Perovskite solar cells are prone to degradation when exposed to humidity and sunlight, and researchers have been devising various ingenuous ways to improve their stability. A University of Oxford research team led by Sai Bai, Feng Gao, and Henry Snaith have found that adding ionic liquids to perovskites markedly improves the devices' long-term stability.

The researchers added the ionic liquid 1-butyl-3-methylimidazolium tetrafluoroborate to the formamidinium-methylammonium-cesium lead halide perovskite. They made a solar cell by using this light-absorbing layer between electron and hole extraction layers. The most stable encapsulated devices lost just 5% of their roughly 20% power-conversion efficiency after being exposed to simulated sunlight for more than 1800 hours at 70–75°C. The team estimates that device efficiency drops to 80% of its peak performance in about 5200 hours.

Ions migrate in the perovskite layer, especially under light and heat, creating defects that can trap charges and bring down efficiency. The ionic liquid unpredictably suppressed this ion migration, and it also facilitates better charge transfer between the perovskite and charge-transport layer, the team reported in a recent issue of *Nature* (doi:10.1038/s41586-019-1357-2).

Researchers at Kyushu University in Japan have made exceptionally thick organic light-emitting diodes (OLEDs) by combining thin organic light-emitting films with hybrid perovskite charge-transport layers. They published their results in *Nature* (doi:10.1038/s41586-019-1435-5).

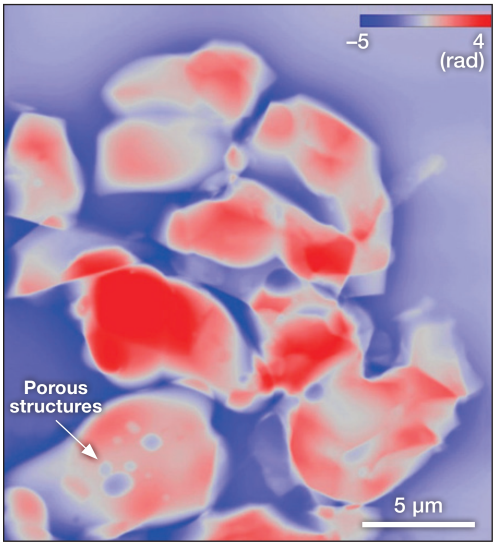
OLEDs hold promise for low-cost, flexible displays and lighting. They are made of a layer of organic light-emitting molecules sandwiched between organic charge-transport layers. The transport layers need to be thick to completely cover the defects and residues on a substrate. But this requires high driving voltage because organic materials are usually poor conductors.

Toshinori Matsushima, Chihaya Adachi, and their colleagues used the perovskite methylammonium lead chloride to make transport layers that were 2000-nm thick, more than 10 times the thickness of standard OLEDs, without requiring high driving voltage. The thick OLEDs could be used to make large, low-cost, efficient displays that emit the same color from different viewing angles.

Advanced instrumentation enables continuous high-resolution x-ray ptychography

X-ray ptychography differs from more commonly known x-ray techniques that rely on attenuation in x-ray intensity to detect matter. In contrast, ptychography functions on diffraction of coherent x-rays. Diffraction patterns result from interference (i.e., superposition) of x-rays scattered by the structural features of the material under investigation. Accordingly, ptychography can provide information at much smaller dimensions than radiography. In principle, this diffraction imaging technique offers wavelength-limited resolution. However, in practice, spatial resolutions are also limited by inaccuracies while positioning the incident beam. Junjing Deng and his colleagues at Argonne National Laboratory have introduced an instrument called the Velociprobe to relax this limitation and advance ptychography imaging. They reported this design in a recent issue of the *Review of Scientific Instruments* (doi:10.1063/1.5103173).

Unlike the traditional ptychography, the Velociprobe provides continuous scanning with about two orders of magnitude improved positional accuracy down to a couple of nanometers (traditional ptychography performs "step scan" where the scanning stage is first moved and then scanned, while the Velociprobe scans as it moves). Such advanced spatial and temporal control is facilitated by (1) a granite stage for higher stiffness, thermal stability, and vibrational response; (2) laser interferometry for accurate position detection; and (3) a specialized control algorithm to interpret position data and effect adjustments without time lags. The name—Velociprobe—implies fast (velocity) measurements with x-rays as a probe.



Ptychographic reconstruction of a perovskite sample of about 21 μm × 24 μm dimensions with a fine resolution close to 6.2 nm. Credit: Junjing Deng.

The Velociprobe exhibits high spatial resolution down to the pixel size, as shown in the Figure where a $LaFe_{0.3}Co_{0.7}O_3$ perovskite structure is imaged. As the x-rays used in the Velociprobe penetrate the sample, structural information is retrieved rather than just from the surface.

For a given sample placement, the probe beam moves to scan an area (typically a raster-like motion), and then the sample is repositioned to image the adjoining portion. The resulting array of diffraction images are stitched to reconstruct the sample. For example, the perovskite structure shown in the Figure is composed of nine

(3 × 3) scanning tiles. The continuous scanning allows entire imaging in 7 minutes (~46 seconds for each tile).

