Understanding perovskite growth could lead to cheaper, more versatile solar panels

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Perovskite semiconductors are the hot topic in photovoltaic research. They're able to produce electricity from light like silicon photovoltaic panels but have many potential advantages, including a theoretically greater maximum efficiency and the fact that they can be sprayed or printed onto a variety of surfaces. Exploiting these advantages first requires a good understanding of how the compounds form, a topic that provides the underlying focus of this research.

An international team led by Professor David Lidzey of the University of Sheffield coated a substrate with chemicals that, upon gentle heating or annealing, form crystals of a particular perovskite known as organolead halide (Figure 1). This process, which takes place at a temperature above 80˚C, was monitored using an X-ray beam (Figure 2), with finished samples made into working solar cells to see how well they converted light into electricity (Figure 3). In this way the researchers were able to match the most efficient solar cells to a particular perovskite crystal structure, information that is crucial for designing a manufacturing process that can consistently produce high efficiency solar panels.

Professor Lidzey said: "This information allows us to define the conditions needed to make the most efficient devices. You could work this out empirically but this X-ray technique allows you to follow the process and so there is less guesswork involved."

Professor Lidzey added: "Perovskites are attracting a great deal of attention in the research community as they could be as efficient as current silicon solar panels but have many advantages. They are easier to make and have much lower embodied energy. Silicon solar panels are made by melting silica, sand, at very high temperatures and are rigid, fragile wafers that need careful handling. Perovskite solar panels are potentially much easier to make because they can be sprayed or even printed from solution before gentle heating above 80oC. This means that they take far less energy to make, known as embodied energy. Silicon solar panels need to run for anything up to three years to claw back the energy used in their production before they produce genuinely carbon free energy. Perovskite solar panels have the potential to repay their embodied energy within months."

Professor Lidzey's team were able to use the X-rays to track the complex evolution of the perovskite crystal growth process, before examining the final structures in detail using an electron microscope. They verified that the perovskite crystals in the most efficient solar cells make close contact with each other with few gaps in between. The key feature of their work however was the ability to investigate this process in real-time, thereby allowing them to pinpoint the conditions required for producing the best samples. This is the understanding that will greatly improve the job of scaling up perovskite solar panel production to commercial levels.

The researchers used two complimentary X-ray techniques to investigate the perovskite formation process. The first experiment used grazing incidence wide angle x-ray scattering, or GIWAXS, and was led by Dr. Samuele Lilliu at XMaS (the UK CRG beamline of the European Synchrotron Radiation Facility, France). GIWAXS is an established method for characterizing the crystal structure of materials such as those considered in this study. The second method, grazing incidence small angle X-ray scattering or GISAXS, provides insight into the size and shape of nano- to micron-sized structures on a substrate, and was performed on beamline I-22 at the Diamond Light Source, the UK's synchrotron science facility in Oxfordshire. The work is the first published study from the newly updated beamline, having benefited from new in-house equipment capabilities that offer in-situ heating of a sample during a GISAXS experiment. Compared to traditional methods, a clear advantage of this approach is the removal of any uncertainties that arise from heating a sample away from a beamline, before transfer to an X-ray experiment chamber.

Dr Nick Terrill, principle Principal beamline Beamline scientist Scientist for I-22 said: "I'm delighted to see this type of data come from I-22, it's been a long term goal to provide this enhanced capability to the researchers who come to Diamond. This technique is getting more popular, there are a number of experiments that have been completed but this is first published research from the upgrade." In time, it is hoped that the upgrade will also allow researchers such as Prof. Lidzey to measure GIWAXS and GISAXS on a sample simultaneously, significantly improving not only the quality of the results, but also the speed at which they can be gathered.

There are a number of steps between this research and commercial perovskite solar panels that have yet to be addressed. Panels that have comparable lifetimes to silicon (25+ years) and efficient perovskite solar cells with zero lead content (that may otherwise prohibit their commercialization due to their toxicity) have yet to be demonstrated, for example. Nevertheless, the research done here should make it easier to produce consistently high quality semiconductors. It's a small but important step. And as the market for solar panels booms into a multi-billion dollar industry, small steps can have very large impacts.

More information: Alexander T. Barrows et al. Monitoring the Formation of a CHNHPbIClPerovskite during Thermal Annealing Using X-Ray Scattering, *Advanced Functional Materials* (2016). DOI:

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