Low-cost molecule boosts stability and amplification characteristics of solution-based polymer semiconductors

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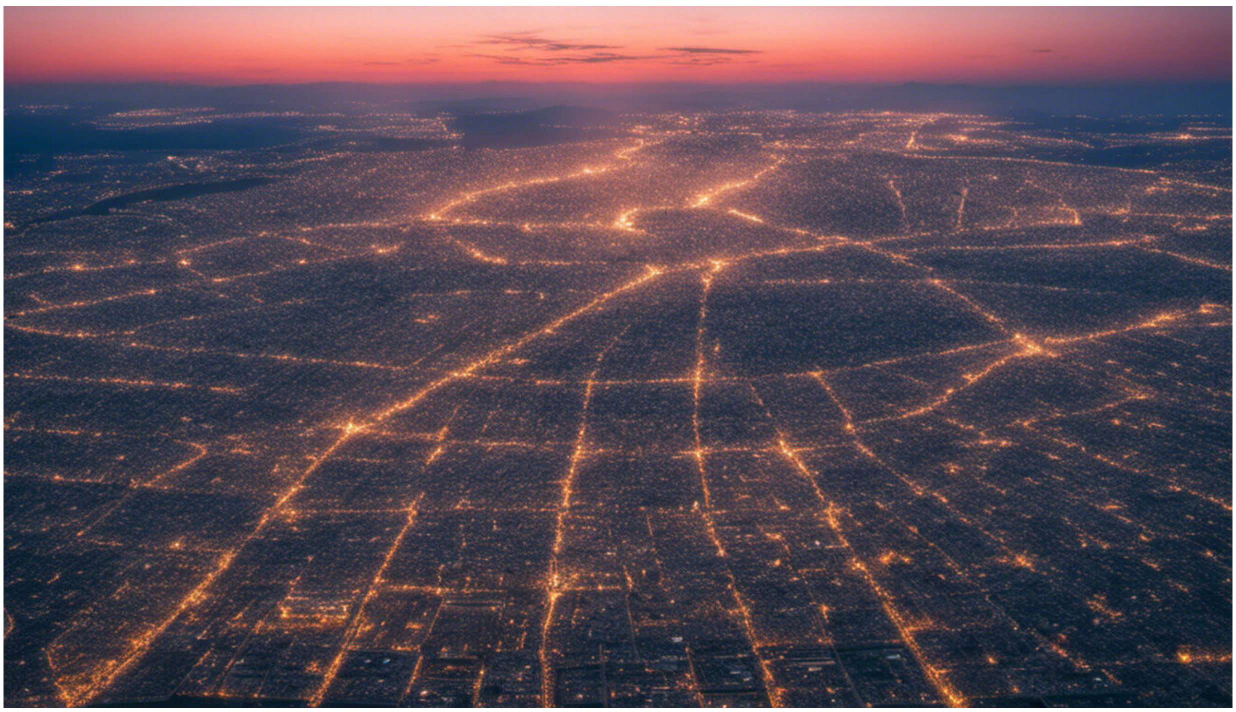

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Replacing traditional rigid silicon wafers with semiconductors made from flexible polymers would herald an age of advanced, 'wearable' electronics. Switching to these semiconductors, known as organic field-effect transistors (OFETs), would also reduce manufacturing costs significantly. However, most plastic materials have trouble moving electrons and their polar opposites—positively charged empty 'holes' inside semiconductor lattices—with sufficient speed for electronic amplification.

Prashant Sonar and co-workers from the A*STAR Institute of Materials Research and Engineering in Singapore have now developed a polymer for solution-based OFET processing that has inherently high carrier mobility and extraordinary air stability. Unlike silicon, polymers are difficult to pack into crystalline structures containing regular pathways for charge carriers. The team's polymer, however, has specifically designed hydrogen bond interactions that create ordered networks for transporting electrons and holes.

Most polymers used in OFETs have a 'donor–acceptor' arrangement of conjugated molecules to enhance the mobility of charge carriers. Using special catalysts, chemists can link together small units of electron-rich and electron-poor aromatic molecules to form an alternating chain of 'block' co-polymers. Sonar and co-workers investigated whether fluorenone—an inexpensive and chemically stable molecule with three fused aromatic rings and a central carbonyl unit—could act as a new type of acceptor block for OFET polymers.

The researchers anticipated that the unusual polarity of fluorenone's carbonyl unit might help it stick to aromatic hydrogen atoms and improve solid-state packing. To test this concept, they made a co-polymer consisting of fluorenone and an aromatic donor known as diketopyrrolopyrrole (DPP), a compound designed to be compatible with large-scale solution processing. The resulting block co-polymer had exceptional thermal stability: it melted only at external temperatures over 300 °C.

When Sonar and co-workers used a technique called spin-coating to convert the fluorenone–DPP co-polymer into an OFET device, they observed impressive amplification characteristics and one of the highest hole mobilities ever recorded for solution-processed transistors. Their tests also showed that this material retained its valuable electronic attributes without decomposing in air—a problem that plagued earlier generations of OFETs. Optical measurements revealed the basis of this high stability: the fluorenone units make electrons in the co-polymer's highest energy states less accessible and therefore less susceptible to air-based impurities.

"Fluorenone is a commercially available, cheap starting material, which has never been studied for OFET use before," says Sonar. The team is now investigating how to utilize it as a novel building block for high-performance organic electronic applications by carefully 'engineering' chemical improvements onto its molecular framework.

More information: Sonar, P., Ha, T.-J. & Dodabalapur, A. A fluorenone based low band gap solution processable copolymer for air stable and high mobility organic field effect transistors. *Chemical Communications* 49, 1588–1590 (2013). pubs.rsc.org/en/content/articl … g/2013/cc/c2cc37131f

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