Korea's UNIST fabricates thinnest oxide semiconductor

Deposition of monolayer hexagonal ZnO on graphene promises highly transparent and flexible opto devices

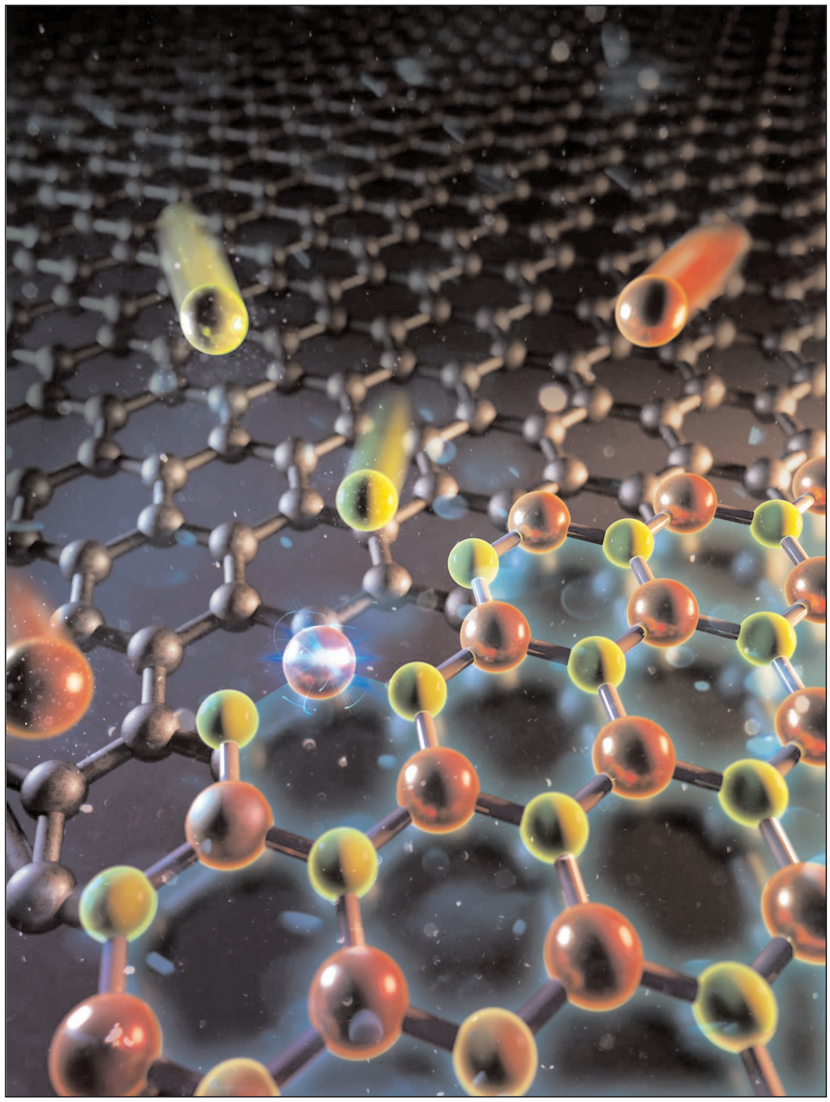
A new study, affiliated with South Korea's Ulsan National Institute of Science and Technology (UNIST), has introduced a novel method for fabricating what is claimed to be world's thinnest oxide semiconductor — two-dimensional zinc oxide (ZnO) just one atom thick. This may open up new possibilities for thin, transparent and flexible electronic devices , such as ultra-small sensors, it is reckoned (Hyo-Ki Hong et al., 'Atomic Scale Study on Growth and Heteroepitaxy of ZnO Monolayer on Graphene', Nano Letters (2017) 17 (1) p120).

The new ultra-thin oxide semiconductor was created by a team led by professor Zonghoon Lee of Materials Science and Engineering at UNIST.

The material is formed by directly growing a single-atom-thick ZnO layer on graphene, using atomic layer deposition (ALD). It is also said to be the thinnest heteroepitaxial layer of semiconducting oxide on monolayer graphene.

"Flexible, high-performance devices are indispensable for conventional wearable electronics," says Lee. "With this new material, we can achieve truly high-performance flexible devices."

As existing silicon fabrication processes become finer, the performance becomes a much more critical issue, and there has been much research on next-generation semiconductors to replace silicon, notes the team. Graphene has superior conductivity properties, but it cannot be used directly as an alternative to silicon in electronics because it has no energy bandgap. In graphene, however, electrons move randomly at a constant speed, regardless of their energy, and they cannot be stopped.

