

To make perovskite solar cells commercially, manufacturers will need to produce high-quality perovskites on large areas for a low cost. The challenge is that scaling up small laboratory devices to more than 25 cm<sup>2</sup> can reduce the power-conversion efficiency anywhere from 10 to 20%.

Researchers from Shanghai Jiao Tong University in China have come up with

an easy route to making uniform, defect-free, large-area perovskite films in air at room temperature. The process does not require conventional solvents and a vacuum. As reported in the journal *Nature* (doi:10.1038/nature23877), researchers made 36 cm<sup>2</sup> solar cells that were more than 12% efficient. The researchers placed a 1:1 mixture of the amine

complex precursors CH<sub>3</sub>NH<sub>3</sub>I<sub>3</sub>•CH<sub>3</sub>NH<sub>2</sub> and PbI<sub>2</sub>•CH<sub>3</sub>NH<sub>2</sub> on a substrate, applied a smooth polyimide film on top, pressed down on it for a minute with a squeezing board to spread the liquid, and then warmed the substrate at 50°C for two minutes. When they peeled off the polyimide film, a dense, uniform perovskite film had formed.

Perovskites' low stability and lead toxicity remain hurdles to commercial use. Double perovskites are an appealing alternative. Now researchers have, for the first time, made double perovskite films and built a working solar cell from the film.

Conventional perovskites have the formula ABX<sub>3</sub>. Double perovskites, in which the unit cell is twice that of a conventional perovskite, have the formula AB'B''X<sub>6</sub>. The double perovskite Cs<sub>2</sub>AgBiX<sub>6</sub> (X=Cl,

Br) is a promising material for solar cells since it is less toxic and stable. However, its precursor's low solubility has so far hampered the fabrication of high-quality films.

The team from the University of Munich, Germany, and Newcastle University, UK, found that annealing at more than 250°C was key for converting the precursors into high-quality perovskite films. They made Cs<sub>2</sub>AgBiBr<sub>6</sub> films by dissolving BiBr<sub>3</sub>, AgBr, and

CsBr in dimethylsulfoxide; preheating the solution to 75°C, and then spin-coating it onto a substrate that was subsequently annealed at 285°C.

Photovoltaic devices made with the films have a power-conversion efficiency of up to 2.43%, an open-circuit voltage of more than 1 V, and a high stability under operating conditions, the researchers reported in the *Journal of Materials Chemistry A* (doi:0.1039/c7ta06816f).

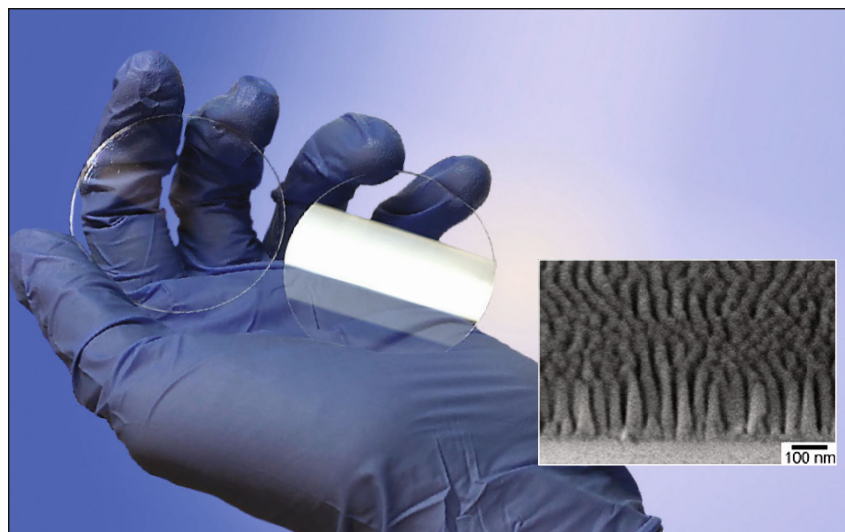
## Nano Focus

### Nanocones make glass invisible

By etching tiny nanoscale features into glass and plastic surfaces, researchers have found a way to cut their light reflection to almost zero, rendering them nearly invisible. This could be a much-needed solution to the annoying glare from phone, TV, and computer screens. Apart from making consumer displays glare-free over a wide range of viewing angles, the nanotextured glass could also make the surface water-repelling and self-cleaning.

