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Interview with 2025 ACS Energy Lectureship Outstanding Mid-Career Award Winner Dr. Bruno Ehrler

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Dr. Bruno Ehrler, the recipient of the 2025 ACS Energy Lectureship Outstanding Mid-Career Award, has established himself as a leading researcher in the field of solar energy materials. Dr. Ehrler has made significant contributions to the understanding of ion migration effects in perovskite solar cells, which is crucial in advancing the efficiency and stability of PSC devices. In this interview, Dr. Ehrler shares insights into his academic path, current research, and perspectives on the future of energy materials science (Figure 1).

Figure 1. Dr. Bruno Ehrler, 2025 ACS Energy Lectureship Outstanding Mid-Career Award Winner.

Yiying Wu: Congratulations on winner the lectureship award. Can you briefly introduce your academic background?

Bruno Ehrler: I am a physicist by training. I studied in Germany originally, and then, I went to England for my master and Ph.D. I got my Ph.D. in the group of Prof. Neil Greenham at Cambridge University and then did a postdoc in the group of Prof. Richard Friend. At the time, I worked on organic photovoltaics, singlet fission materials, and quantum dot photovoltaics. Afterward I became a group leader here at AMOLF in Amsterdam. AMOLF is a Dutch national institute for materials science. Since 2020, I also became a professor at the University of Groningen in The Netherlands. My group mostly focuses on material science for solar energy, which currently means perovskite material science. In particular, we focus on ion migration in perovskites. We apply our understanding of this effect to improve solar cells, and we are also looking to exploit this effect in other applications like memory devices for low-energy computation.

Yiying Wu: Could you provide some details about your institution, AMOLF?

Bruno Ehrler: AMOLF is not so well-known because it is a fairly small institute on the global scale. We are a Dutch national lab similar to NREL in the USA or the Max Planck Institute in Germany. AMOLF focuses on fundamental science research and primarily material science. Our materials science research can be split between three distinct topics. The first one is energy materials, where my group is based. The second focus is autonomous matter, which involves materials for soft robots and biological systems. The third focus is information matter, which studies how information is processed in materials. An example would be the low-energy computation application that I mentioned earlier.

In AMOLF, we typically work on the same topic with a few research groups, so that we can gather enough focus and mass to make an impact in that particular area. We have started photovoltaics research in 2012 with a grant from the government, and now, we have five research groups that work on the topic.

Yiying Wu: What are some of your recent research projects, and how do they address challenges in energy materials?

Bruno Ehrler: Our main focus is on the effects of ion migration on perovskite solar cells. In a silicon crystal, you have silicon atoms that are bound by powerful covalent bonds, and it is hard to move those atoms through the crystal. But perovskites are compound semiconductors. They are made from many different atoms, and the bonds between the atoms are partially ionic bonds, which are much weaker bonds compared to the covalent bonds in a conventional semiconductor. If you have a vacancy or an interstitial in perovskites, it is very easy to move an atom across the crystal. Therefore, ion migration in perovskites is quite efficient, and ionic conductivity is also high. You can almost consider perovskites as solid electrolytes.

It has been shown recently that a large part of the short-term perovskite solar cell degradation comes from the generation of free mobile ions. The free ions can move around the crystal and cause all kinds of havoc. For example, they can screen the

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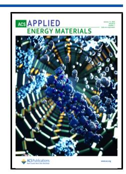

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internal electric field, and they can also start reactions at the interfaces between the perovskite layer and other layers. It is essential to understand the fundamental properties of ions inside perovskites and consequently know how to stop ions moving or stop ions from being generated in the first place. Alternatively, we can try to find perovskite solar cell materials that are unaffected by ion migration, which means that the solar cell still works well, despite the mobile ions.

We use a couple of different techniques to study ion migration effects. We use electrical techniques like capacitance and impedance measurements. We use optical techniques like correlative microscopy. We also use electron microscopy to compare structure and properties on the nanoscale. We combine all these different techniques to quantify how much time and how much energy it takes to move ions inside perovskites and how the migration effect relates to the degradation of the perovskite solar cells.

More recently, we also have exploited the ionic properties of perovskites for other applications. It is quite unique that perovskites can have good ionic conductivity while retaining good semiconducting properties like electron conductivity and light absorption coefficient. Usually a mobile ion would always create an electronic defect that ruins the electrical properties of a semiconductor. The electronic structure of perovskites is relatively insensitive to crystallographic defects, which is a rare property.

For that reason, we can use ions in perovskites to implant memory on a device. The time scale of ionic motion is many orders of magnitude slower than that of electronic motion. We can apply a pulsed electric field to move the ions to one direction, which changes the resistance of the device, and the ions would stay there for a while. In this way, the ions will form a new quasi-steady state, which works like a synapse in our brains. Based on the history of the applied pulsed electric field, we can switch the device on and off with very little energy. This principle is the basis of perovskite-based low-energy memristive devices that we recently published. We are not the first group to use perovskites for memristor applications. Our contribution is to downscale the device size to microns so that the energy consumption for switching can be reduced to the femtojoule regime.

Yiying Wu: The ion migration effect in perovskites is a critical issue. Is it primarily caused by halide migration, or are other factors at play?

