ACS Energy Letters

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ENERGY FOCUS

Women Scientists at the Forefront of Energy Research: A Virtual Issue, Part 3

Cite This: *ACS Energy Lett.* 2021, 6, 58−68

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This is the third part of a series that recognizes women energy researchers who have published new advances from their laboratories in *ACS Energy Letters.* The two previous virtual issues of this series were published in January (https://pubs.acs.org/doi/10.1021/acsenergylett.9b02695) and February 2020 (https://pubs.acs.org/doi/10.1021/acsenergylett.0c00083). *In this virtual issue we highlight contributions from 20 new scientists.* We have compiled one representative paper from each of these scientists to highlight a recent contribution. Their inspirational stories and advice to newcomers in the field should provide motivation to advance the scientific research in energy conversion and storage. Through their personal reflections, these researchers discuss the successful career paths they have taken to become leaders in the scientific community. It is our hope that these personal reflections can motivate many young researchers to tackle challenges in clean energy.

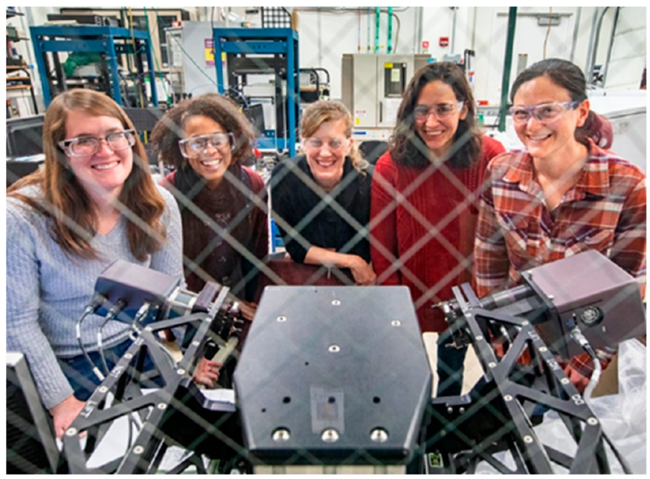
We would like to thank Katerina E. Aifantis, Veronica Augustyn, Mei Cai, Kyoung-Shin Choi, Nam-Soon Choi, Maria Forsyth, Naomi S. Ginsberg, Cristina Pozo-Gonzalo, Julia W. P. Hsu, Eunjoo Jang, Sofia Masi, Delia Milliron, Lena Kourkoutis, Pooi See Lee, Maria Antonietta Loi, Lauren E. Marbella, Jovana V. Milić, Adele C. Tamboli, Emily Warren, and Hongli (Julie) Zhu for their contributions to this virtual issue. (Please note that many of the photos included here were taken prior to the Covid lockdown.)

■ UTILIZING SITE DISORDER IN THE DEVELOPMENT OF NEW ENERGY-RELEVANT SEMICONDUCTORS

Rekha R. Schnepf, Jacob J. Cordell, M. Brooks Tellekamp, Celeste L. Melamed, Ann L. Greenaway, Allison Mis, Geoff L. Brennecka, Steven Christensen, Garritt J. Tucker, Eric S. Toberer, Stephan Lany, and Adele C. Tamboli

ACS Energy Lett. 2020, 5 (6), 2027−2041 (Focus Review)

DOI: 10.1021/acsenergylett.0c00576



(Left to right) NREL researchers Annie Greenaway, Riley Whitehead, Kaitlyn VanSant, Rekha Schnepf, and Adele Tamboli among some of NREL's photovoltaic materials characterization tools. (Photo courtesy Werner R. Slocum (NREL, October 2019))

Scientific research is a tool that can be used to make the world a better (or worse) place, and considering the possible outcomes of my research has been a central driver in my career choices. At the National Renewable Energy Laboratory (NREL), I have found like-minded scientists who are inspired by our lab's mission to advance renewable energy. At NREL, we consider the energy impact of our work first and then pursue the scientific knowledge needed to realize that impact. Every day, I ask myself how I am making the world a better place: What impact might our research have on combatting climate change? How can we most effectively transfer our discoveries to deployment? Equally important is to consider how we approach the practice of science. How are we removing barriers to success and improving diversity, equity, and inclusion in the scientific community and in my workplace? How can we draw out the strengths of our team members and enable them to be the best, most empowered scientists they can be?

With my research team, I have been lucky to participate in the full pipeline of scientific research, from fundamental questions such as how the microscopic structure of a material

Received: November 16, 2020
Accepted: November 18, 2020

influences properties, to on-sun testing of packaged photovoltaic devices (we even sent a tandem solar cell to the international space station!). My work at NREL began with a focus on lowering the cost of multijunction photovoltaics to enable higher panel efficiencies while maintaining scalability. However, it has expanded to include work on light-emitting diodes for more energy efficient illumination, solar fuels, and discovery and development of new materials to enable all of these energy applications and more.

Adele C. Tamboli Researcher V-Materials Science

ELECTROLYTE-ADDITIVE-DRIVEN INTERFACIAL ENGINEERING FOR HIGH-CAPACITY ELECTRODES IN LITHIUM-ION BATTERIES: PROMISE AND CHALLENGES

Koeun Kim, Hyunsoo Ma, Sewon Park, and Nam-Soon Choi

ACS Energy Lett. **2020**, 5 (5), 1537−1553 (Focus Review)
DOI: 10.1021/acsenergylett.0c00468

Nam-Soon Choi (Photo courtesy of Nam-Soon Choi)

Electrolyte systems—my current field of research—create complex interactions with electrodes in a battery and significantly affect the battery's performance. The reason I was inspired by the not-so-simple mechanism of battery electrolytes and continued my research in this field can be traced back to 2004, when I was working as a senior researcher after completing my doctoral program, at the R&D center of Samsung SDI—a company specializing in battery technology. I took part in a project for developing high-energy batteries with a team of experts responsible for the design, manufacture, and evaluation of battery systems, and our research focused not only on the characteristics of electrolytes but also on the suitability of the developed electrolytes toward electrodes and manufacturing process. Through this process, I developed fluoroethylene carbonate, which is the most potent additive for improving the performance of high-capacity Si anodes. This experience of working with industry experts on the project enabled me to evolve material development strategies for overcoming the limitations of existing electrolytes.