When light travels from air to glass, the abrupt change in refractive index between the materials makes around 8% of light bounce back. Manufacturers coat device displays and eyeglasses with antireflective films to reduce this unwanted reflection. Antireflective coatings have a refractive index and thickness designed to make reflected light waves interfere in a way that they cancel each other out. But the films only work at a certain wavelength.

A better way to completely eliminate reflection is to get rid of the abrupt change in refractive index at the air-glass



Glass surfaces with etched nanotextures reflect so little light that they become essentially invisible, as seen in this image, which compares the glare from a conventional piece of glass (right) to that from nanotextured glass (left), which shows no glare at all. (Inset) Cross-sectional scanning electron microscope image shows a glass surface textured with 170-nm-tall cones. The cones are packed very close to each other, only 52 nm apart. A two-inch piece of glass has 900 billion cones on its surface. Credit: Brookhaven National Laboratory.

interface. Texturing the surface by creating tiny nanoscale structures is one way to do this. These structures are smaller than the wavelength of light. "As the light moves through this forest of structures into glass, it sees a gradual change in the

refractive index," says Charles Black, director of the Center for Functional Nanomaterials at Brookhaven National Laboratory. "It's the ultimate way to do antireflection in that it works across all wavelengths."

Such antireflective nanotexturing is found in moth eyes and cicada wings. Researchers have tried to mimic such nanostructures with mixed success.

Black and his colleagues used block copolymers in their approach, as described in an article published in a recent issue of *Applied Physics Letters* (doi:10.1063/1.5000965). They first made a template with the block copolymer polystyrene-*b*-poly(methyl methacrylate), which self-assembles into a periodic pattern. They then used plasma etching to transfer this pattern to a glass surface. They

placed the template on a glass surface, and a hot plasma gas etched out the tiny areas that were not protected by the template. This left the glass surface covered with densely packed cone-shaped structures that were less than 10 nm in width.

Covering both surfaces of the glass with 280-nm-tall nanocones reduced the reflections of all visible and near-infrared wavelengths to less than 0.2%. Taller nanocones made the glass surface more antireflective, the researchers found.

Black's research team has used a similar technique before to create nanotextures

on silicon to increase light absorption in solar cells. The textured surface should stay dust-free since the space between the cones is too tiny for dust particles, which are typically tens of micrometers in size.

The techniques are compatible with industrial processes used for microelectronics and displays, says Black, which makes them amenable to being made practical. The researchers now need to investigate whether the nanostructured glass will be robust and economical enough for commercial use.

**Prachi Patel**

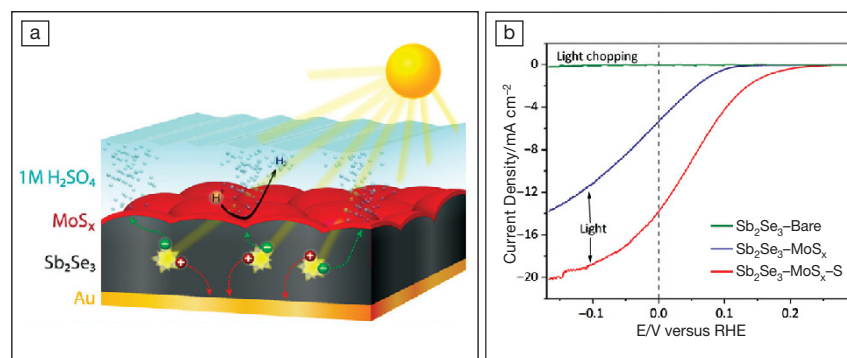
### Energy Focus

#### Earth-abundant photocorrosion-resistant material used for solar water splitting

A simple and low-temperature antimony (Sb) deposition method has been used to generate a new photocorrosion-resistant material for water-splitting applications. Research led by David Tilley of the University of Zürich made the conventional protective layer in a solar water-splitting application an obsolete requirement by introducing a combination of  $\text{Sb}_2\text{Se}_3$  and  $\text{MoS}_x$ , which functions without the need of any protective layer. Their research was published in a recent issue of the *Journal of Materials Chemistry A* (doi:10.1039/c7ta08993g).

