Organic electronics: Sustainability during the entire lifecycle

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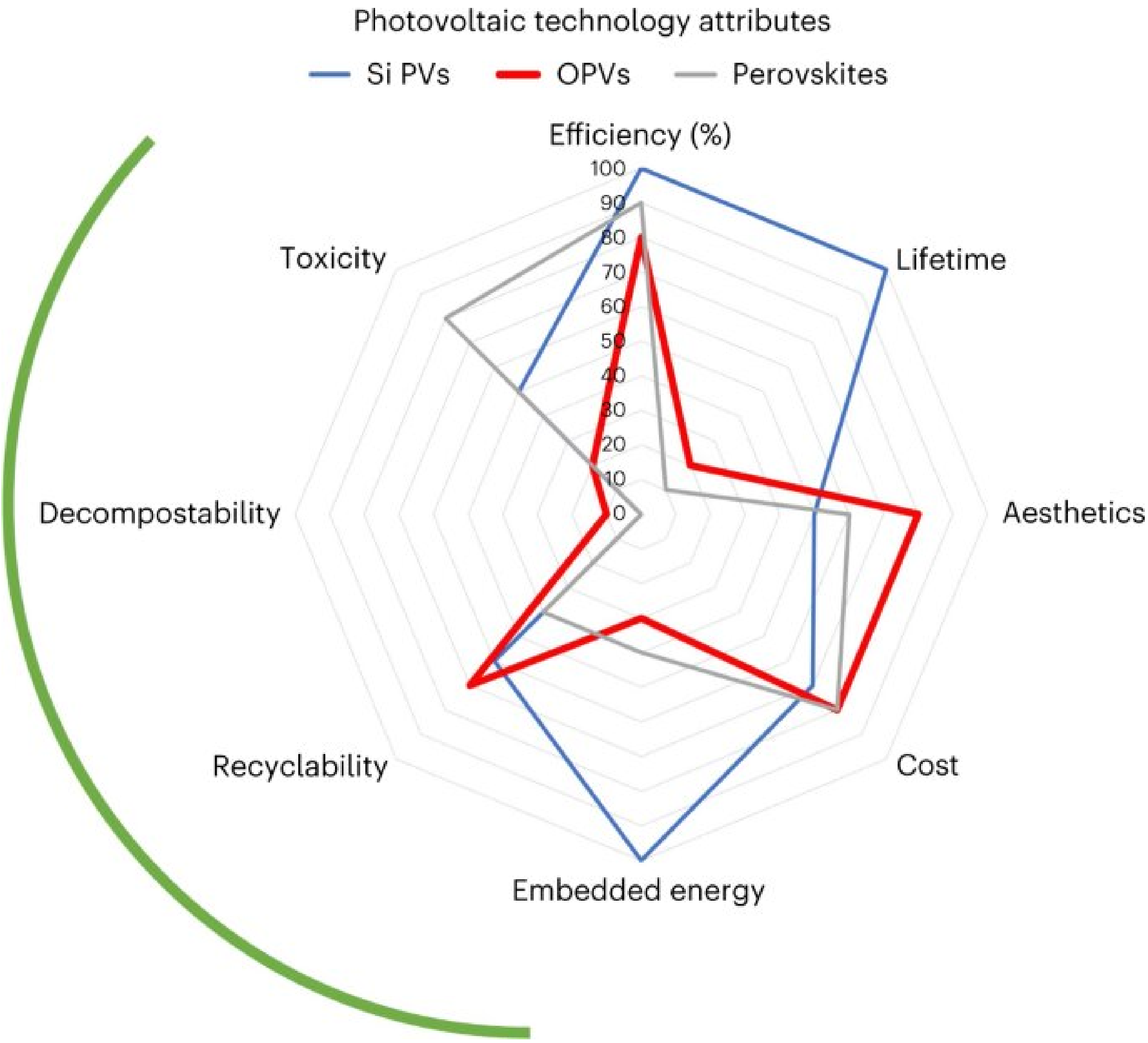