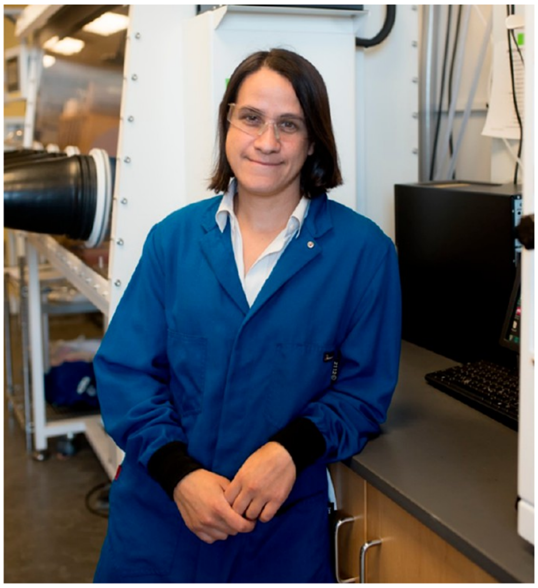
Based on personal experience, I would like to tell younger researchers in the field the following four points which I consider important: (1) For practical use of a new material through R&D, "it is more important to see the woods instead of the tree." (2) You must have the flexibility to accept that your research outcome may not be perfect. Developing a new material and accurately interpreting the functions of that material can only be achieved through continued research and taking into account the new advances made by several researchers. (3) The same material may vary in its performance depending on the system manufacturing and evaluation conditions. Therefore, transparency must be maintained during research. (4) Although research focusing on performance improvement is important, efforts to understand the degradation behavior of systems and materials could be a foundation for scientific advancement.

Nam-Soon Choi Associate Professor

INFLUENCE OF CRYSTALLINE AND SHAPE ANISOTROPY ON ELECTROCHROMIC MODULATION IN DOPED SEMICONDUCTOR NANOCRYSTALS

Sungyeon Heo, Shin Hum Cho, Clayton J. Dahlman, Ankit Agrawal, and Delia J. Milliron

ACS Energy Lett. 2020, 5 (8), 2662−2670 (Letter)
DOI: 10.1021/acsenergylett.0c01236



Delia Milliron in her lab at The University of Texas at Austin (Photo courtesy Rebecca Wunderlich)

Intellectually, I fell quickly and completely for materials chemistry and the quest for connections tying molecular and atomic scale phenomena to macroscopic, useful properties. In my undergraduate years, through course work and research, I explored my interest in different types of material properties (mechanical, biochemical, and optoelectronic) and research approaches (synthesis, theory, and devices) that I might pursue as my career progressed. Around my senior year, I realized that the research questions that thrilled me had great relevance in enabling a clean energy and sustainable future. I started then on a personal mission I have pursued ever since, to answer questions underpinning technologies and to open doors to new solutions that can help overcome challenges facing renewable energy generation and storage and efficient energy use. Having had the privilege of being immersed in outstanding research institutions ever since, I have learned more about these challenges from those around me whose perspectives are informed by decades of experience in relevant specialties ranging from interfacial chemistry, to nanocrystals, building technologies, membrane separations, or colloidal assembly. With so many ideas that could be pursued we self-critically try to focus on problems and questions that *matter*, that could unlock something significant, or help us refine our formulation of the next question, so that ultimately we can help solve some of the biggest problems in the world—energy problems. Following this path with my group and collaborators, I've had the opportunity to pursue research with relevance to photovoltaics, energy-saving smart windows, batteries, fuel cells, and more.

Delia Milliron Professor

PHOTOELECTROCHEMICAL NITROGEN REDUCTION TO AMMONIA ON CUPRIC AND CUPROUS OXIDE PHOTOCATHODES

Youn Jeong Jang, Ann E. Lindberg, Margaret A. Lumley, Kyoung-Shin Choi
ACS Energy Lett. 2020, 5 (6), 1834−1839 (Letter)
10.1021/acsenergylett.0c00711

Kyoung-Shin Choi (Photo courtesy of Kyoung-Shin Choi)

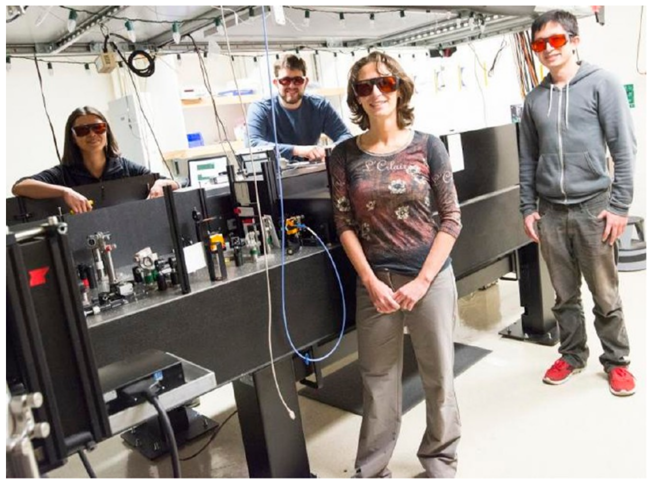
I started working on photoelectrochemical water splitting as a postdoctoral researcher. At that time, I found that only a limited number of semiconductor electrodes had been investigated as photoelectrodes, which was surprising, given the vast number of promising semiconductor materials available. I realized that the study of semiconductor photoelectrodes was limited partly because many semiconductors, especially more complex semiconductors, can be prepared only as powders and using powders to prepare high-quality photoelectrodes can be challenging. Thus, when I started my research group as an assistant professor, I decided to develop solution-based electrochemical methods to grow semiconductor films directly on the underlying conducting substrate. The only problem was that I was trained as a solid-state chemist and my understanding of electrochemistry was limited. Starting an independent career based on a method that I had not specialized in was surely concerning. However, I imagined the positive impact I could make if I were successful, and I proceeded with my plan. At the beginning of my career, there were many days when I doubted my decision, but with perseverance I was able to make my ideas work. In fact, I have found that the combination of solid-state chemistry and electrodeposition has made my group uniquely positioned to make distinctive research contributions not just to solar fuels but also to other energy-related sciences that require solid-state electrode materials.

My advice to young researchers: In order to build your own unique research project, it may be necessary to pursue an unexplored research path. However, do not be too afraid. With hard work and tenacity, you will soon become an expert in a new field. (No one is born as an expert.) I find that the joy and excitement I get from my research is always proportional to the uncertainty I initially had about my idea!

