

### Conjugated Polymer Film Fluorescence Enhances Images of Latent Fingerprints

Latent fingerprints—those left on surfaces without any ink—are often a critical clue for investigators at crime scenes. However, the high-sensitivity methods currently used in forensic science to detect latent fingerprints are cumbersome and difficult to employ. Now, in a recent issue of *Chemical Communications* (Issue 16, DOI: 10.1039/b902316j, p. 2112), G. Kwak, W.-E. Lee, W.-H. Kim, and H. Lee of Kyungpook University in Korea introduce a method of using a conjugated polymer thin film and fluorescent imaging for rapid, reusable latent fingerprint detection that may help overcome these issues.

The highly fluorescent conjugated polymer poly[1-phenyl-2-(p-trimethylsilyl)phenylacetylene] (PTMSDPA) is known to have a large (0.26) fractional free volume as a film, which allows chemicals to easily diffuse into it. The research group

previously determined that the intensity of fluorescence of PTMSDPA significantly increases when it absorbs certain chemicals, and speculated that this might also be the case for materials on human skin. To test this hypothesis, the group first exposed a free-standing, 30- $\mu\text{m}$ -thick film of PTMSDPA to a sample of simulated human sebum (a 50:50 wt% mixture of a lipid standard and a fatty acid standard) and found that the fluorescent intensity of the film under UV illumination increased by more than an order of magnitude shortly after contact with the simulated sebum. Notably, no lateral diffusion of the fluorescence increase was observed until 30 minutes after the first exposure, suggesting that any spatial patterns (i.e., fingerprints) would persist in the fluorescence.

The group next directly deposited a real fingerprint on a similar film of PTMSDPA, and obtained images of the polymer's fluorescence under UV illumination. The images show the fingerprint

pattern with high resolution, to the point that pores on the ridges are more evident than in conventional chemical imaging techniques. The group was further able to successfully transfer latent fingerprints to the PTMSDPA film from glass, steel, and polyethylene terephthalate (PET) plastic by gently pressing the film onto these surfaces. Transfers from paper were not successful, which the researchers suggest is because of the paper's porosity and roughness. The group was able to erase a fingerprint image on the film by washing it with acetone, and demonstrated the re-use of a film to detect a second print.

These results demonstrate that polymer thin films and UV fluorescent imaging may be the key to simple, rapid, and reusable latent fingerprint detection, which would earn the thanks of crime scene investigators everywhere.

COLIN MCCORMICK

### Percolation Model Developed to Describe Charge Transport in FETs Constructed from CNT Networks

Films composed of random carbon nanotube (CNT) networks are increasingly being used for electronic applications. The low cost and flexibility of submonolayer CNT films have led to their use as sensors and as field effect transistors (FETs). Individual CNTs have been reported to have field effect mobilities of 10,000–100,000  $\text{cm}^2/\text{Vs}$ . However, carbon nanotube network FETs (CNTN-FETs), which contain both metallic and semiconducting CNTs, display mobilities on the order of 10  $\text{cm}^2/\text{Vs}$  for unprocessed films and 80  $\text{cm}^2/\text{Vs}$  after the films are processed to break metallic network conduction. Because only the semiconducting CNTs can have their conductance modulated, it is critical to have semiconducting CNTs percolate the film, whereas a percolative metallic network would short out the device. Controlling tube density, tube-tube junction characteristics, and the fraction of tubes that are semiconducting may all lead to improved device performance. Recently, M.A. Topinka, M.W. Rowell, D. Goldhaber-Gordon, and M.D. McGehee of Stanford University and the SLAC National Accelerator Laboratory, Menlo Park, and D.S. Hecht and G. Gruner of the University of California, Los Angeles have investigated how current flows through CNTN-FETs, and have provided evidence for three possible types of CNTN-FETs with fundamentally different gating

mechanisms. They have also developed an electronic phase diagram for CNTN-FETs.

As reported in *Nano Letters* (DOI: 10.1021/nl803849e; Web publication: March 30), Topinka, Goldhaber-Gordon, McGehee, and co-researchers used electric force microscopy (EFM) in conjunction with standard conductance measurements to map the location of voltage drops in CNT films (prepared using chemical vapor deposition) with current flowing through them. The researchers showed that the electrical performance and the voltage-drop maps can be drastically different for two devices even when they were fabricated immediately adjacent to each other on the same CNT film, that is, with constituent CNT characteristics that are statistically identical. For one device, voltage decreased slowly between source and drain electrodes while in another device voltage drops precipitously at one location, indicating large, dominating local resistances in the latter but none in the former. Numerical simulations of the electrostatic potential and current flow were performed in order to better understand the source of these experimental results. In the simulations, tubes 4  $\mu\text{m}$  in length were placed in random orientations until the desired density was reached. Using tube and junction resistivities of 13  $\text{k}\Omega/\mu\text{m}$  and 200  $\text{k}\Omega/\text{junction}$ , respectively, the overall resistance of the network of tubes was solved using a sparse matrix inverter available in commercial software. The average conductance for 300 random films

(with densities varying between 0 and 0.75 tubes/ $\mu\text{m}^2$ ) agrees with theoretical results for conduction through a two-dimensional system of percolating sticks. In addition, simulations of films just above the percolation threshold (0.48 tubes/ $\mu\text{m}^2$ ) explain the experimental voltage-drop maps; the networks showing the highest conductance have current flowing along many parallel paths while the networks showing the lowest conductance have one or only a few conducting paths.

Taking into consideration published results on metallic-semiconducting nanotube junctions as well as the fact that most methods of carbon nanotube synthesis produce mixtures of metallic and semiconducting tubes, the researchers realized a relatively small number of metallic tubes can disrupt conduction through an otherwise robust semiconducting network. The researchers therefore modified their simulation by making a portion of the network tubes semiconducting, and were able to construct a phase diagram that describes the nature of a CNT film as a function of tube density and semiconductor fraction. CNT-FETs can be constructed from films in three regions in the phase diagram, but those FETs can operate by two different gating mechanisms, involving the potential barrier formed at the metal-semiconductor junctions or the unblocked semiconducting paths that connect source to drain.

The researchers said, "Enriching the population of semiconducting tubes to 90% or