Organic electronics—a hot matter

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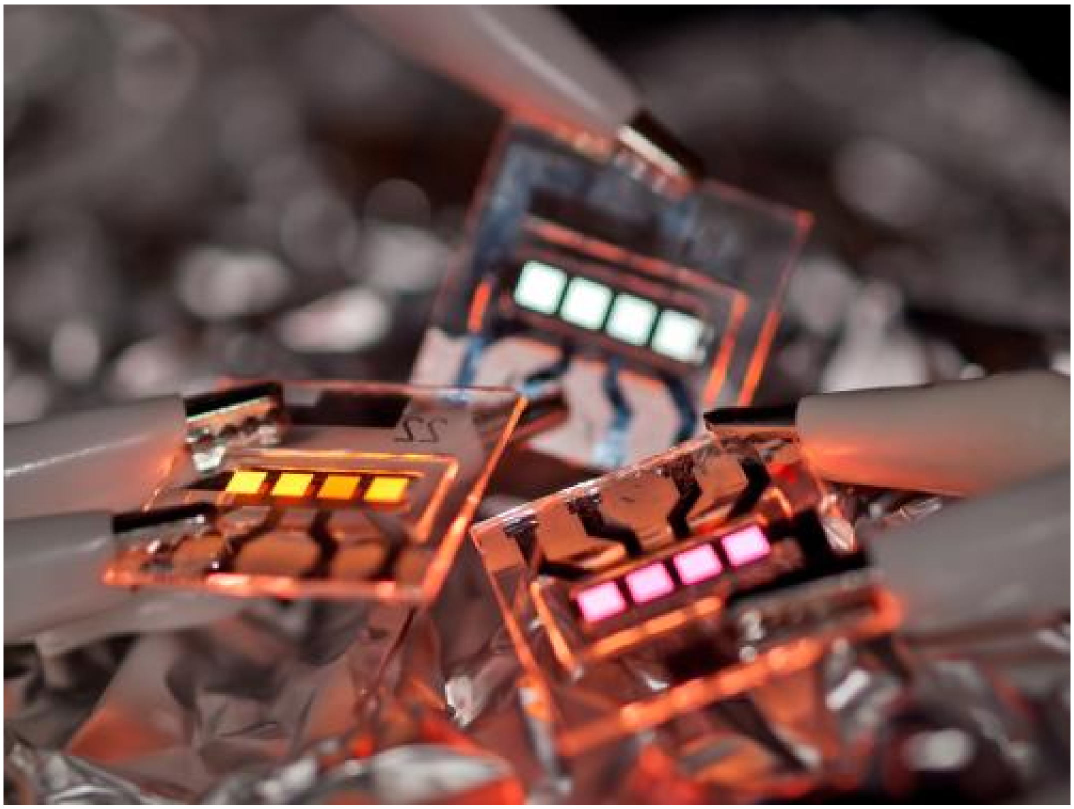

Organic light emitting devices are surface beamers that can be applied even onto flexible substrates in a very thin coating. Particularly when it comes to very bright light levels, non-homogeneities can occur with self-heating. Photo: IAPP

Organic semi-conductors could revolutionise electronics in various areas. Nowadays, components put out such high performances that they are used in small devices like mobile phones. With larger devices, however, the organic components heat up in such an uncontrollable manner that they break down or conduct electricity in an irregular way. Physicists of the TU Dresden (Dresden University of Technology) and mathematicians of the WIAS have collaborated to analyse the typical feedback effects and they describe them for organic semi-conductors in the *Physical Review Letters*.

When mobile phone displays continued to become larger, at first you had to look directly at the front of the device in order to be able to see anything – normal LEDs only emitted light in one direction. A modern Smartphone using a display with organic LEDs does not have that problem. Light is emitted in all directions, and everything can be seen even from a diagonal point of view. There are now even large-scale organic LEDs, allowing for entirely new forms of room lighting. But when the flow of electricity becomes too strong, sudden non-homogeneities appear in the intensity of light, the surface appears spotty. Another field of application is solar energy: With organic solar cells, foils can be produced that generate small amounts of electricity, e.g. to take with you as "energy to go".

In terms of organic components, the long-known Arrhenius law applies: Electric conductivity increases more strongly the higher the temperature gets, so the electricity going through the components increases as well, heating up the material. Thus a feedback loop is created, in which the components continue to be heated up even further – experiments usually end with the component being blown. So far, these effects have only been known with non-organic semi-conductors. Components that react so strongly to temperatures that feedback can result are called thermistors. Thermistors are used especially in performance electronics. Today, organic semi-conductors can also reach self-heating levels.

The principle has actually been known for quite some time, but nobody ever noticed that is also applies to organic electronics. Dr Thomas Koprucki of the WIAS explains: "We noticed that organic semi-conductors should after all be predestined for electro-thermal feedback effects. Nobody saw this before. We were able to point our colleagues in Dresden in the right direction as to what to focus on for the measurements."

The experiments had already shown that the currents increase enormously during the self-heating process. But if the calculations were correct, there had to be a point at which the voltage would decrease despite the energy increase – completely against all intuition. That would mean that there are two entirely different, stable levels of energy that overlap in a very small voltage area – where they can tip over from one level to the other. Sent on the right track by these model predictions, the physicists at the TU Dresden were able to adapt their experiments in a way that they could actually measure that exact effect for organic semi-conductors.

In this case, the processes in the component were measured for the carbon compound C60 between two points. In order to detect the effect in its entirety, they had to not only show a decrease in the voltage, but also the switch between the two stable levels of energy strength. Based on the model calculation it was clear from the start that non-destructive proof could only be obtained if the component were cooled and protected by a pre-resistance. This allowed the physicists to actually record the bi-stability of the component. With the two switching voltages, the strength of the electric current switched by a factor of 10.

Axel Fischer from the Institute for Applied Photophysics (IAPP) at the TU Dresden explains: "We used the carbon compound C60 for our measurements because it is very stable in its temperature. Therefore we can see the Arrhenius law in its purest form. Aside from that, C60 layers can have strong currents even with low voltages so the typical thermistor effects can be proven in a rather simple way."

Using that broader understanding of self-heating in organic semi-conductors, researchers can now further develop organic components in a way that they can reduce the disruptive effects, e.g. by way of a geometric construction of the heat deflection and the electronic contacts. That way there can be large-surface illumination foils in the future that will be able to emit light in a very smooth and steady manner.

More information: Fischer, A. et al. Self-Heating, Bistability, and Thermal Switching in Organic Semiconductors. *Phys. Rev. Lett.* 110, 126601 (2013).
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