Doubling the efficiency of organic electronics

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Double doping could improve the light-harvesting efficiency of flexible organic solar cells (left), the switching speed of electronic paper (center) and the power density of piezoelectric textiles (right). (The solar cell was supplied by Epishine AB.) Credit: Johan Bodell/Chalmers University of Technology

Researchers from Chalmers University of Technology, Sweden, have discovered a simple new tweak that could double the efficiency of organic electronics. OLED-displays, plastic-based solar cells and bioelectronics are just some of the technologies that could benefit from their new discovery, which deals with "double-doped" polymers.

The majority of electronics are based on inorganic semiconductors such as silicon. Crucial to their function is a process called doping, which involves weaving impurities into the semiconductor to enhance its electrical conductivity. This allows various components in solar cells and LED screens to work.

For organic—that is, carbon-based—semiconductors, this doping process is also highly important. Since the discovery of electrically conducting plastics and polymers, a field for which the Nobel Prize was awarded in 2000, research and development of organic electronics has accelerated quickly. OLED-displays are one example already on the market, for example, in the latest generation of smartphones. Other applications have not yet been fully realised, due in part to the fact that organic semiconductors are not yet efficient enough.

Doping in organic semiconductors operates through what is known as a redox reaction. This means that a dopant molecule receives an electron from the semiconductor, increasing the electrical conductivity of the semiconductor. The more dopant molecules that the semiconductor can react with, the higher the conductivity—at least up to a certain limit, after which the conductivity decreases. Currently, the efficiency limit of doped organic semiconductors has been determined by the fact that the dopant molecules could only exchange one electron each.

But now, in an article in the scientific journal *Nature Materials*, the group of Christian Müller, professor of Polymer Science at Chalmers University of Technology, together with colleagues from seven other universities, demonstrates that it is possible to move two electrons to every dopant molecule.

Double doping could improve the light-harvesting efficiency of flexible organic solar cells. (The solar cell was supplied by Epishine AB.) Credit: Johan Bodell/Chalmers University of Technology

"Through this double-doping process, the semiconductor can therefore become twice as effective," says David Kiefer, Ph.D. student in the group and first author of the article.

According to Christian Müller, this innovation is not built on some great technical achievement. Instead, it is simply a case of seeing what others have not seen. "The whole research field has been totally focused on studying materials that only allow one redox reaction per molecule. We chose to look at a different type of polymer with lower ionisation energy. We saw that this material allowed the transfer of two electrons to the dopant molecule. It is actually very simple," says Müller, Professor of Polymer Science at Chalmers University of Technology.

The discovery could allow further improvements to technologies which today are not competitive enough to make it to market. One problem is that polymers simply do not conduct current well enough, so making the doping techniques more effective has long been a focus for achieving better polymer-based electronics. Now, this doubling of the conductivity of polymers, using only the same amount of dopant material over the same surface area as before, could represent the tipping point needed to commercialise several emerging technologies.

"With OLED displays, the development has come far enough that they are already on the market. But for other technologies to succeed and make it to market, something extra is needed. With organic solar cells, for example, or electronic circuits built of organic material, we need the ability to dope certain components to the same extent as silicon-based electronics. Our approach is a step in the right direction," says Müller.

The discovery offers fundamental knowledge and could help thousands of researchers to achieve advances in flexible electronics, bioelectronics and thermoelectricity. Christian Müller's research group is researching several applied areas based on polymer technology. Among other things, his group is looking into the development of electrically conducting textiles and organic solar cells.

More information: David Kiefer et al, Double doping of conjugated polymers with monomer molecular dopants, *Nature Materials* (2019). DOI: 10.1038/s41563-018-0263-6

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