

ers to dissociate at the electrodes, leading to efficient photocurrent generation. As n increased, the luminescence of the materials shifted toward longer, redder wavelengths. The redshift also happened when the material was exposed to the laser for a long time, because thermal fluctuations reoriented the surface organic

cations in the monolayer perovskite. The color shift can be reversed by exposing the sample to higher power laser annealing under vacuum. This cycle could be repeated tens of times.

The disordering of the organic cations also creates defects that trap only positively charged carriers, allowing elec-

trons to circulate longer. To test this, the researchers made a photodetector with the monolayer perovskites. The detector had a low current in the dark. But the current increased linearly with laser power because under illumination, excitons tunneled across the interlayers, creating a highly conductive state.

Concentrated photovoltaic (CPV) devices, which use lenses and mirrors to focus sunlight onto small, highly efficient solar cells, can have power-conversion efficiencies as high as 46%. Very expensive multi-junction solar cells made with III–V semiconductors, such as gallium indium phosphide, are often used for such devices.

Could perovskite solar cells, which suffer from instability under light and heat,

be used for CPV technology? University of Oxford researchers led by Henry Snaith answer that question in a study published in *Nature Energy* (doi:10.1038/s41560-018-0220-2). They found that the efficiency of halide perovskite solar cells went up from 21.1% to a peak of 23.6% when simulated sunlight was increased to 14 times the standard irradiance of 1 Sun.

The researchers assessed a range of perovskite materials for their stability

under high-intensity light. Perovskites containing a mixed cation formamidinium-cesium composition gave the most stable solar cells under high irradiance, and they chose $\text{Fa}_{0.83}\text{Cs}_{0.17}\text{PbI}_{2.7}\text{Br}_{0.3}$ for the CPV device. They found that their devices, maintained at room temperature during operation, retained 90% of their original efficiency after 150 hours spent under 10 Suns of concentrated light.

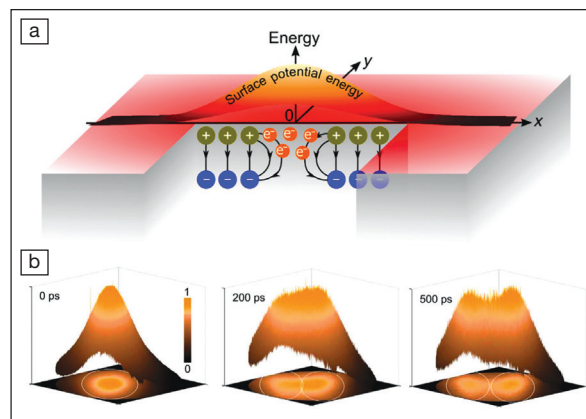
Separating photo-induced electrons provides a new paradigm in optoelectronic control

Manipulating the distribution of photo-induced electrons on semiconductor surfaces is meaningful to develop novel optoelectronic technologies. Yet, it is a challenging task due to the lack of feasible methods. Keshav M. Dani and co-workers from Okinawa Institute of Science and Technology, Japan, have filled the niche. They demonstrated that a beam of ultrafast light pulse could pull apart the photo-induced electrons on a GaAs semiconductor surface. This study was recently published in *Science Advances* (doi:10.1126/sciadv.aat9722).

The ability to record movies of ultrafast charge transport in semiconductors with an advanced time-resolved photoemission electron microscope (TR-PEEM) inspired this work. This unique microscope developed within this research group can image surface electron motion in semiconductors with high spatial and temporal resolution. “Using our TR-PEEM, last year we recorded a movie of electrons moving across a semiconductor heterojunction,” says E. Laine Wong of Okinawa

Institute of Science and Technology, the first author of the article. “We then wanted to see if we could drive the motion of electrons in a homogeneous semiconductor by utilizing intensity variations in an optical pulse.”

The technique used to separate the surface photo-induced electrons is based on the surface photovoltage effect. Upon shining a light pulse from a laser source onto a p -type semiconductor, where the light pulse has higher energy than the semiconductor’s bandgap, electrons and holes will be generated near the semiconductor surface. The subsequent drift of the photo-induced electrons toward the surface weakens the intrinsic electric field in the semiconductor and results in a lateral surface potential difference. This potential difference then drives the surface photo-induced electrons apart. Specifically, the researchers irradiated a p -type Zn-doped GaAs semiconductor with an excitation



(a) The illustration of the surface photovoltage effect that leads to the surface potential variation; (b) the evolution of the surface-electron distribution profile into two separated Gaussian peaks within 500 ps after photoexcitation. Credit: *Science Advances*.

pulse having a Gaussian-shaped intensity profile. This irradiation divided the photo-induced electrons into two groups over 500 ps after a 45-fs photoexcitation.

The rate and the degree of the transient electron separation depended on the concentration of the charge carriers (photo-induced electrons and holes). With a relatively low charge-carrier density of $2.8 \times 10^{18} \text{ cm}^{-3}$, the distribution profile of the surface electrons only developed into a single flat-top Gaussian peak; that is,



the surface electrons were not separated. At charge-carrier densities of $8.4 \times 10^{18} \text{ cm}^{-3}$ and above, the surface electron redistributed into two groups, as evidenced from the two separated Gaussian peaks. Additionally, the peak separation broadened with elevated charge-carrier density

because higher charge-carrier density led to stronger lateral surface potential that forced the surface electrons apart.

