

**E**lectrification of remote areas needs low-cost, off-grid power systems. Solar flow battery (SFB) technology is one such option. However, obtaining both high energy-conversion efficiency and long device lifetime simultaneously for SFB systems has been a challenge.

Work by Anita Ho-Baillie, Song Jin, and co-workers, reported in *Nature Materials* (doi:10.1038/s41563-020-0720-x), showed that a combination of high-efficiency (FAPbI<sub>3</sub>)<sub>0.83</sub>(MAPbBr<sub>3</sub>)<sub>0.17</sub> perovskite/silicon tandem solar cell and redox batteries based on bis-

(trimethylammonio)propyl viologen (BTMAP-Vi) and 4-trimethylammonium-TEMPO (NMe-TEMPO) redox couples can provide a high-performance solar flow battery.

The authors have used numerical methods for the rational design of components to achieve an optimal match between the maximum power point voltage ( $V_{MPP}$ ) of the solar cell and formal cell potential ( $E^0_{cell}$ ) of the redox flow battery. The authors achieved 20.1% solar to output electricity efficiency. This perovskite on a Si tandem cell is

compatible with aqueous organic SFBs while being cost-effective. The Si bottom cell with a gold back-contact comes in contact with the aqueous electrolyte. The performance of the photo-electrode (i.e., the tandem cell with the electrolyte) is similar to the performance of a solid-state tandem solar cell, indicating the compatibility of the tandem cell and electrolytes for flow battery applications. The conceptual design in this work could help in future optimization for storage systems with integrated solar conversion ability.

**K**nowledge of the electronic energy landscape of an electronic material is important for the optimization of its optoelectronic properties, as well as its application in devices. Formamidinium lead triiodide (FAPbI<sub>3</sub>), a three-dimensional electronic material, shows an intriguing quantum confinement effect, as reported by Laura Herz from the University of Oxford and co-workers in *Nature Materials* (doi:10.1038/s41563-020-0774-9). The authors used

temperature-dependent absorption spectroscopy and *ab initio* simulations to confirm the presence of an intrinsic quantum confinement in the nominally bulk semiconductor FAPbI<sub>3</sub>. They attribute this quantum confinement with a length scale of 10–20 nm to the coexistence of different crystallographic phases or domains in the bulk film of FAPbI<sub>3</sub>.

The authors consider this discovery to be highly exciting since it obviates

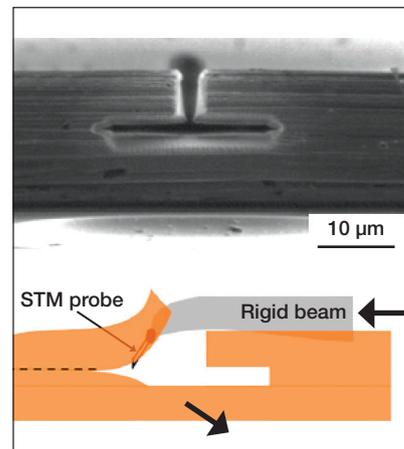
expensive top-down nano-processing steps needed to achieve an electronic quantum confinement effect while maintaining an efficient flow of electrical current through the film. They expect that the intrinsically formed nanostructures in bulk perovskite material will enhance radiative recombination, thus lowering the threshold for amplified spontaneous emission and facilitate the realization of an electrically pumped laser using this material.

### Nanoindentation on peeled high-performance polymeric fibers reveals failure mechanisms

**H**igh-performance fibers are key to many structural and lightweight applications as they are the main reinforcing components of continuous fiber-reinforced composites and fabrics. These fibers are drawn from synthetic polymers such as poly(*p*-phenylene terephthalamide) (PpPTA) or ultrahigh-molecular-weight polyethylene (UHMWPE). During the drawing process, highly oriented and crystalline nanofibrils of 10–50 nm width form and assemble into larger bundles of 100–500 nm width, thereby creating a hierarchical microstructure. Although it is known that hierarchy generally improves the properties of materials, its role in the failure of synthetic fibers has not been studied. In particular, measuring properties at

the intermediate submicrometric scale is challenging. To better understand the role of this organization in the mechanical performance of fibers, the research groups of Yuris Dzenis at the University of Nebraska–Lincoln and Kenneth Strawhecker at the US Army Research Laboratory have taken up the challenge and studied the mechanical interactions between the bundles. Their results were published in *ACS Applied Materials and Interfaces* (doi:10.1021/acsami.9b23459).

To measure the properties at the submicrometric scale, they developed a special protocol in which a T-shaped notch was first cut using focused ion beam milling. Then, a scanning tunneling microscope probe was inserted into the notch to peel away a thin layer of the fiber that delaminated at the bundle interface. The uncovered polymeric surface was then probed by nanoindentation to measure the interfacial separation



Electron micrograph showing the T-shaped notch made by focused ion beam and cartoon showing the peeling process using the scanning tunneling microscope (STM) probe. Credit: ACS Publications.

energy absorption between bundles. Taylor Stockdale, the first author of the article, explains that “by performing repeated indents at the same location, we

could subtract the absorbed energy due to elastic recovery and gain better insight into the energy required to separate two bundles.”

Applying this method to two polymers with different crystallinity and chain flexibility, UHMWPE and PpPTA, it was found that both fibers had similar microstructures and tensile properties, and they showed intermediate scale fibrillation between bundles under tensile failure. However, the interactions between bundles were stronger for PpPTA as compared to UHMWPE, presumably due to more interconnected crystals.

