Method for creating high-quality two-dimensional materials could enable industrial-scale production

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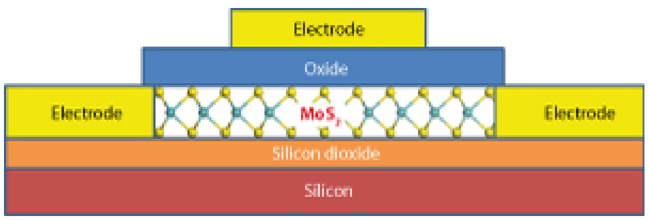

Transistors made of films of two-dimensional molybdenum disulfide (MoS2) could be integrated with other silicon electronics devices. Credit: A*STAR Institute of Materials Research and Engineering

Two-dimensional materials have a whole host of exotic properties because they are just one atom thick. A*STAR researchers have now developed a method for creating large areas of atom-thin material for use in electronic devices.

Graphene, a single layer of carbon atoms arranged into a honeycomb-like pattern, is the most famous example of a two-dimensional material. It is stronger than steel, has excellent electrical properties, and could be used to make two-dimensional devices that are much smaller than those currently made from bulk or thin-film silicon. However, it is not a semiconductor. And so scientists are turning to other materials that have this essential property for creating transistors.

Shijie Wang from the A*STAR Institute of Materials Research and Engineering and his collaborators have now demonstrated a technique for creating a single atomic layer of molybdenum disulfide—a two-dimensional semiconductor.

Molybdenum disulfide belongs to a family of materials called transition-metal dichalcogenides. They have two chalcogenide atoms (such as sulfur, selenium or tellurium) for every transition-metal atom (molybdenum and tungsten are examples). These materials and their wide range of electrical properties provide an excellent platform material system for versatile electronics. But creating high-quality material over areas large enough for industrial-scale production is difficult.

"Traditional mechanical exfoliation methods for obtaining two-dimensional materials have limited usefulness in commercial applications, and all previous chemical methods are incompatible for integration with device fabrication," says Wang. "Our technique is a one-step process that can grow good-quality monolayer films, or few layers of molybdenum disulfide films, at wafer scale on various substrates using magnetron sputtering."

The team fired a beam of argon ions at a molybdenum target in a vacuum chamber. This ejected molybdenum atoms from the surface where they reacted with a nearby sulfur vapor. These atoms then assembled onto a heated substrate of either sapphire or silicon. The team found that they could grow monolayer, bilayer, trilayer or thicker samples by altering the power of the argon-ion beam or the deposition time.

They confirmed the quality of their material using a number of common characterization tools including Raman spectroscopy, atomic force microscopy, X-ray photoelectron spectroscopy and transmission electron microscopy. The researchers also demonstrated the excellent electrical properties of their molybdenum disulfide films by creating a working transistor (see image).

"Our next step in this work will focus on the application of this technique to synthesize other two-dimensional materials and integrate them with different materials for various device applications," says Wang.

More information: "Growth of wafer-scale MoS_2 monolayer by magnetron sputtering." *Nanoscale* 7, 2497–2503 (2015). dx.doi.org/10.1039/c4nr06411a

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