Kyoung-Shin Choi Professor of Chemistry

CARRIER DIFFUSION LENGTHS EXCEEDING 1 μm DESPITE TRAP-LIMITED TRANSPORT IN HALIDE DOUBLE PEROVSKITES

Milan Delor, Adam H. Slavney, Nathan R. Wolf, Marina R. Filip, Jeffrey B. Neaton, Hemamala I. Karunadasa, and Naomi S. Ginsberg
ACS Energy Lett. 2020, 5 (5), 1337−1345 (Letter)
DOI: 10.1021/acsenergylett.0c00414



Prof. Naomi S. Ginsberg with group members (left to right) Cathy Wong, Ben Cotts, and Hao Wu in her spectroscopy laboratory (Photo by Kelly Owen, Berkeley Lab)

My commitment to the physical sciences was truly solidified as I began learning about light−matter interactions during an undergraduate research project in NMR that motivated a first career shift from biomedical engineering toward atomic and optical physics. My interests in this area first led me to a Ph.D. studying the fluid properties of and potential for quantum information storage in cold atomic gases bottled up in a vacuum chamber. All the while, I cultivated every manner of indoor and outdoor garden that a graduate student might manage—one of my saddest student days involved saying goodbye to a beautiful, variegated croton that could not move with me when I graduated. The way that this plant had materialized from a combination of whatever was in the soil, CO_2, and sunlight totally awed me, so when I came across the possibility to combine studying photosynthesis and light−matter interactions, I was sold! My appreciation for energy science has since deepened and broadened, and my curiosity to explain how light energy can be transferred, transduced, and translated in complex materials—photosynthetic or otherwise—has been a driving force in my independent research ever since. I delight in applying my earlier rigorous training on far more controlled, isolated systems to the study of more disordered materials that exist outside of that vacuum chamber and that could make a difference in our collective future! There are an infinite number of tantalizing fundamental problems to be solved in energy science, and we might as well be learning about the core underpinnings of light−matter interactions through the lens of conservation and renewable energy rather than in a more abstract way. If only I had had the confidence to make such statements 20 years ago... My advice to the student I was and to those that come across this narrative is to invest in discovering and nurturing your authentic self and follow its voice. Do not let it be drowned out by all of the other voices that may seem to be speaking more loudly to you. Knowing and sustaining yourself is the most important step down the path to contributing to a sustainable world.

Naomi S. Ginsberg Assoc. Professor of Chemistry and Physics

■ NEGATIVE THERMAL QUENCHING IN $FASnI_3$ PEROVSKITE SINGLE CRYSTALS AND THIN FILMS

Simon Kahmann, Olga Nazarenko, Shuyan Shao, Oleh Hordiichuk, Mikaël Kepenekian, Jacky Even, Maksym V. Kovalenko, Graeme R. Blake, and Maria A. Loi

ACS Energy Lett. 2020, 5 (8), 2512−2519 (Letter)
10.1021/acsenergylett.0c01166

Prof. Dr. Maria Antonietta Loi (Photo courtesy Sylvia Germes)

I have always been fascinated by light and by optical properties of materials. When I was a master student, I joined a group specialized in optical spectroscopy (Bongiovanni and Mura group at the University of Cagliari) also because while visiting their laboratory I was totally amazed by the beauty of the many lasers' colors and the photoluminescence of the materials investigated. However, I was not feeling satisfied when friends and family were asking me "What is the purpose of your research?". At that time my story was that we were looking for better materials for displays. While I was finding my day-to-day work very fulfilling (so much so that I continued with a Ph.D.), I was not convinced about the ultimate motivation of my work. When looking for a postdoctoral position I was checking several fields that could have a brilliant future... but it was only when I met Serdar Sariciftci at a conference that I got convinced that the development of a new solar cell technology was the topic that I was looking for. I could continue working with light, with new interesting semiconductors...; moreover, the application was not only challenging but also extremely relevant to society.

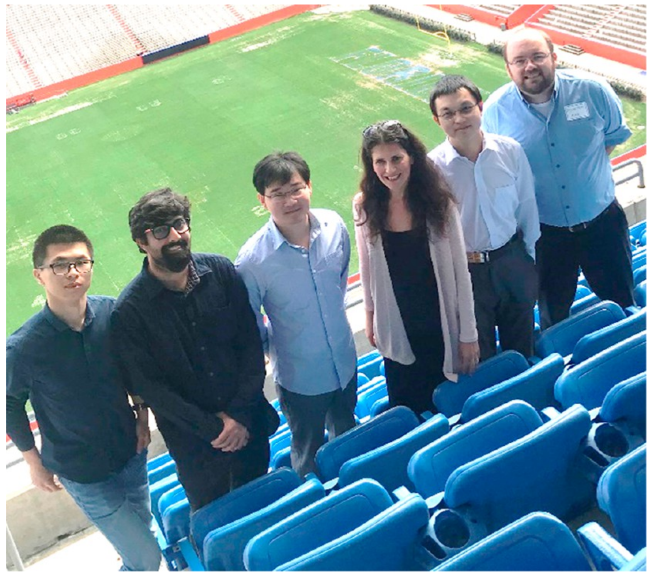
Later on, when building my group at the University of Groningen, I decided that solar cells were one of the topics I wanted to work on, but not the only one. If we want to stop global warming and make society transit toward renewable energies, we should also develop technologies to save energy...; therefore, we should develop efficient light-emitting diodes and better or different types of electronics which use less energy. This is my motivation and my way of contributing to society as a solid-state physicist fascinated by light.

Maria Antonietta Loi Full Professor, Chair of Photophysics and OptoElectronics

■ CONCENTRATION-GRADIENT PRUSSIAN BLUE CATHODES FOR Na-ION BATTERIES

Pu Hu, Wenbo Peng, Bo Wang, Dongdong Xiao, Utkarsh Ahuja, Julien Réthoré, and Katerina E. Aifantis

ACS Energy Lett. 2020, 5 (1), 100−108 (Letter)
DOI: 10.1021/acsenergylett.9b02410



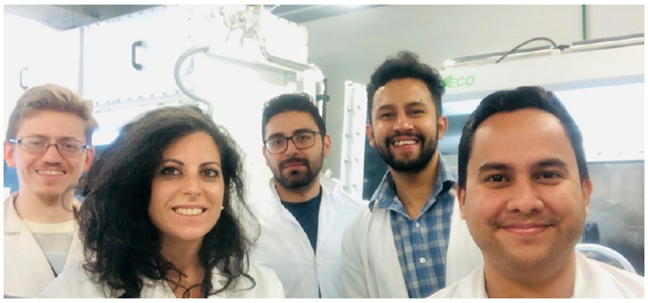
Left to right: Dr. Fei Shuang, Utkarsh Ahuja, Prof. Pu Hu (now Wuhan Institute of Technology), Prof. Katerina E. Aifantis, Dr. Bo Wang, Prof. Bryan Khur (now Sweet Briar College). (Photo courtesy Katerina E. Aifantis)

My continuous interest and love for energy storage is not only its scientific beauty but also the impact it has in our environment. Currently, my research focuses on the fabrication of novel electrode materials and understanding their performance through modeling and experiments, with support from the USA National Science Foundation. When I first started working on Li-ion batteries, as a 17-year-old undergraduate, my motivation was purely from a mechanics point of view, as I was trying to understand my father's (Prof. E.C. Aifantis) pioneering work in gradient plasticity/elasticity. I was fascinated to learn that the limiting factor in commercializing Si anodes was that they experience an over 300% volume expansion upon lithiation. With limited knowledge on the underlying electrochemical processes, I was able to develop the first design criteria that predicted mechanically stable high capacity anode configurations. I was immensely surprised and enthused when I noticed that my work was being accepted and used by the electrochemistry community. A turning point was meeting Professors Vasant Kumar (Cambridge), Aishui Yu (Fudan), and of course Hong Li (Beijing Institute of Physics) who introduced nanoscale-Si anodes. With their support, along with that of my student Dr. Haokun Deng (Eve, Ltd.), Dr. Claudio Capiglia (Talg), Prof. Thapanee Sarakonsri (Univ of Chiangmai), and Prof. Pu Hu (Wuhan Institute of Technology), I ventured deeper into the mechanics of energy storage and set up my own lab, becoming also an electrochemist. The energy storage community is the most welcoming and

supportive I have met, and the friendly environment we cultivate allows for fruitful international collaborations for the benefit of our society.
Katerina E. Aifantis Associate Professor