Mingyang Li of Sun Yat-sen University, China, who is not involved in the work, says, “The capability of imaging the charge transport on semiconductor surfaces with

excellent resolutions could verify the simulated motions of photocarriers during photo-reactions. The manipulation of the photo-induced electron distribution might also be used to improve the performance of photoelectrochemical cells.”

Tianyu Liu

Automotive clearcoats characterized in search for improvement

In the automotive industry, four layers of coatings on the car body are typically used, each with 10–30 μm thickness, in order to provide protection from UV rays, scratches, and corrosion of the metallic frame, and for aesthetic purposes including color. The top coating, called clearcoat, is of particular importance since a strong clearcoat will also protect and maintain the performance of the underlying coatings.

Currently, the automotive industry uses the Crockmeter and the Amtec-Kistler Carwash tests to assess the scratch resistance of their coatings. These tests simulate scratching conditions during usage of a car. The clearcoats are then classified based on their physical appearance. But scratch mechanics is a complex intertwining of viscoelasticity, plastic flow, and fracture, and industry seeks a better understanding of

these different regimes in order to improve the coating formulations.

This is the task tackled by research teams from Eastman Chemical Company, Hyundai-Kia America Technical Center, the National Institute of Standards and Technology, and Anton Paar USA Inc.; they published their results in a recent issue of *Progress in Organic Coatings* (doi:10.1016/j.porgcoat.2018.09.011). For their study, the researchers chose commercially available clearcoats and experimental coatings based on solvent or waterborne chemistry, and with tunable cross-linking density. Each formulation was coupled with a specific underlying basecoat to test its compatibility and adhesion.

“Scratch has been often viewed as a surface issue as opposed to a bulk or interface issue in the coatings industry,” says Linqian Feng, the corresponding author of the study. “The nanoscratch methods specified in the automotive industry today do not necessarily probe the whole depth of the clearcoat where the

interface with the basecoat becomes a major consideration.”

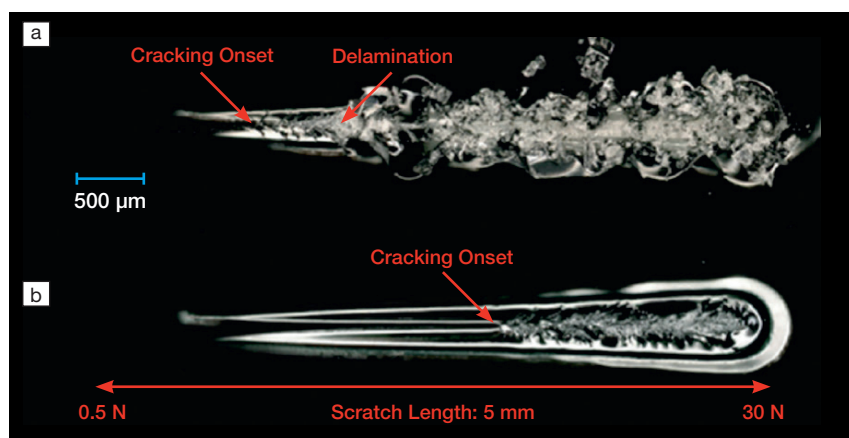
After being sprayed onto a steel plate, the dual coats were submitted first to industrial scratch tests. Then, using diamond tips of 1 μm , 50 μm , and 200 μm diameter and increasing loadings, the researchers used a tribometer and a nano-scratcher to examine the deformation regimes occurring during scratching. The loading conditions were similar to those occurring under a scratch from a brush, a key, or a cart.

The researchers observed that the clearcoats deformed elastically at low scratch loads. As the severity of the scratch increased, the coatings deformed plastically, fractured, and delaminated (see Figure). The coatings that allow for a large initial deformation or which were highly cross-linked were found to be tougher and showed higher fracture and delamination resistance.

“[The researchers] have done a nice job marrying industrial coating producers and scratch testing experts to develop correlations between state-of-the-art lab tests and industry standard tests,” says Jeffrey Wheeler, a senior scientist and *in situ* mechanical testing expert from ETH Zürich in Switzerland, who did not take part in this study. “The next step would be to extend these bench tests to include environmental testing to match the service conditions these coatings may experience during their life, such as salt abrasion at low or high temperature.”

“Future work could definitely build on the current understanding of the properties of each layer in the system. In particular, we would be interested in [the effects of the impinging of] stone chips, which are an impact phenomenon that is of great importance in the automotive industry,” Feng says.

Hortense Le Ferrand



Optical micrographs of scratch patterns obtained with a diamond tip of 200 μm diameter on two waterborne clearcoats cross-linked using formaldehyde where the deformation at break was 2% and 8% with toughness of 0.4 MPa and 3 MPa for (a) and (b), respectively. Credit: *Progress in Organic Coatings*.