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ORGANIC FLEXIBLE ELECTRONICS

High density three dimensional integration of organic transistors

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With low temperature solution based processes and excellent mechanical flexibility, the organic field effect transistor (OFET) technology is promising for creating a wide range of emerging flexible electronics towards applications of internet of everything. However, despite of remarkable progress in developing high performance organic semiconductor materials, advances in low voltage high density organic integrated circuits remain very rare, especially in printing processes. The capability of integrating more transistors in a given area is important for making circuits to fulfill complex signal processing tasks.

A three-dimensional (3D) integration approach to achieve high density OFET integration has recently been demonstrated by the research team led by Sungjune Jung from Pohang University of Science and Technology (POSTECH), Korea, through collaboration with the Research Center for Organic Electronics (ROEL) at Yamagata University, Japan. In their work, 3D monolithic integration of dual-gate n-type and p-type OFETs is implemented on a plastic foil with a record density of 60 transistors per square centimetre. The fabricated devices exhibit good yield, uniformity, and stability. In addition, by interconnecting those integrated dual-gate OFETs, they propose a 3D universal NAND gate and its array as a new facile route to design printed flexible integrated circuits. It is further estimated that this technology would enable to use printing processes to fabricate up to about 2700 transistors on the size of a standard credit card, which is compatible with the transistor count of the first commercial 4-bit microprocessor. Such a 3D monolithic integration strategy is possible to be extended to other printable transistor technologies, such as oxide semiconductors, carbon nanotubes, and 2D materials.

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SEMICONDUCTOR THEORY

Direct or indirect band gap

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The direct or indirect nature to the bandgap of a semiconductor is a fundamental property. Despite the extensive research and broad applications of the conventional semiconductors, the understanding of the mechanisms determining their direct or indirect nature to the bandgap remains a challenge. Lack of fundamental understanding of the mechanism controlling the indirect bandgap nature of Si might be the main reason for the difficulty of developing Si-based direct bandgap materials.

Yuan *et al.* resolved this long-standing puzzle by presenting a unified theory for understanding the direct or indirect nature of bandgap in conventional group II–VI, group III–V, and group IV semiconductors unambiguously. They found that the occupied cation *d* bands play a prime role in forming the direct or indirect bandgap of semiconductors via the *s*–*d* and *p*–*d* coupling with the states of the X- and L-valley, which remarkably pushes their energy levels up, but leaves the Γ-valley intact. The either lacking or low-lying of the occupied *d* orbitals in cations of Diamond, Si, Ge, and Al-containing group III–V semiconductors explains their nature of indirect bandgap.

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