■ STABILIZATION OF BLACK PEROVSKITE PHASE IN $FAPbI_3$ AND $CsPbI_3$

Sofia Masi, Andrés F. Gualdrón-Reyes, and Iván Mora-Seró
ACS Energy Lett. 2020, 5 (6), 1974−1985 (Review)
DOI: 10.1021/acsenergylett.0c00801



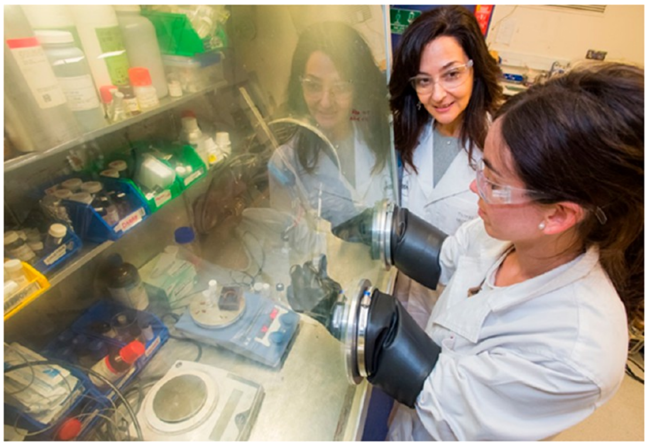
Left to right: Patricio Serafini, Sofia Masi, Jesús Alberto Sanchez-Diaz, K. M. Muhammed Salim, Andrés F. Gualdrón-Reyes. (Photo courtesy Sofia Masi)

Being a chemistry and environmental enthusiast, I have always wanted to contribute in the field of renewable energy. Due to my university studies in chemistry, mainly including the area of basic research, I was slightly hesitant to move to another more applicative field, such as energy and photovoltaics. However, my background was key to starting my Ph.D. path with perovskite in 2013, just a year after the biggest publication, after which the photovoltaic investigation has grown like never before. When I started learning about the fascinating world of perovskite, I saw an opportunity, through my chemical experience, to bring a refreshing perspective to energy research, by taking advantage of the innovations developed in the photovoltaic community.

My Aha! moment was when I realized that the supramolecular interaction in solution has strong repercussions on the properties of the solid-state film and, in turn, on the efficiency of the device. But my gratifying moments came when I stabilized metastable perovskite in air, giving me the opportunity to study new perovskite materials in depth (and for a more relaxing day in the laboratory!) and also when I reached the 20% of efficiency with an inverted device architecture! During my scientific career, I have learned that the most important quality is starting from your background, as this can be crucial for doing unique and universal studies at the same time. Be open to collaborations between people from the most diverse fields and groups, then become a great strength to advance your ideas. This is my advice for younger researchers: do not be discouraged when the work never seems to end. Sometimes even small things take a long time. Finally, a quality life and a real balance between career and family will reward you.
Sofia Masi Postdoctoral Researcher

■ HIGHLY HOMOGENEOUS SODIUM SUPEROXIDE GROWTH IN $Na-O_2$ BATTERIES ENABLED BY A HYBRID ELECTROLYTE

Nagore Ortiz-Vitoriano, Iciar Monterrubio, Laura Garcia-Quintana, Juan Miguel López del Amo, Fangfang Chen, Teóphyllo Rojo, Patrick C. Howlett, Maria Forsyth, and Cristina Pozo-Gonzalo
ACS Energy Lett. 2020, 5 (3), 903−909 (Letter)
DOI: 10.1021/acsenergylett.0c00081



Dr. Cristina Pozo-Gonzalo (L) and Dr. Nerea Casado (R) working with battery materials in a glovebox. (Photo courtesy Deakin University)

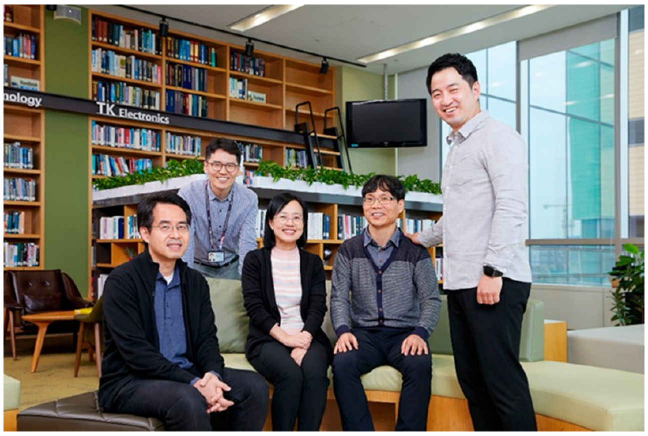
I believe that as a researcher, it is very important to have a curious mind and seek understanding of intrinsic chemical or physical processes. This way of thinking comes naturally when you find a research area that you feel passionate about. In my case, I am excited about reducing our waste and environmental footprint, and I follow this interest in my research. That is why I am passionate about new energy storage technologies that minimize the use of scarce and toxic products which are detrimental to the environment. This has also led to an interest in the recovery of products or resources to maximize their lifetime and minimize the need for new materials.

For instance, sodium air batteries tick all of the above boxes by using sodium and oxygen as the active materials. I feel passionate about understanding the intermediate species generated during battery operation in the electrolyte and on the interface of the electrodes and how I can control the reaction mechanism to improve battery lifetime.

