Examples of organic electronics: flexible solar cells (left, supplied by Epishine AB), electronic paper (center) and piezoelectric textiles (right). Photomontage: Johan Bodell/Chalmers University of Technology

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Breakthrough in organic electronics

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 our everyday 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. It is this that allows various components in solar cells and LED screens to work.

For organic – that is, carbon-based – semiconductors, this doping process is similarly of extreme importance. Since the discovery of electrically conducting plastics and polymers, a field in which a Nobel Prize was awarded in 2000, research and development of organic electronics has accelerated quickly. OLED-displays are one example which are 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 have so far not been 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 have only been able to exchange one electron each.

But now, in an article in the scientific journal Nature Materials, Professor Christian Müller and his group, together with colleagues from seven other universities demonstrate that it is possible to move two electrons to every dopant molecule.

"Through this 'double doping' process, the semiconductor can therefore become twice as effective," says David Kiefer, PhD 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, which 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 Christian 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, and 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, while using only the same amount of dopant material, over the same surface area as before, could represent the tipping point needed to allow several emerging technologies to be commercialised.

“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 Christian 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 themselves are researching several different applied areas, with polymer technology at the centre. Among other things, his group is looking into the development of electrically conducting textiles and organic solar cells.

Read the article in Nature Materials: "Double Doping of Conjugated Polymers with Monomer Molecular Dopants"

The research was funded by the Swedish Research Council, the Knut and Alice Wallenberg Foundation, and the European Research Council (ERC), and was carried out in collaboration with colleagues from Linköping University (Sweden), King Abdullah University of Science and Technology (Saudi Arabia), Imperial College London (UK), the Georgia Institute of Technology and the University of California, Davis (USA), and the Chemnitz University of Technology (Germany).

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Chalmers University of Technology in Gothenburg conducts research and education in technology and natural sciences at a high international level. The university has 3100 employees and 10,000 students, and offers education in engineering, science, shipping and architecture.

With scientific excellence as a basis, Chalmers promotes knowledge and technical solutions for a sustainable world. Through global commitment and entrepreneurship, we foster an innovative spirit, in close collaboration with wider society. The EU's biggest research initiative – the Graphene Flagship – is coordinated by Chalmers. We are also leading the development of a Swedish quantum computer.

Chalmers was founded in 1829 and has the same motto today as it did then: Avancez – forward.

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