Bruno Ehrler: That is mostly true. However, there are so many different types of perovskites, so making a general statement like this is tricky. In the most common perovskites, the halide vacancies are the most mobile type of ions on the time scale of typical lab measurements. However, on the time scale of a 20-year degradation cycle of a perovskite solar cell, we probably also need to consider the effects of other types of ions.

Yiying Wu: From your perspective, what has been the most significant impact of your research work so far?

Bruno Ehrler: Scientifically, I think my impact is in the understanding of ion migration. We started focusing on this effect a few years ago when the perovskite community still had more focus on improving the efficiency of solar cells. Now that the efficiency is high, the stability of the device receives more attention. Perovskite ion migration is an interesting field of research because it involves a diverse range of mechanisms, and there is a lot to explore. As I mentioned, the ion migration effect can change the electrical properties and the chemistry of the materials and the devices. You can fine-tune the effect with all kinds of mechanisms. You can introduce additives. You can introduce 2D perovskite layers. You can change the growth conditions and the aging conditions. Moreover, all these mechanisms influence each other in a complex way.

Talking about other ways to make an impact, I was recently involved in a in a Dutch government project to kickstart the solar industry in The Netherlands called SolarNL. I have contributed to the writing of this plan and the research program that belongs to SolarNL. It is a program across the whole country involving 79 Ph.D. students. The initiative has been ongoing for 2 years, and we are quite optimistic about its success.

Yiying Wu: Could you share more about your experience with the SolarNL initiative, particularly its challenges and successes?

Bruno Ehrler: SolarNL is a group effort. At AMOLF, we had the benefit of being a neutral partner in the whole initiative. We are not a government institute directly. We are not a government ministry. We are also not a company that has a direct financial stake in the initiative. As scientists, we are also experienced in writing proposals. As such, I think the combination of those aspects put us in a position where we could take the lead.

A little earlier, the Dutch government established a fund, called Growth Fund, to stimulate the economic growth of The Netherlands. The fund was established when the interest rate was so low that the country could basically borrow money for free. In 2022, we then experienced an energy crisis that resulted in dramatically rising energy prices. The crisis made the Dutch government realize that controlling your own energy supply is crucial. At the same time, of course, they realized that solar photovoltaics will play an essential role in the energy supply. Solar energy is great because it is a renewable energy, but it also offers an opportunity to build your own local energy industry. That is not the case for oil and gas for most countries. If you do not have oil and gas resources, then you cannot build your own industry. Renewables offer a new opportunity for energy independence to countries that react now.

For SolarNL, we got together with the Dutch companies, all Dutch universities involved in solar cell research, the universities of applied science, and TNO, an applied research institute. In 2016, we had already organized all the solar cell research groups in The Netherlands within a consortium called Solar Lab. Therefore, we knew exactly what everybody is doing and what every group is good at. That is part of the reason we could very quickly set up SolarNL.

The Dutch government fully supported the program, very much motivated by the prospect of achieving an independent energy supply through renewable energy technology.

The SolarNL program has three aspects. The first one is achieving local silicon solar cell production. The second aspect is about solar foils. This part involves the perovskite solar cell research. The third aspect is device integration, into buildings, vehicles, and infrastructure. This part of the program is highly customer oriented. For building integration, for example, you may need to talk to the architect. You need to talk to the local landscape designers if they will integrate solar cell panels into landscapes.

The solar cell industry is very competitive. However, the market grows extremely quickly, 25% every year. So, if you add a little bit of production somewhere, it does not really change anything for other countries. There is always going to be enough market, at least on the global scale. This means that competition between different companies in such a program is not as much of a problem as one might think. The challenge is in the cost structure. You can only be cost competitive if you achieve large-volume production right away. You cannot start slowly and then scale up because it is not going to be cost competitive.

Yiying Wu: Since the 2025 energy lectureship award is cohosted by our journal and the ACS Energy & Fuels division, do you have any suggestions for *ACS Applied Energy Materials*?

Bruno Ehrler: I have been publishing in ACS journals for a long time already, and I always had good experience. One thing that is super important for me as an author is that the editors are very reasonable people, and that all editors are scientists themselves. For example, if an unreasonable review is coming in, the editor typically understands that and discards the review. Also, if you send our rebuttal and the rebuttal is well done, then typically the editor can make the judgment quickly without sending the paper back for more peer review because the editor is an expert in the field themselves. Overall, the publication experience has been fast and smooth for me.

In terms of research topics to publish in the future, I think it becomes increasingly important for energy researchers to think about the embedding of solar and also other energy technologies into the context of energy systems of the future. In the past, solar photovoltaics could seamlessly integrate into the fossil fuel-dominated power systems because the solar electricity capacity was small. But now, the scale of solar energy systems has become so large that it impacts the robustness of our existing power structure. It is important that we understand and address the impact of new energy technologies on the systems level and think about incorporating catalysis, other renewable energy sources, and storage technologies into the power system. Though this sounds more like a power system/policy design issue, energy materials research is directly affected by it. We need to work on energy materials solutions that also work on the systems level.

Bruno Ehrler
Chengmei Zhong orcid.org/0000-0003-3630-894X
Yiying Wu orcid.org/0000-0001-9359-1863

AUTHOR INFORMATION

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