Docket #: S22-216

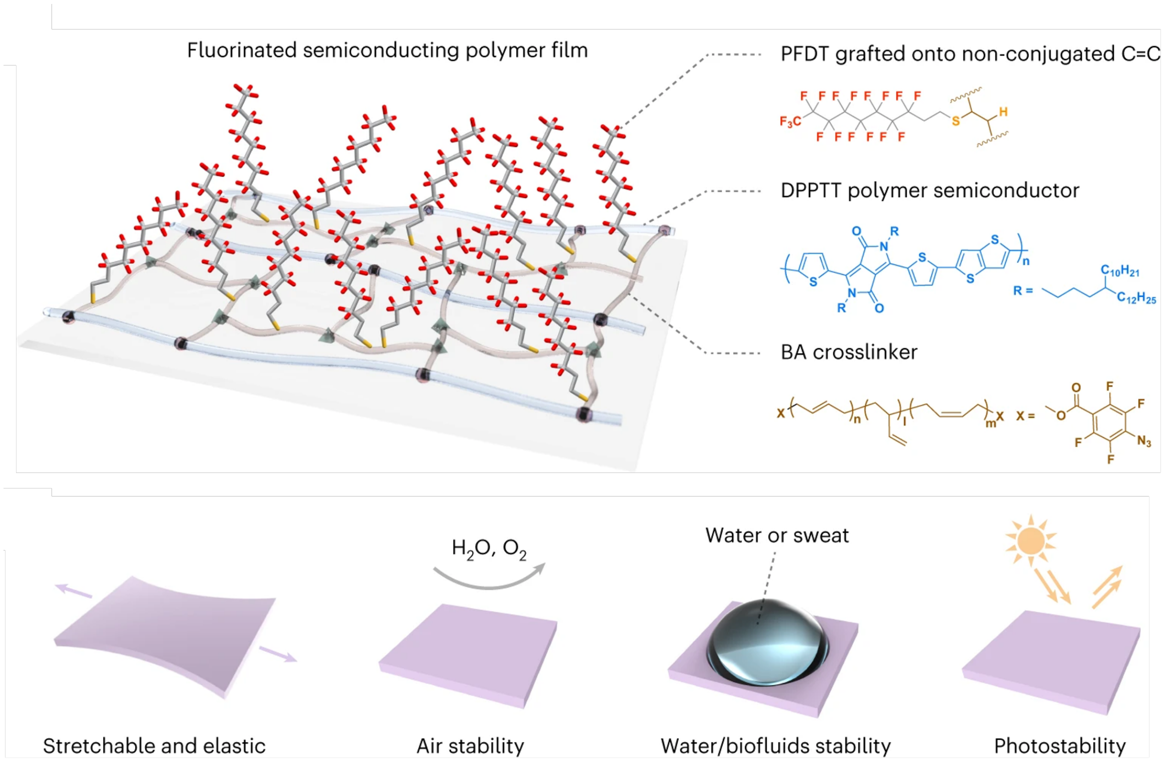
Highly stable and stretchable polymer electronics through fluorinated monolayer encapsulation

Researchers at Stanford have developed an innovative molecular engineering strategy to enhance the stability and performance of polymer semiconductors (PSCs).

Skin-like PSCs hold great promise for advanced wearable and implantable devices, including real-time health monitors, robotic sensory skins, and medical systems. These materials offer key advantages such as mechanical flexibility, solution-processability, and chemical tunability. However, their widespread use has been limited by poor long-term stability, particularly under harsh environmental conditions like humidity, oxygen exposure, and direct contact with biofluids. Instability arises from the large free volume within PSC films, which accelerates the diffusion of environmental species and leads to charge trapping and morphological degradation over time. Existing strategies, such as bulk encapsulation or additive blending, often add mechanical complexity or thickness while providing limited and inconsistent improvements, especially outside of dry-air conditions.

To overcome these challenges, Stanford researchers developed a two-step surface treatment that creates a fluorinated protective layer. This coating greatly improves durability and preserves high charge mobility even after long exposure to humidity, water, sweat, and sunlight. It also enhances light stability and reduces contact resistance, enabling reliable performance in real-world conditions.

This platform technology advances the practical deployment of soft, stretchable electronics across biomedical, wearable, and outdoor applications.



Three-dimensional illustration of a fluorinated semiconductor film, showing PFDT molecules covalently bonded to non-conjugated C=C sites within the rubber matrix of a crosslinked composite. The resulting film remains stretchable and elastic while maintaining stable charge transport performance under prolonged exposure to harsh environmental conditions.

Applications

- Stretchable and wearable electronics that maintain performance in humid air, water, and sweat
- Flexible biosensors, displays, and energy devices (e.g., OLEDs, photovoltaics) with improved environmental stability
- Surface coating platform for attaching functional molecules to polymer-based electronic systems

Advantages

- Maintains electrical performance in harsh conditions, including moisture, sweat, and sunlight

- Fluorinated monolayer resists mechanical strain and prevents delamination
- Improves device efficiency by lowering contact resistance
- Eliminates bulky encapsulation, enabling thinner and more flexible designs

Publications

- Zheng, Y., Michalek, L., Liu, Q., Wu, Y., Kim, H., Sayavong, P., ... & Bao, Z. Environmentally stable and stretchable polymer electronics enabled by surface-tethered nanostructured molecular-level protection. Nature Nanotechnology, 18(10), 1175-1184.

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