Chemists advance organic semiconductor processing

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Any machinist will tell you that a little grease goes a long way toward making a tool work better. And that may soon hold true for plastic electronics as well.

Carnegie Mellon University chemists have found that grease can make some innovative plastics vastly better electrical conductors. This discovery, published June 25 in *Advanced Materials*, outlines a chemical process that could become widely adopted to produce the next generation of tiny switches for transistors in radio frequency identification tags, flexible screen displays, and debit or key cards.

"This research brings us closer to developing organic semiconductors with electrical and physical properties far superior to those that exist today," said principal investigator Richard D. McCullough, professor of chemistry and dean of the Mellon College of Science at Carnegie Mellon. "We were surprised and amazed with our findings." The new process involves adding a little grease in two ways, say the investigators. The first step involves chemically combining an inherently conducting polymer (ICP) with a grease-like chemical. The second step involves depositing this hybrid material — called a block copolymer — onto a greased platform.

On the surface layer of a transistor, ICPs make good electrical conductors that provide the switch element for a transistor to turn on and off. But ICPs are by nature brittle. To counter this brittleness, scientists chemically link ICPs with grease-like, elastic polymers to make block copolymers.

“These block copolymers are very promising for creating future materials, such as lightweight, thin composite films for ebook readers that you could roll up like today’s newspapers,” said Genevieve Sauvé, a research associate who conducted the latest research under conditions similar to a commercial production setting.

While they provide much-needed flexibility, elastic polymers insulate rather than conduct electricity. Block copolymers that contain grease-like polymers are less effective electrical conductors than pure ICPs. Yet in the right processing setting, the opposite can hold true, the Carnegie Mellon scientists now report. It just depends how you treat a transistor’s silicon dioxide base layer.

As part of the current study, the Carnegie Mellon team tested four block copolymers, each with a different ratio of insulating elastic polymer to conducting polymer. When they applied thin films of these different polymers to untreated silicon dioxide, they found the greater the overall amount of insulating polymer in the final film, the worse that film performed in conducting an electric charge. The result is a flexible switch layer that doesn’t work very well.

But when the scientists pretreated the transistor’s silicon dioxide platform with OTS-8 — a chemical that creates a grease-like coating — they found that transistors incorporating any of the four block copolymers conducted an electric charge with remarkable ease, even when the insulating polymer constituted more than half of the applied block copolymer.

“Something amazing is happening at the molecular interface between our block copolymer and the OTS-8-treated surface so the block copolymers self-assemble with great precision,” Sauvé said. “In fact, we think that the grease-like, insulating polymer in the material and the grease-coated surface both somehow exert important effects in driving this self-assembly."

Block copolymers with up to 57 percent insulating polymer performed 10 times better on OTS-8-treated surfaces than they did on untreated surfaces, according to the investigators. More importantly, the block copolymers were nearly equal in their performance to ICPs alone on treated surfaces, according to McCullough.

"This is the first report that copolymers are good organic semiconductors," McCullough said. "These results mean that we could soon design devices that are both flexible and highly functional."

OTS-8 appears to help the block copolymers assemble into nanowires that are much more highly organized than those that self-assemble on untreated silicon dioxide, according to Sauvé. (See available images)

The Carnegie Mellon team used block copolymers containing ICPs called regioregular polythiophenes (rr-P3HTs), which were initially described by McCullough in 1992. In subsequent research, McCullough's laboratory has developed cost-efficient methods to produce rr-P3HTs so they can be put into solution and sprayed onto surfaces using ink-jet printing. McCullough has also shown that rr-3PHTs can be modified to attach to different surfaces. By chemically linking rr-P3HTs with other elastic polymers, McCullough's group has also produced conductive plastics with a range of physical properties that could suit different device applications.

The insulating, elastic polymer used in this latest work is poly(methylacrylate), or PMA. Sauvé is using this system to evaluate nanowire assembly and conductive properties of block copolymers made with polymers other than PMA. These additional polymers are being developed by research scientist Mihaela Iovu in McCullough's lab.

Eventually, Sauvé says, polymer chemists could replace a silicon dioxide base with a flexible plastic so consumers could roll up plastic displays.

Link: www3.interscience.wiley.com/cg … t/114282726/PDFSTART

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