The  $\text{Sb}_2\text{Se}_3$  thin films were fabricated through selenization of simple, low-temperature electrodeposited Sb films. Current state-of-the-art photocathodes need a protective layer of titanium dioxide ( $\text{TiO}_2$ ). Initially, Tilley's group used  $\text{Sb}_2\text{Se}_3$  with the  $\text{TiO}_2$  protective layer and a platinum (Pt) catalyst. However, they soon realized the stable nature of  $\text{Sb}_2\text{Se}_3$  and found low-cost amorphous  $\text{MoS}_x$  to replace scarce and expensive Pt.

Tilley says, "We considered that the  $\text{Sb}_2\text{Se}_3$  might be stable without protective layers, and we also wanted to explore earth-abundant alternatives to state-of-the-art HER catalysts like Pt and  $\text{RuO}_x$ . One such candidate which came to our mind was amorphous  $\text{MoS}_x$  as it could be prepared by a simple electrodeposition method which



(a) Schematic representation of  $\text{Sb}_2\text{Se}_3$ - $\text{MoS}_x$  photocathode. (b) Current density-potential characteristics of  $\text{Sb}_2\text{Se}_3$ - $\text{MoS}_x$  (non-sulfurized) and  $\text{Sb}_2\text{Se}_3$ - $\text{MoS}_x$ -S (sulfurized) photocathode in 1 M  $\text{H}_2\text{SO}_4$  under simulated 1 sun illumination ( $100 \text{ mW cm}^{-2}$ ). The bare  $\text{Sb}_2\text{Se}_3$  is under light chopping (i.e., light was blocked as the device was measured under dark conditions). Reproduced from *J. Mater. Chem. A* 5 (2017), p. 23139, with permission from the Royal Society of Chemistry.

was low cost and fast." The photocorrosion-resistant behavior of  $\text{Sb}_2\text{Se}_3$  in combination with  $\text{MoS}_x$  eliminates the need for any such coating.  $\text{Sb}_2\text{Se}_3$ - $\text{MoS}_x$  is one of the few materials that is immune to photocorrosion while providing the high photocurrent that is required for water-splitting applications.

A sulfurization process became the key factor in increasing the photocurrent of the device. A high photocurrent density of 5.2 and 13  $\text{mA cm}^{-2}$  at 0 V versus RHE was recorded for  $\text{Sb}_2\text{Se}_3$ - $\text{MoS}_x$  and  $\text{Sb}_2\text{Se}_3$ - $\text{MoS}_x$ -S (sulfurized photocathode coupled with the catalyst), respectively. The sulfurization only affects the surface of the  $\text{MoS}_x$  layer as indicated in elemental mapping performed through energy-dispersive x-ray spectroscopy.

Kazuhiro Takanabe of the Physical Science and Engineering Division at

King Abdullah University of Science and Technology (KAUST), highlights the importance of this publication in the field of solar water splitting. "Chalcogenide semiconductors have been long considered as photoelectrochemical material, but its stability in water under illumination remains an issue. Ramanujam et al. (this study) exhibited a way of the successful decoration of  $\text{Sb}_2\text{Se}_3$  with a hydrogen evolution catalyst ( $\text{MoS}_x$ ) to solve the photocorrosion path. This methodology can be applied to various materials, and thus it is an important finding," Takanabe says.

Tilley and his research team are now looking to gain a deeper understanding of recombination mechanisms in the  $\text{Sb}_2\text{Se}_3$ - $\text{MoS}_x$ -S photocathode to increase the photovoltage.

**Rahim Munir**