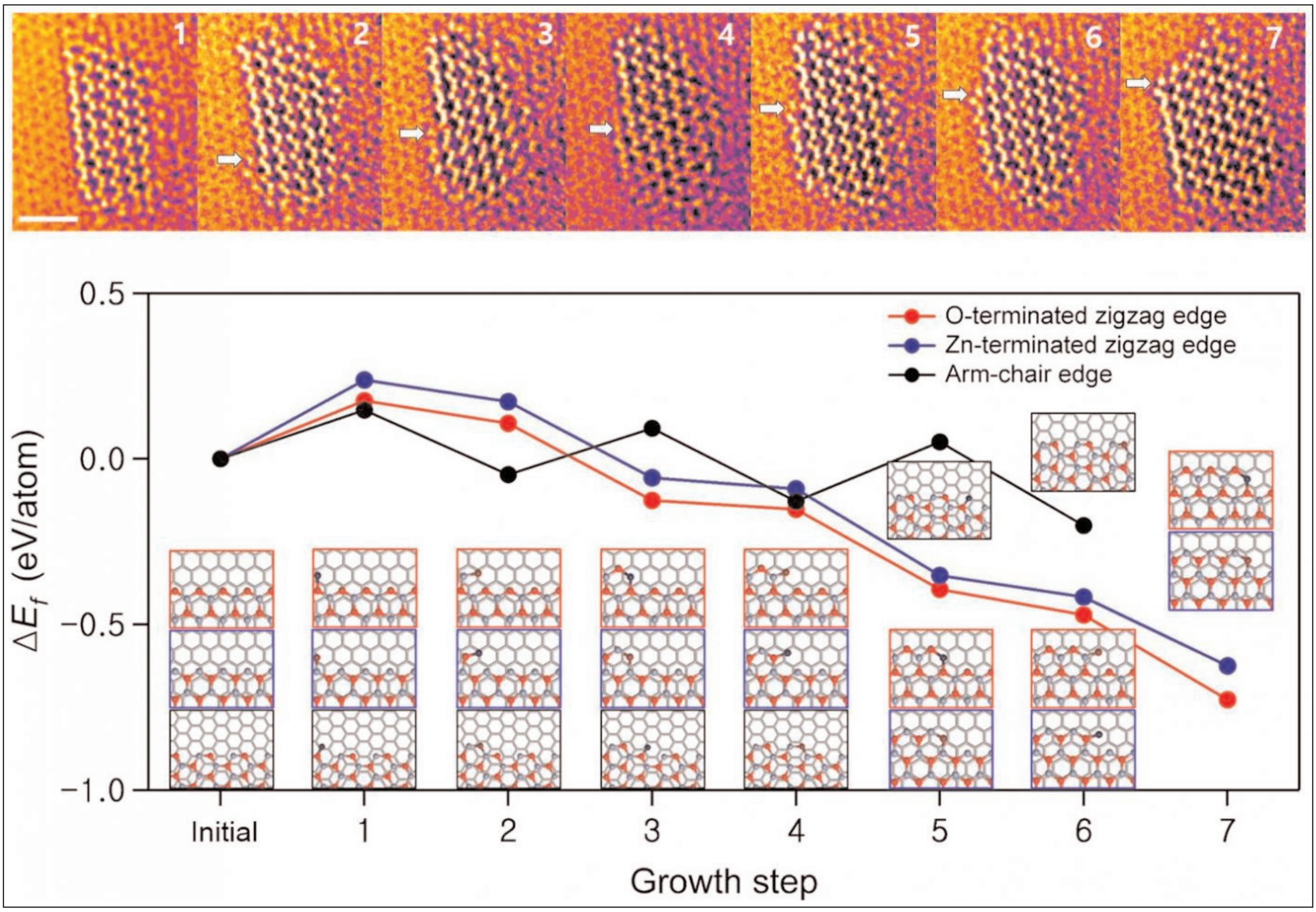


Growth of ZnO on graphene layer, consisting of interconnected hexagons of carbon atoms. Zinc atom shown as red spheres; oxygen atom as green spheres. (Credit: UNIST.)

To solve this, the research team decided to demonstrate atom-by-atom growth of zinc and oxygen at the preferential zigzag edge of a ZnO monolayer on graphene through in-situ observation. They then experimentally determine that the thinnest ZnO monolayer has a wide bandgap (up to 4.0eV), due to quantum confinement and a graphene-like 'hyper-honeycomb' structure, as well as high optical transparency. Existing oxide semiconductors have a relatively large bandgap, in the range of 2.9–3.5eV. The greater the bandgap energy, the lower the leakage current and excess noise.

"This is the first time to actually observe the in-situ formation of hexagonal structure of ZnO," says the paper's first author, Hyo-Ki Hong of Materials Science and Engineering. "Through this process, we could understand the process and principle of 2D ZnO semiconductor production," he adds.

"The heteroepitaxial stack of the thinnest 2D oxide semiconductors on graphene has potential for future optoelectronic device applications associated with high optical transparency and flexibility," notes Lee. "This



Lateral growth of ZnO monolayer along the zigzag edges. Credit: UNIST.

study can lead to a new class of 2D heterostructures, including semiconducting oxides formed by highly controlled epitaxial growth through a deposition route."

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