Unmasking the properties of 2-D materials

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It is now possible to grow large-area ultrathin sheets of molybdenum disulfide, a two-dimensional (2D) material promising the next generation of electronic and optoelectronic devices, thanks to a new twist on a standard method developed by A*STAR scientists.

Molybdenum disulfide, one of a family of so-called semiconducting transitional metal dichalcogenides (TMDCs), has attracted considerable attention as a 2D material, thanks to its remarkable electronic and optoelectronic properties. But preparing large-area atomically thin layers of TMDCs is notoriously difficult, with conventional growth methods such as mechanical exfoliation and physical vapor deposition yielding single-layer films only a few micrometers in size.

To overcome the limitation of such a useful material, Dongzhi Chi and Hongfei Liu of the A*STAR Institute of Materials Research and Engineering searched for a way to modify a standard fabrication technique, to grow high quality, millimeter-sized single-layer molybdenum disulfide nanosheets.

"The growth mechanism of 2D films is still not fully understood and is a major hurdle for their large scale adoption in electronic applications," says Chi. "Growing large-area 2D materials allows for large scale fabrication of integrated circuits using conventional semiconductor processing methods."

By modifying chemical vapor deposition—a manufacturing tool used in everything from sunglasses to potato chip bags and fundamental to the production of much of today's electronic devices—they were able to grow single-layer molybdenum disulfide nanosheets of greatly increased grain size.

"Smaller grain sizes result in structural defects, so devices fabricated with such materials perform poorly," explains Chi. "Larger grain sized 2D TMDCs, however, minimize these defects and lead to improved performance."

In a pressurized reaction chamber, powdered molybdenum trioxide and sulfur were vaporized. To create larger grain sizes, the researchers increased the temperature of the reaction chamber and used a silicon or quartz shadow mask, held over a sapphire substrate, to indirectly supply the molybdenum trioxide and sulfur vapors to the advancing molybdenum disulfide growth front on the substrate.

Ripples were introduced into the single-layer molybdenum disulfide nanosheets by illuminating them with a laser. These ripple structures are predicted to have a significant effect on the electronic, mechanical, and transport properties of single-layer molybdenum disulfide.

To compare the single-layer molybdenum disulfide nanosheets and their laser-induced ripple structures, the researchers used a number of characterization tools, including Raman scattering and photoluminescence spectroscopy as well as atomic-force microscopy.

"Studying these materials may lead to the discovery of new physics and also aid fabrication of electronic and optoelectronic devices with novel functions and improved performances," says Chi.

More information: Hongfei Liu et al. Dispersive growth and laser-induced rippling of large-area singlelayer MoS2 nanosheets by CVD on c-plane sapphire substrate, *Scientific Reports* (2015). DOI:

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