My second but equally important piece of advice is regarding collaborations and mentorship; I have found it extremely important in my career to find a supportive and complementary network of researchers that want to work together to unravel the science behind specific areas of research. I also value this role in my own group, where I get to support and mentor young researchers to help them find their own voice and direction.
Cristina Pozo-Gonzalo Senior Research Fellow

■ ENVIRONMENTALLY FRIENDLY InP-BASED QUANTUM DOTS FOR EFFICIENT WIDE COLOR GAMUT DISPLAYS

Eunjoo Jang, Yongwook Kim, Yu-Ho Won, Hyosook Jang, and Seon-Myeong Choi
ACS Energy Lett. 2020, 5 (4) 1316−1327 (ACS Editors' Choice Perspective)
DOI: 10.1021/acsenergylett.9b02851



Left to right: Taehyung Kim, Seonmyeong Choi, Eunjoo Jang, Kwanghee Kim, and Sungwoo Kim. (Photo courtesy Eunjoo Jang)

I joined Samsung Electronics about 20 years ago; at that time, the company was seeking serious opportunities to make a breakthrough by adopting novel materials in electronic devices since it was the best way to procure technological leadership in the field of electronics. Quantum dot is a promising material for applications in next-generation semiconductor applications, and I was appointed to initiate a project based on display applications. As a fresher after completing my Ph.D., I was brave enough to work in the field that was relatively new to me. Although I did not have a thorough understanding of the fundamentals or basics of the field, I was fascinated by the beauty of the material science ever since I started to study light emitting quantum dots. However, industrial projects focus on target-driven approaches, collective efforts, and tangible and timely outcomes much more than the scientific findings. We are often under severe competitions while we aim to pursue our goals with limited resources. From time to time, I faced a challenge that was beyond my abilities or capabilities; however, at every moment I struggled, I was encouraged with support and advice and was motivated by my mentors and colleagues to continue to make efforts. Finally, when we built a factory for mass production of quantum dot made through our laboratory process and when the first quantum dot TV was released in 2015, I could not do anything but being grateful to everybody. I learned that scientific honesty and openness are the keys toward achieving meaningful conclusions, and I would like to share this experience and work together with all my collaborators in industry and academia.

Eunjoo Jang Quantum Dot Development, Fellow

■ FREE-RADICAL CATALYSIS AND ENHANCEMENT OF THE REDOX KINETICS FOR ROOM-TEMPERATURE SODIUM–SULFUR BATTERIES

Ajit Kumar, Arnab Ghosh, Maria Forsyth, Douglas R. MacFarlane, and Sagar Mitra

ACS Energy Lett. 2020, 5 (6), 2112–2121 (Letter)

DOI: 10.1021/acsenergylett.0c00913

Maria Forsyth (Photo courtesy of Deakin University)

In my senior high school years, I was always intensely interested in chemistry, physics, and mathematics and I had a curiosity about how things worked. I knew at an early stage that I wanted to do research at a University. During the latter stages of my Ph.D. in cryobiology, a field far from the energy discipline I now work in, I became involved in a small industry project looking to replace existing, liquid-based high-voltage aluminum electrolytic capacitors that were implanted in the body for cardiac defibrillation with more compact and safer solid-state devices. At the time I was merely working as part-time technician making films of PEO-based solid polymer electrolytes and assembling capacitor devices. But I became fascinated with these materials and began to read the literature, which convinced me that I wanted to better understand ion dynamics in these polymer conductors. This led me to write to Professor Mark Ratner at Northwestern University whose team, together with that of the late Professor Duward Shriver, were at the forefront of polymer electrolyte research in the USA in 1990. That was more than 30 years ago, and I've never looked back. It was such an exciting time in energy materials research, and in particular polymer materials—I was exposed not only to ionic conducting polymers but also to other functional polymer materials, including electronically conducting polymers like the polythiophene and polypyrrole families (Nobel prize in 2000).

I was inspired by my two advisors, the many high-profile visiting professors, as well as the now "legends" in battery research, whom I met during those early years at various conferences, to continue working on novel electrolyte materials for energy storage. Those formative years at Northwestern taught me the importance of interdisciplinary and collaborative research; it showed me that by combining design and synthesis with theory and computation alongside advanced materials characterization, one could make true leaps in understanding and materials development. The world has changed since my time as a postdoc and as a junior university academic. Now we not only design, model, and characterize materials but we also translate them into real devices. The majority of my Ph.D. students now can combine doing MD simulations or machine learning methods with assembling and testing a lithium or sodium battery! I think energy storage research has a very

exciting future as we look to address the important societal challenges ahead, including cleaner, more sustainable and affordable energy for all.
Maria Forsyth Alfred Deakin Professor

■ CHALLENGES IN LITHIUM METAL ANODES FOR SOLID-STATE BATTERIES

Kelsey B. Hatzell, Xi Chelsea Chen, Corie L. Cobb, Neil P. Dasgupta, Marm B. Dixit, Lauren E. Marbella, Matthew T. McDowell, Partha P. Mukherjee, Ankit Verma, Venkatasubramanian Viswanathan, Andrew S. Westover, and Wolfgang G. Zeier

ACS Energy Lett. 2020, 5, 3, 922−934 (Perspective)
DOI: 10.1021/acsenergylett.9b02668

Lauren E. Marbella and Richard May (Photo courtesy Mindy Farabee)

I first became interested in using NMR spectroscopy for energy research during my Ph.D. with Jill Millstone at the University of Pittsburgh. We were synthesizing new types of nanoparticle alloys that have potential applications in heterogeneous catalysis. I was fascinated by the fact that we could use NMR to provide entirely new insight into particle formation and emergent properties that were not accessible with other techniques. My excitement continued to grow during my postdoctoral fellowship with Clare Gray at the University of Cambridge, where I used NMR and MRI to study beyond Li-ion technologies, including Na ion batteries and all-solid-state batteries.

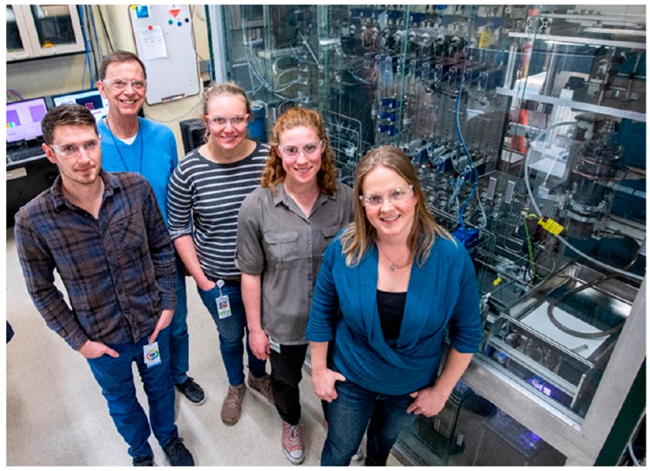
Upon starting at Columbia University in 2018, I knew that I wanted to use my expertise in NMR to study electrochemical interfaces and use this insight to enable next-generation energy materials. Electrochemical interfaces play a critical role in device performance in batteries, fuel cells, and catalysts, and NMR is one of the most powerful tools to identify both structure and dynamics at these interfaces during operation. My group is motivated by the goal that these discoveries will be used to devise strategies to improve device lifetime and efficiency.