Another interesting finding was that the energy absorbed at the interfaces between the bundles was more than 10 times higher than the energy absorbed at the nanofibril level, of  $\sim 13\text{--}27\text{ J.m}^{-2}$  and  $\sim 0.3\text{--}0.5\text{ J.m}^{-2}$ , respectively. Although

structures fail at their weakest point, the fibrillation happened at the bundles level in their experiments. The researchers point out that to understand the real fracture of the fibers in tension mode, direct *in situ* characterization of nanofibrils and bundles would be required.

This study contributes to our understanding and quantification of the interaction mechanisms in high-performance fibers. This research could lead to further enhancement of fiber properties by developing a drawing process that would result in an optimum microstructure. Among the many avenues the researchers plan to pursue, “further *in situ* multiscale testing and extracting individual nanofibrils and nanofibril bundles to perform tensile tests would be of great value,” says Dzenis. “The results can lead to new fundamental scaling models of the discovered unique

fractal fracture behavior of hierarchical high-performance fibers.”

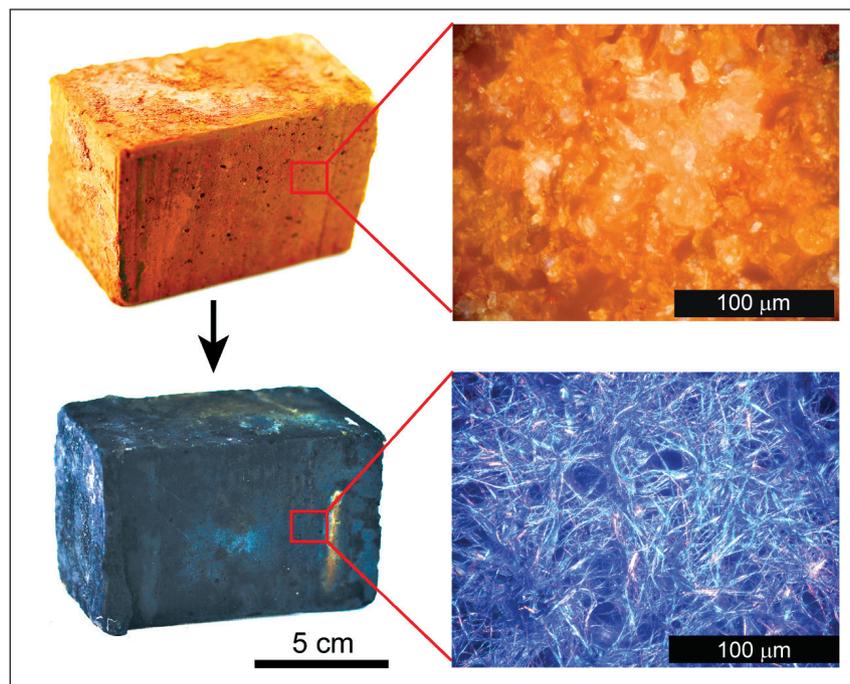
Flavia Libonati, an associate professor at the Università di Genova, Italy, and affiliated with the Laboratory for Atomistic and Molecular Mechanics at the Massachusetts Institute of Technology and who did not participate in this study, says that “the fracture mechanisms resemble the failure of fibers present in natural and biological materials and, in particular, the role of the interfaces in the load transfer and the importance of hierarchy on the amplification of the mechanical performance with respect to the building blocks. A deeper understanding of such mechanisms and of the processing–structure–property relationships, via multiscale modeling and experiments, can pave the way toward the design of better advanced materials.”

**Hortense Le Ferrand**

### Electrochemical energy-storage material architecture built brick-by-brick

Red bricks form load-bearing walls, line chimneys, and adorn architecturally aesthetic facades of countless buildings around the world. Most common fired bricks are comprised of silica ( $\text{SiO}_2$ ), alumina, ( $\text{Al}_2\text{O}_3$ ), and hematite (iron oxide, or  $\text{Fe}_2\text{O}_3$ )—the latter being responsible for its recognizable red color. Masons have relied on this ubiquitous and inexpensive construction material for thousands of years. Recently, researchers have unlocked a red-hot discovery: everyday bricks can not only provide shelter but also pave the way toward a new electrochemical energy-storage material.

A close examination of a typical fired brick reveals a highly porous microstructure that can easily take up solvents and materials such as polymers. The iron oxide component provides positive iron ions that can promote the synthesis of the polymer poly(3,4-ethylenedioxythiophene), or PEDOT. This conductive polymer coats the inner surfaces of the brick pores, and, owing to its high electronic conductivity and ability to rapidly transfer charge, functions



Photograph of a commercially available brick, as well as analysis of its microstructure, before and after it is coated with the polymer poly(3,4-ethylenedioxythiophene) to become an energy-storage module. Credit: D’Arcy Research Laboratory, Washington University in St. Louis.

as an active material in an electrochemical capacitor (conventionally known as a supercapacitor). Once an appropriate electrolyte is added to the brick, the resulting functional standalone energy-storage device

mimics a “brick-mortar-brick” structure and delivers over 10,000 stable charge/discharge cycles. Areal capacities of these devices reach 1.6 Farads per square centimeter. This storage capability, coupled with