A qualitative comparison of traditional and printed photovoltaics technologies. Credit: *Nature Materials* (2023). DOI: 10.1038/s41563-023-01579-0

Organic electronics can make a decisive contribution to decarbonization and, at the same time, help to cut the consumption of rare and valuable raw materials. To do so, it is not only necessary to further develop manufacturing processes, but also to devise technical solutions for recycling as early on as the laboratory phase. Materials scientists from FAU are now promoting this circular strategy in conjunction with researchers from the U.K. and U.S. in the journal *Nature Materials*.

Organic electronic components, such as solar modules, have several exceptional features. They can be applied in extremely thin layers on flexible carrier materials and therefore have a wider range of applications than crystalline materials. Since their photoactive substances are carbon based, they also contribute to cutting the consumption of rare, expensive and sometimes toxic materials such as iridium, platinum and silver.

Organic electronic components are experiencing major growth in the field of OLED technologies in particular, and above all for television or computer screens. "One the one hand, this is progress, but on the other, it causes some problems," says Prof. Dr. Christoph Brabec, Chair of Materials Science (Materials in Electronics and Energy Technology) at FAU and Director of the Helmholtz Institute Erlangen-Nürnberg for Renewable Energy (HI ERN).

As a materials scientist, Brabec sees the danger of permanently incorporating environmentally friendly technology into a device architecture that is not sustainable on the whole. This not only affects electronic devices, but also organic sensors in textiles that have an extremely short operating life. He states, "Applied research in particular must now set the course to ensure that electronic components and all their individual parts must leave an ecological footprint that is as small as possible during their entire lifecycle."

More efficient synthesis and more robust materials

The further development of organic electronics themselves is elementary here, since new materials and more efficient manufacturing processes lead to the reduction of outlay and energy during production. "Compared with simple polymers, the manufacturing process for the photoactive layer requires significantly higher amounts of energy as it is deposited in a vacuum at high temperatures," explains Brabec.

The researchers are therefore proposing cheaper and more environmentally-friendly processes, such as deposition from water-based solutions and printing using inkjet processes. "One major challenge is developing functional materials that can be processed without toxic solvents that are harmful to the environment," Brabec says. In the case of OLED screens, inkjet printing also offers the possibility of replacing precious metals such as iridium and platinum with organic materials.

In addition to their efficiency, the operating stability of materials is decisive. Complex encapsulation is required in order to protect the vacuum-deposited carbon layers of organic solar modules, which can make up to two thirds of their overall weight. More robust combinations of materials could contribute to significant savings in materials, weight and energy.

Planning the recycling process in the laboratory

To make a realistic evaluation of the environmental footprint of organic electronics, the entire product lifecycle has to be considered. In terms of output, organic photovoltaic systems are still lagging behind conventional silicon modules, but 30% less CO_2 is emitted during the manufacturing process. Aiming for maximum efficiency levels is not everything, says Brabec. "Eighteen percent could make more sense environmentally than 20, if it's possible to manufacture the photoactive material in five steps instead of eight."

In addition, the shorter operating life of organic modules is also relative if you look more closely. Although photovoltaic modules based on silicon last longer, they are very difficult to recycle. "Biocompatibility and biodegradability will increasingly become important criteria, both for product development as well as for packaging design," says Brabec. "We really must start taking recycling into consideration in the laboratory."

This means, for example, using substrates that can either be easily recycled or that are as biodegradable as the active substances. Using what is known as multilayer designs as early on as the product design phase could ensure that various materials can easily be separated and recycled at the end of the product lifecycle. Brabec says, "This cradle-to-cradle approach will be a decisive prerequisite for establishing organic electronics as an important component in the transition to renewable energy."

More information: Iain McCulloch et al, Sustainability considerations for organic electronic products, *Nature Materials* (2023). DOI: 10.1038/s41563-023-01579-0

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