My advice for students, especially young women, looking to embark on energy research is to find a field that you are passionate about and, more importantly, find good mentors who will support you throughout your career. I would not be the researcher that I am today without my own network of exceptional mentors, and I feel lucky that I have the privilege to mentor such an amazing group of students.
Lauren E. Marbella Assistant Professor of Chemical Engineering

■ A TAXONOMY FOR THREE-TERMINAL TANDEM SOLAR CELLS

Emily L. Warren, William E. McMahon, Michael Rienäcker, Kaitlyn T. VanSant, Riley C. Whitehead, Robby Peibst, and Adele C. Tamboli

ACS Energy Lett. 2020, 5 (4), 1233−1242 (Perspective)
DOI: 10.1021/acsenergylett.0c00068



Emily Warren with her research team at NREL (January, 2020). Left to right: John Mangum, Jeff Carapella, Theresa Saenz, Olivia Schneble, and Emily Warren. (Photo courtesy Werner R. Slocum, NREL)

I loved science and the environment from a young age, even fundraising with my friends in elementary school to "save the rainforest." I studied chemical engineering at Cornell as an undergraduate, and that was where I first learned about the energy industry in the context of the petroleum processing. It was not until I traveled to Nigeria as part of a class focused on sustainable development that I realized how renewable energy combined my academic interests with my humanitarian and environmental values. In my graduate studies at Cambridge and Caltech, I became fascinated with how we can use solar energy to create electricity and drive chemical reactions.

During my Ph.D. and my career at NREL, I have found that the most productive and rewarding research occurs when teams of people with different backgrounds work together. I have worked on projects ranging from fundamental electrochemistry, to world-record solar cells, to prototyping solar-thermoelectric generators. Siloed academic disciplines are not going to solve the massive challenges in the generation, transmission, and storage of renewable energy that still need cost-effective solutions! Breaking down those silos will require scientists who can connect and listen, acknowledging the expertise of others and engaging in open and honest communication on multiple levels. So: Do not be afraid to learn new things or work on a project outside your comfort zone; research success is built on trying, failing, and then trying again with the new insight gained. Always approach your colleagues at all levels with a respect and curiosity—you never know who you'll meet that will spark that critical connection to drive energy innovation forward.
Emily L. Warren Researcher IV-Semiconductor Engineering

■ ALTERED STABILITY AND DEGRADATION PATHWAY OF $CH_3NH_3PbI_3$ IN CONTACT WITH METAL OXIDE

Sampreetha Thampy, Boya Zhang, *K*i-Ha Hong, Kyeongjae Cho, and Julia W. P. Hsu

ACS Energy Lett. 2020, 5 (4), 1147−1152 (Letter)

DOI: 10.1021/acsenergylett.0c00041

Julia W. P. Hsu (Photo courtesy of Lakisha Ladson)

My journey in energy research was neither deliberate nor planned but happened through serendipity. There were no "Aha!" moments; instead, it was steered by the research I have done. In 2005, when I was studying how to control the shape and growth location of ZnO nanorods on surfaces at Sandia National Laboratories, I came across a drawing of an ideal bulk heterojunction structure for the then-new organic solar cells. Infiltrating polymers into an orderly grown ZnO nanorod forest would create such a structure. So controlled ZnO nanorod growth served as a spring board into these emergent solar cells. After moving to the University of Texas at Dallas in 2010, I built a research program in energy and environment based on previous solution growth of metal oxide nanostructures. The two main activities involve studying metal-oxide nanomaterials as transport layers for organic solar cells and synthesizing earth-abundant transition metal oxide compounds to replace platinum group metal catalysts. An outcome of the catalyst research was a unique instrument that combined temperature-programmed desorption with spectroscopic techniques to identify the gas-phase molecules. As the efficiency of halide perovskite solar cells increases, their thermal stability becomes even more critical. Based on our expertise on metal-oxide nanomaterials and using the unique instrument we built for catalyst studies, we performed the first work to understand how metal oxides can trigger perovskite degradation. Currently, we are researching a nonequilibrium processing method to minimize such unintentional interfacial reactions.

Energy research requires expertise from diverse disciplines. I encourage young researchers to be curious and learn about topics that might seem irrelevant to your current projects. The more you know, the easier it will be to pivot when new exciting research topics arise.

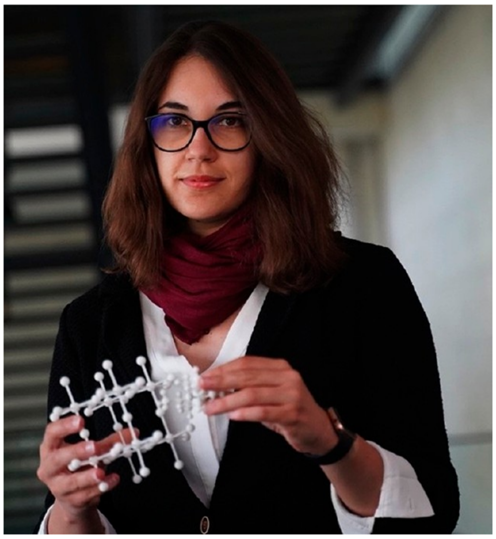
Julia W. P. Hsu Professor and Texas Instruments Distinguished Chair in Nanoelectronics

ONLINE MEETINGS IN TIMES OF GLOBAL CRISIS: TOWARD SUSTAINABLE CONFERENCING

Jovana V. Milić, Bruno Ehrler, Concha Molina, Michael Saliba, and Juan Bisquert

ACS Energy Lett. 2020, 5 (6) 2024–2026 (Energy Focus)

DOI: 10.1021/acsenergylett.0c01070



Dr. Jovana V. Milić (Photo courtesy Christian Doninelli)

My scientific journey commenced in Serbia, where I was born and educated before moving to Switzerland for graduate studies. Coming from a family of beekeepers, my curiosity was driven by the complexity, cooperation, and sustainability of biological systems. This fostered a number of interests throughout my education with particular passion for science, art, and sports. What defined my path was the involvement with Petnica Science Center, which enables young students to pursue their scientific interests through various research programs. In this stimulating environment, I became captivated by the electronic effects in organic molecules and oscillatory reactions, leaving me deeply intrigued by the interactions of electrical, magnetic, and electromagnetic fields with molecular materials and their dynamics, thereby igniting a spark that fueled my professional development. I have been fascinated by these processes in nature, such as in photosynthesis, which has inspired the development of stimuli-responsive systems in the course of my Ph.D. at ETH Zurich, as well as closely related photovoltaic technologies during my postdoctoral research at EPFL.