The fast sampling opens the possibility of *in situ* and *in operando* imaging. Alternatively, three-dimensional ptychography also provides an interesting avenue. Deng says that the Velociprobe is also a proof-of-concept for technologies and techniques to be incorporated into an upgrade of the instruments used at the Advanced Photon Source, a synchrotron facility at the Argonne National Laboratory, such as the PtychoProbe. Orders-of-magnitude improvement in the x-ray flux from the soon-to-be upgraded synchrotron is anticipated.

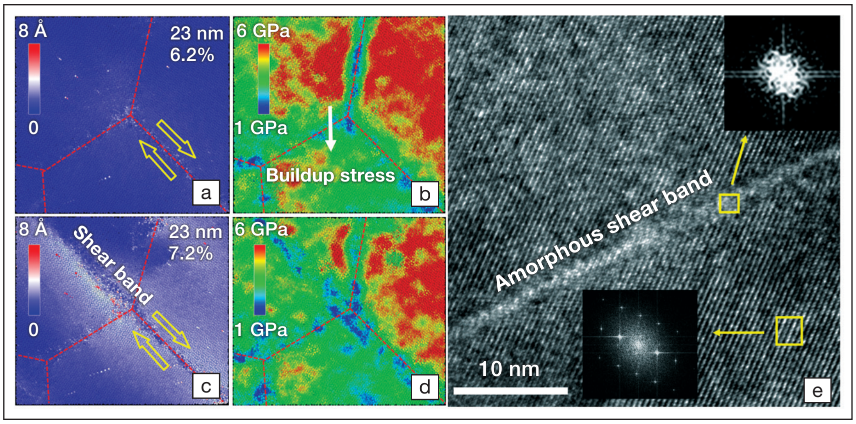
Jeff Gelb from Sigray, Inc., an industrial developer of laboratory x-ray systems, says that coherent diffraction imaging techniques, such as ptychography, are the future of synchrotron x-ray imaging. Gelb, who was not involved in this study, says the lensless approaches represent a major breakthrough in overcoming the limits imposed by x-ray optics, and that researchers have only begun to scratch the surface of what is possible with coherent radiation.

Aashutosh Mistry

Intermetallic samarium cobalt deforms without dislocation activity

The bending of metals is mediated by dislocations. Half-planes of atoms shift around, interacting primarily with grain boundaries, but also with other microstructural defects. As deformation continues, these interactions pile up and frustrate dislocation motion, which both increases the material's strength and reduces its ductility. The Hall–Petch relation, an empirical rule introduced in the 1950s, expresses this interplay between material strength, dislocation motion, and grain size. An international group of researchers has identified deformation that does not involve dislocations. This gives rise to an extended regime of inverse Hall–Petch behavior.

In a recent issue of *Nature Communications* (doi:10.1038/s41467-019-11505-1), Izabela Szlufarska and Hubin Luo of the University of Wisconsin–Madison and their colleagues discussed the unusual deformation mechanism of samarium cobalt. SmCo^5 is a hard magnetic intermetallic with hexagonal—but not close-packed—symmetry. "The initial goal of this project was to understand how we can control the grain size and texture of this material through plastic deformation," says Szlufarska. In particular, the researchers were interested in controlling the material's magnetic behavior through its microstructure, so Luo carried out molecular dynamics simulations to determine the active slip systems. However, no slip system had a low enough activation energy. Instead, the model predicted direct amorphization along shear planes. "Our first reaction was to question these predictions," Szlufarska says. "We spent a significant amount of time testing [them]."



Amorphous shear bands. (a–d) Displacements of atoms relative to their positions in the unstrained samples and distribution of von Mises stress in the same area around a triple junction for grain size of 23 nm under the strain of 6.2% (a, b), and the strain of 7.2% (c, d). (e) High-resolution transmission electron micrograph of a selected shear band and its surrounding regions. Fast Fourier transform patterns are shown in the insets. Scale bar, 10 nm. Credit: Hubin Luo and Hongliang Zhang.

Among those experiments were tensile tests. The researchers varied grain sizes across samples to examine the Hall–Petch behavior of SmCo^5. Inverse Hall–Petch behavior, where strength increases with grain size, had been predicted and observed in previous work, but such behavior was found only with grain sizes below about 15 nm. In SmCo^5, Szlufarska and her team observed strengthening over grain sizes from 5 nm to 65 nm. This led to deeper investigations, and the eventual discovery of direct amorphization in noncrystallographic planes.

While plastic deformation is typically accompanied by dislocation motion, in SmCo^5, deformation is initially mediated by grain-boundary sliding, before the stress buildup at a triple junction gives way to the nucleation of 2-nm thick amorphous shear bands. As a deformation mechanism, these amorphous shear bands can accommodate very large strains—up to 20% without fracture in micropillar samples of SmCo^5.

"We have discovered a new class of mechanisms underlying plasticity in materials and our next step is to find other materials that deform in this way," Szlufarska says. To help them accomplish that, the researchers need to identify exactly why and how direct amorphization occurs. If direct amorphization along shear bands can be controlled independently of dislocation-based deformation mechanisms, Szlufarska thinks it might be possible to design materials with heretofore anti-correlated properties such as high strength and large ductility.

Antonio Cruz