McCulloch, Thomas Anthopoulos and Frédéric Laquai to give insights into their personal career paths, provide application and interview tactics, and field questions from the floor.

KSC would like to thank the KAUST Office of Sponsored Research (OSR) for funding the event which underpins our commitment to solar energy in the region, the advancement of multidisciplinary research and dedication to the education and development of young scientists.

Congratulations: Iain McCulloch receives multiple honors

KSC Center Director, Professor Iain McCulloch received an unprecedented series of honors in spring 2020. In April the European Academy of Sciences awarded Prof. McCulloch the 2020 Blaise Pascal Medal in Materials Sciences. This was quickly followed by the announcement in May that Prof. McCulloch had been elected a Fellow of the Royal Society. The Royal Society, founded in 1660, is both the United Kingdom's national science academy and a fellowship of the world's pre-eminent scientists and researchers.

Iain McCulloch

> Obviously it is a huge honor to be elected as a Fellow of the Royal Society," said McCulloch. "I know it is a cliché, but it is completely true that science is a team endeavor, and success arises when you are lucky enough to work with great team members, colleagues and collaborators."

In June this run of accolades was rounded off by Prof. McCulloch winning the Royal Society of Chemistry's Interdisciplinary Prize for advances made in the design, synthesis and innovative application of functional materials in optics, electronics and energy.

Derya Baran welcomed into the ranks of the Global Young Academy

In June KSC's Assistant Professor Derya Baran was selected to join the Global Young Academy (GYA), the first member to represent a Saudi Arabian institution.


Derya Baran

> Joining GYA was important to me, enabling me to make a change and be influential on a global scale. I think that GYA would be the perfect platform to debate and discuss ideas with like-minded, enthusiastic and dynamic members of the future." said Prof. Baran.

The GYA aims to give a voice to young scientists by connecting and developing talents from around the world to reduce the science gap between low, middle, and high-income countries. Prof. Baran is one of 40 new members from 30 different countries invited to join the academy.

Save the date ! *KAUST Research Conference:*

Accelerating Solar Energy Research towards meeting Vision 2030 Goals
February 22-24, 2021

Ph.D. Profile

Esma Ugur

Esma Ugur is a fourth-year Ph.D. student working in Prof. Frédéric Laquai's Ultrafast Dynamics Group within the KAUST Solar Center (KSC). Her research mainly focuses on the understanding of charge carrier transport and recombination processes in metal halide perovskite absorber layers and perovskite/selective layer interfaces.

Before joining Prof. Laquai's group, Esma obtained her B.Sc. degree in Physics from the Middle East Technical University in Ankara, Turkey and completed her M.Sc. at the TOBB University of Economics and Technology. During her undergraduate studies she concentrated on solid-state physics and became particularly interested in photovoltaic devices. When she decided to continue her career in this field, she applied to carry out a Ph.D. in Prof. Frédéric Laquai's group to extend her knowledge towards understanding the losses in devices. 'I first came to KSC through KAUST's Visiting Student Research Program (VSRP). Becoming familiar with KSC during this period was a great experience. This short visit also made me more comfortable at the beginning of my Ph.D. since I already knew the direction I wanted to go. Also, I had a chance to experience life at KAUST before starting my Ph.D. journey.' said Esma.

During her Ph.D., Esma has gained extensive experience in perovskite solar cell fabrication and managed to obtain devices with a power conversion efficiency exceeding 22% using her modified 2-step interdiffusion process. Moreover, she actively contributed to KSC perovskite baseline studies which aimed to achieve solar cells with efficiencies above 20%. 'In addition to solar cell fabrication and characterization, in the Ultrafast Dynamics group I have had the chance to learn the advanced spectroscopy techniques and deep analysis which helped me a lot in understanding the perovskite solar cells' working mechanism.' she said, continuing 'Now, with the help of the experiences I had in the KSC and Ultrafast Dynamics group, I am planning to continue my academic carrier as a postdoc to expand my knowledge with different solar cell materials.'


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Esma Ugur conducting her research within the Ultrafast Dynamics Group's laser facilities.

KAUST Solar Center

Contact Us

Website
ksc.kaust.edu.sa

E-mail:
ksc@kaust.edu.sa

SOCIAL MEDIA

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