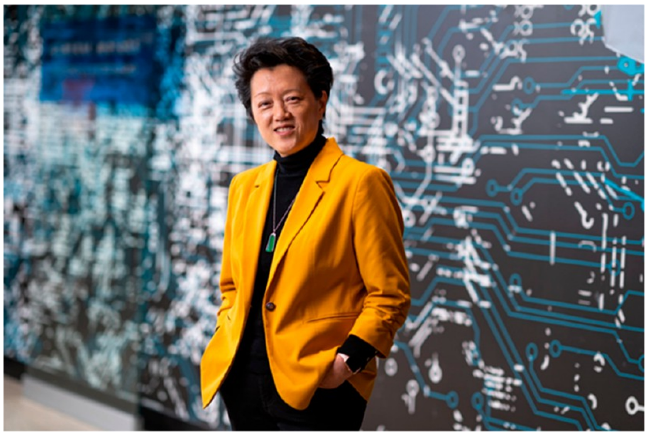
Today I pursue these interests while leading a team at the Adolphe Merkle Institute of the University of Fribourg, relying on bioinspired supramolecular design concepts in energy conversion. My involvement in energy research has been additionally motivated by the ongoing global challenges, providing a unique platform to explore the phenomena that intrigued me with real-world applications at the interface of chemistry, physics, and engineering. I remain inspired by the beauty of the molecular world that also nurtures my love of art, whereas international collaborations continue to complement the team spirit of sportsmanship. Along the way, I have learned to appreciate the importance of following intuition and the critical role of diversity and interdisciplinary cooperation in addressing complex challenges. I further recognize the profound impact of science outreach and mentorship on empowering young scientists, while being enthusiastic about the continuation of this journey.

Jovana V. Milić Group Leader, Photovoltaics, Soft Matter Physics

OPPORTUNITIES AND CHALLENGES OF HIGH-ENERGY LITHIUM METAL BATTERIES FOR ELECTRIC VEHICLE APPLICATIONS

Shuru Chen, Fang Dai, and Mei Cai

ACS Energy Lett. 2020, 5 (10), 3140−3151 (Focus Review)
DOI: 10.1021/acsenergylett.0c01545



Mei Cai (Photo courtesy Steve Fecht)

When I first entered my Ph.D. program, my dream was to work in biomedical engineering making artificial organs. While I was at Wayne State University Medical School, an unexpected twist happened. Due to my extensive knowledge of biochemistry, I was selected for a summer internship at General Motors' (GM) R&D Center working on improved cabin air quality for the Cadillac brand. The experience of working for GM over two consecutive summers completely changed my career path.

I joined GM as a full-time employee and was pulled into the H_2 fuel cell research program due to my previous chemical engineering training. At that point, my entry into energy research was no longer deliberate. When I started working in fuel cell research, spanning electrocatalysts to bipolar plates to onboard H_2 storage, it really opened my eyes to what could be accomplished in clean energy research.

I am now working on the development of advanced battery materials and chemistry which could enable a new generation of high energy density and low-cost batteries for electrical vehicles applications. What I love the most about my job is the continuous improvement of technology and innovation.

GM has been using renewable energy for the last 20 years and is committed to a vision of a decarbonized automotive industry. The company provides us with a great platform to practice the full gamut of innovation, from idea generation to technology development and product implementation, which is always a fascinating process for me. For the newcomers in the field, especially women technologists, there are a range of opportunities available, and we are having increasing influence in renewable energy. What is possible today being just the beginning.

Mei Cai GM Technical Fellow and Manager of the Energy Storage Materials Group

DEFORMATION DURING ELECTROSORPTION AND INSERTION-TYPE CHARGE STORAGE: ORIGINS, CHARACTERIZATION, AND DESIGN OF MATERIALS FOR HIGH POWER

Veronica Augustyn, Ruocun Wang, Nina Balke, Matt Pharr, and Craig B. Arnold

ACS Energy Lett. 2020, 5, 3548−3559 (Perspective)
DOI: 10.1021/acsenergylett.0c01823

Veronica Augustyn (far right) with SciBridge cofounder John Paul Eneku and student volunteers at the 2017 African Materials Research Society Conference in Gaborone, Botswana. (Photo courtesy Veronica Augustyn)

My research group investigates the synthesis and mechanisms of materials operating in electrochemical environments relevant for energy applications. I am also the faculty advisor for SciBridge, a student-run organization that collaborates with universities in east Africa on hands-on experiment kits and educational materials on renewable energy. These two endeavors exemplify what I love about energy research: the intersection of science, engineering, and society. My "Aha!" moments—times when I feel truly creative and inspired—usually come when some seemingly random accumulation of discussions, readings, and presentations begin to synthesize into a radical concept (at least, in my mind!). Of late, I've become absolutely fascinated by fluids under confinement by materials. There are many examples of such hybrids, from clays and minerals, to synthetic materials such as metal organic frameworks. I am especially interested in how these types of materials behave in electrochemical environments, where the confinement of fluids in material cavities can affect transport and reactivity.

Another big "Aha!" moment for me was attending the 2012 Joint Undertaking for an African Materials Institute (JUAMI) school in Addis Ababa, Ethiopia. This two-week experience consisted of learning about renewable energy from global experts with a team of students from the U.S. and several east African countries. The experience left an indelible mark on me: I was quite ignorant of scientific research and institutions in Africa and the many challenges faced by my peers in developing countries. It also led me to team up with another JUAMI participant, John Paul Eneku, Assistant Lecturer of Physics at Makerere University, to start the SciBridge project. The project is now entering its eighth year and has developed and shipped dozens of hands-on experiment kits to our partner universities (primarily in Uganda) that cover topics such as dye-sensitized solar cells, aluminum air batteries, and thermoelectrics. The kits find use in university classrooms as well as high schools, community events, and independent research projects.

My advice for newcomers to the field is your uniqueness is your strength and follow your passions. We need your individual creativity to truly advance science, technology, and society.

Veronica Augustyn Assistant Professor of Materials Science & Engineering

PROCESSING STRATEGIES TO IMPROVE CELL-LEVEL ENERGY DENSITY OF METAL SULFIDE ELECTROLYTE-BASED ALL-SOLID-STATE Li METAL BATTERIES AND BEYOND

Daxian Cao, Yuyue Zhao, Xiao Sun, Avi Natan, Ying Wang, Pengyang Xiang, Wei Wang, and Hongli Zhu

ACS Energy Lett. 2020, 5 (11), 3468−3489 (Review)
DOI: 10.1021/acsenergylett.0c01905

Hongli (Julie) Zhu, Assistant Professor, Northeastern University (Photo courtesy Hongli Zhu)

When I started my career at Northeastern University in 2015, I was thinking of working on clean energy using 2D materials and focusing on the conversion of renewable feedstocks, e.g., lignocellulosic waste material into other forms that are useful for energy applications and/or sustainable materials and manufacturing. At that time, the metallic 1T transition metal sulfide, such as metallic phase 2D molybdenum disulfide (MoS_2), attracted my attention because of its excellent metallic property and catalytic activities. We studied the material atomic structure−properties−applications relationships of metallic MoS_2. Furthermore, we conducted structural designs by using MoS_2 nanosheet as building blocks to assemble hollow tube, vertically aligned nanosheets array, and hollow porous flat boxes.

