the surface electrons were not separated. At charge-carrier densities of 8.4×10^{18} 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."

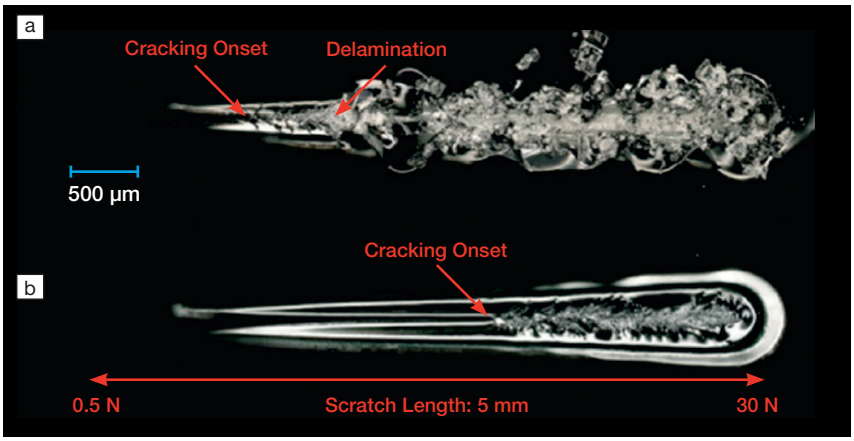
After being sprayed onto a steel plate, the dual coats were submitted first to industrial scratch tests. Then, using diamond tips of 1 µm, 50 µm, and 200 µm diameter and increasing loadings, the researchers used a tribometer and a nano-scratcher to examine the deformation regimes occurring during scratching. 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.*

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