Technique allows integration of single-crystal hybrid perovskites into electronics

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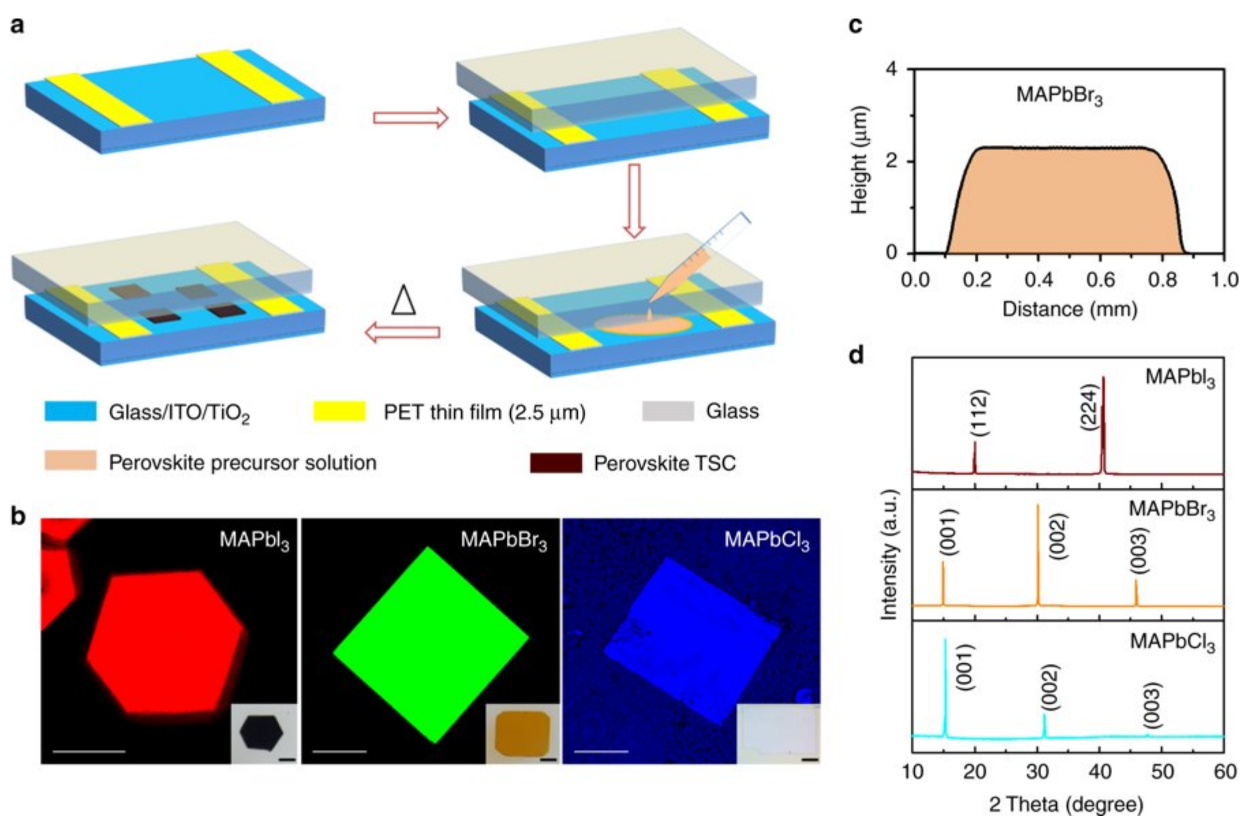

Hybrid perovskite TSC fabrication. a Schematic representation of spatially confined inverse temperature crystallization method for producing thin single crystals (TSCs). b Fluorescence microscopy images of MAPbI3, MAPbBr3, and MAPbCl3 TSCs (which are excited with a pulsed 450, 473, and 405 nm laser, respectively). Scale bar: 100 μm. Inset: optical images of MAPbI3, MAPbBr3, and MAPbCl3 TSCs. Scale bar: 200 μm. c Height profile of MAPbBr3 TSC indicating its thickness is about 2.45 μm. d XRD spectra of synthesized MAPbX3 TSCs, where X = I, Br, and Cl, respectively. Credit: *Nature*

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An international team of researchers has developed a technique that, for the first time, allows single-crystal hybrid perovskite materials to be integrated into electronics. Because these perovskites can be synthesized at low temperatures, the advance opens the door to new research into flexible electronics and potentially reduced manufacturing costs for electronic devices.

Hybrid perovskite materials contain both organic and inorganic components and can be synthesized from inks, making them amenable to large-area roll-to-roll fabrication. These materials are the subject of extensive research for use in solar cells, light-emitting diodes (LEDs) and photodetectors. However, there have been challenges in integrating single-crystal hybrid perovskites into more classical electronic devices, such as transistors.

Single-crystal hybrid perovskites are preferable because single-crystalline materials have more desirable properties than polycrystalline materials; polycrystalline materials contain more defects that adversely affect a material's electronic properties.

The challenge in incorporating single-crystal hybrid perovskites into electronics stems from the fact that these macroscopic crystals, when synthesized using conventional techniques, have rough, irregular edges. This makes it difficult to integrate with other materials in such a way that the materials make the high-quality contacts necessary in electronic devices.

The researchers got around this problem by synthesizing the hybrid perovskite crystals between two laminated surfaces, essentially creating a single-crystal hybrid perovskite sandwich. The perovskite conforms to the materials above and below, resulting in a sharp interface between the materials. The substrate and superstrate, the "bread" in the sandwich, can be anything from glass slides to silicon wafers that are already embedded with electrodes – resulting in a ready-made transistor or circuit.

The researchers can further fine-tune the electrical properties of the perovskite by selecting different halides for use in the perovskite's chemical make-up. The choice of halide determines the bandgap of the material, which affects the color appearance of the resulting semiconductor and leads to transparent and even imperceptible electronic devices when using high-bandgap perovskites.

"We have demonstrated the ability to create working field-effect transistors using single-crystal hybrid perovskite materials fabricated in ambient air," says Aram Amassian, corresponding author of a paper on the work and an associate professor of materials science and engineering at NC State.

"That's of interest because traditional single-crystal materials have to be manufactured in ultra-high vacuum, high-temperature environments, and often require exquisite epitaxial growth," Amassian says. "Hybrid perovskites can be grown from solution, essentially from an ink, in ambient air at temperatures below 100 degrees Celsius. This makes them attractive from a cost and manufacturing standpoint. It also makes them compatible with flexible, plastic-based substrates, meaning that they may have applications in flexible electronics and in the internet of things (IoT).

"That said, there are still major challenges here," Amassian says. "For example, current hybrid perovskites contain lead, which is toxic and therefore not something that's desirable for applications like wearable electronics. However, research is ongoing to develop hybrid perovskites that don't contain lead or that are even entirely metal-free. This is an exciting area of research, and we feel this work is a significant step forward for the device integration of these materials, leading to the development of new technological applications."

The paper, "Single crystal hybrid perovskite field-effect transistors," is published in the journal *Nature Communications*.

More information: Weili Yu et al. Single crystal hybrid perovskite field-effect transistors, *Nature Communications* (2018). DOI: 10.1038/s41467-018-07706-9

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