Metal sulfide is a very interesting material, but with the research on energy ongoing, I paid more attention to tackle the safety issue in energy storage. Therefore, we shifted more efforts on solid-state ionic conductor and all-solid-state batteries, especially the metal sulfide high ionic conductor (another kind of metal sulfide). Sulfide composites have been receiving increasing attention as solid electrolytes in all-solid-state batteries due to their high ionic conductivity and favorable mechanical features. However, sulfide solid electrolytes still face challenges, including the need for (1) a higher voltage stability window and (2) a better electrode−electrolyte interface. In our lab, we are trying to improve metal sulfide stability and develop all-solid-state lithium batteries. Recently, we investigated the Li metal interface stabilization, electrochemical stability window extension, air stability improvement of metal sulfide electrolyte, cathode interface stabilization, and cell-level energy density improvements.

My advice to the younger generation is never stop pursuing your dreams. Work hard, dream it possible, chase the sun, and find the beautiful. "Those times when you get up early and you work hard; those times when you stay up late and you work hard; those times when you don't feel like working, you're too tired, you don't want to push yourself, but you do it anyway; that is actually the dream. That's the dream." — Kobe Bryant
Hongli Julie Zhu Assistant Professor

NANOSCALE ELEMENTAL MAPPING OF INTACT SOLID−LIQUID INTERFACES AND REACTIVE MATERIALS IN ENERGY DEVICES ENABLED BY CRYO-FIB/SEM

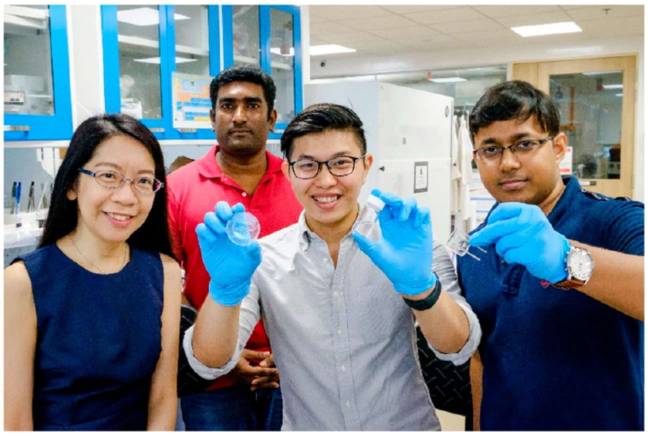
Michael J. Zachman, Zhengyuan Tu, Lynden A. Archer, and Lena F. Kourkoutis
ACS Energy Lett. 2020, 5 (4), 1224−1232 (Letter)
DOI: 10.1021/acsenergylett.0c00202

The Kourkoutis Electron Microscopy Group in Fall 2019. Left to right: William Xu, Taylor Moon, Noah Schnitzer, Ismail El Baggari, Michelle Smeaton, Yue Yu, Danielle Markovich, Berit Goodge, Erin Fleck, Elisabeth Bianco, Lena F. Kourkoutis (Photo courtesy Lena Kourkoutis)

As an electron microscopist and physicist, I develop new approaches to image and probe materials and devices down to the atomic scale. Each one of these developments is motivated by key scientific questions in a specific field; questions that cannot be answered directly using existing techniques. As a graduate student I primarily focused on understanding how new electronic phases emerge at atomically abrupt interfaces between complex oxides, but I also learned about the opportunities and challenges in energy storage and conversion as part of EMC^2, the Energy Materials Center at Cornell. Working closely with experts in materials design, synthesis, and device characterization was eye opening and planted the seed for my future work in this field. As a postdoc, however, I stepped almost completely outside my area of expertise and joined the Max Planck Institute of Biochemistry to understand how cryogenic electron microscopy is used to image biological molecules. This experience seeded the idea of what has become one of my group's main contributions to energy research, which is the development of cryogenic electron microscopy approaches to reveal processes at interfaces between liquids and solids—processes that play a key role in the operation of energy devices, including batteries, fuel cells, and electrolyzers. My advice to graduate students is to ask questions, learn from others, and be bold enough to explore new areas of research during your postdoctoral career. It is often these new experiences that will set you apart as you build your own group and establish your independent research program.
Lena F. Kourkoutis Associate Professor and Faculty Fellow

MOLECULAR LEVEL ASSEMBLY FOR HIGH-PERFORMANCE FLEXIBLE ELECTROCHROMIC ENERGY-STORAGE DEVICES

Guofa Cai, Jingwei Chen, Jiaqing Xiong, Alice Lee-Sie Eh, Jiangxin Wang, Masayoshi Higuchi, and Pooi See Lee
ACS Energy Lett. 2020, 5 (4), 1159−1166
DOI: 10.1021/acsenergylett.0c00245



Me (left) and my research team (from right: Dr. Kaushik Parida, Ph.D. student Matthew Tan, and Dr. Gurunathan Thangavel) on our "aha!" moment upon establishing a thermally stable ionic conductor in a collaboration project. (Photo courtesy Kok Wei Ming Lester)

While I was fascinated by the stunning beauty of Salar mines, Chile, I was wondering about the extent of environmental impact on extensive mining of lithium, imagining the amount of water used with the two rivers flowing into the salt flat, and the creation of lime waste for separation of magnesium from the mine. Meanwhile, geopolitical risks may lead to uncertainties on the global cobalt market. With these impetuses, I extended my research toward beyond lithium ion solutions for electrochemical devices. There are plenty of opportunities, unaddressed issues, and challenges awaiting to be tackled for topics beyond lithium storage. The development of supercapacitors and nonlithium batteries based on aluminum, zinc, or magnesium are some of the attractive options. A few years ago, I started to lead a collaborative consortium NTU-HUJ in SHARE CREATE, which focused on additive manufacturing for energy solutions. This brought me to develop printable materials for electrochemical energy storage and energy harvesting. I have worked on printable electrochromic-energy storage devices, high-energy supercapacitors, alternative batteries, wearable energy storage, and stretchable nanogenerator energy harvesting. Accompanying the emergence of soft electronics, deformable energy storage and energy harvesting solutions are desirable for use on curvilinear surfaces. I am currently devoting efforts to materials design and syntheses to realize stretchable ionic conductors, intercalation type layered materials, self-healable stretchable electrodes, electrically conductive liquid metal, and hierarchical bonded supramolecular elastomers as viable options to pursue multifunctionalities of energy devices. I encourage young researchers in the field to take bold approaches in tackling energy challenges and develop system thinking strategies which are deemed crucial for effective implementations of solutions.

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https://pubs.acs.org/10.1021/acsenergylett.0c02398

Notes

Views expressed in this Energy Focus are those of the authors and not necessarily the views of the ACS.
The authors declare no competing financial interest.

https://dx.doi.org/10.1021/acsenergylett.0c02398
ACS Energy Lett. 2021, 6, 58−68