Editorial

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Recycle and recover

The development of more sustainable electronics is increasingly vital.

Last month, the 28th edition of the United Nations Climate Change Conference — or COP28 — took place in Dubai, United Arab Emirates. The meeting opened with the establishment of a new loss and damage fund of more than US$700 million to help support nations affected by climate change. But the headline from this iteration of the annual climate summit was the signing of an agreement that calls on nations to transition away from fossil fuels in energy systems[1]. The agreement also calls for a tripling of global renewable energy capacity by 2030, and an increase in technologies such as carbon capture and storage. The wording of the statement — and its potential for different interpretations — left some scientists disappointed[2]. But this was still a notable outcome for the summit.

The necessity of such steps was immediately reclarified with the announcement earlier this month that 2023 had been the warmest year on record[3]. For electronics research, these developments reiterate the importance of considering the way we design, build, use and discard electronic devices. To start, it is estimated that more than 50 million tonnes of electronic waste is produced globally every year, and less than 20% of this is reported as being collected and recycled[4]. These problems mean that how a device will ultimately be dismantled and destroyed needs to be considered during the creation of any new system.

But creating sustainable electronic devices is challenging, and the precise challenges will depend on the material system involved. Organic materials are potentially a good starting place. But building organic electronic devices can still require hazardous solvents and lead to toxic by-products. In an Article in this issue of *Nature Electronics*, Kyoseung Sim and colleagues report flexible electronic devices made from organic electronic materials that can be recaptured and reused.

The computer-generated image illustrates a flexible electronic device developed by Sim and colleagues using their closed-loop recycling approach.

The researchers — who are based at Ulsan National Institute of Science and Technology — develop processes to recycle all the necessary organic electronic materials, including conductors, semiconductors and dielectrics. The method also only requires non-hazardous solvents for both fabrication and recycling.

To illustrate the capabilities of this closed-loop recycling approach, the team fabricate a range of wearable devices, including electrochemical transistors and inverters, electrodes for electrophysiological signal monitoring and skin-mountable keypads. They also show that different devices can be reconstructed from materials recycled from other devices without having to replenish any materials.

The ability to repair and reuse devices is also an important consideration in the development of more sustainable electronics. In an Article elsewhere in this issue, Je-Sung Koh, Daeshik Kang, Seungyong Han and colleagues provide an unusual solution, at least when it comes to malfunctioning foldable displays: crumple-recoverable electronics.

The researchers — who are based at Ajou University and Sungkyunkwan University — integrate silver nanowires, a shape-memory polymer and an elastomer to create sheet-like devices with mechanical properties that can be transformed through thermal modulation. As a result, the devices can be tuned from an elastic state suitable for smoothing out wrinkles formed during crumpling to a plastic state suitable for free-standing operation. It is an approach inspired by the emergence process of butterfly wings, which have different stiffnesses as they unfold.

The team use the approach to create touch panels that can be packed into small capsules with volumes of only 1 ml. These devices can subsequently be unpacked and recovered, a point they illustrate by showing that the smoothed-out panels can be used to play video games such as Google's Dinosaur Game and Brick Out. As Yaokang Zhang and Xuechang Zhou of Shenzhen University note in an accompanying News & Views article, this crumple-recoverable electronics approach could potentially help address a problem with many foldable tablets and smartphones, where creases can appear on the displays after repeated folding.

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