# New process isolates promising material molybdenum disulfide

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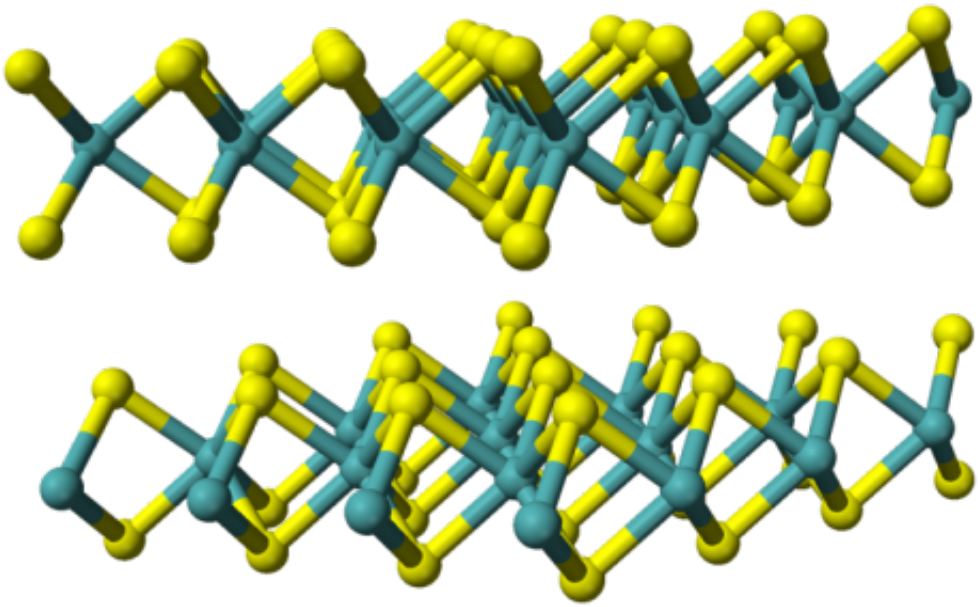

Ball-and-stick model of the part of the crystal structure of molybdenite, MoS2. Crystal structure data from The American Mineralogist Crystal Structure Database. Credit: Wikipedia

After graphene was first produced in the lab in 2004, thousands of laboratories began developing graphene products worldwide. Researchers were amazed by its lightweight and ultra-strong properties. Ten years later, scientists now search for other materials that have the same level of potential.

"We continue to work with graphene, and there are some applications where it works very well," said Mark Hersam, the Bette and Neison Harris Chair in Teaching Excellence at Northwestern University's McCormick School of Engineering and Applied Science, who is a graphene expert. "But it's not the answer to all the world's problems."

Part of a family of materials called transition metal dichalcogenides, molybdenum disulfide (MoS2) has emerged as a frontrunner material for exploration in Hersam's lab. Like graphene, it can be exfoliated into atomically thin sheets. As it thins to the atomic limit, it becomes fluorescent, making it useful for optoelectronics, such as light-emitting diodes, or light-absorbing devices, such as solar cells. MoS2 is also a true semiconductor, making it an excellent candidate for electronics, and it historically has been used in catalysis to remove sulfur from crude oil, which prevents acid rain.

Hersam's challenge was to find a way to isolate atomically thin sheets of this promising material at a larger scale. For the past six years, his lab has developed methods for exfoliating thin layers of graphene from graphite, using solution-based methods.

"You would think it would be easy to do the same thing for molybdenum disulfide," he said. "But the problem is that while the exfoliation is similar to graphene, the separation is considerably more challenging."

Hersam's research is described in the paper "Thickness sorting of two-dimensional transition metal dichalcogenides via copolymer-assisted gradient ultracentrifugation," which was published in the Nov. 13 issue of *Nature Communications*.

To sort graphene layers, Hersam used centrifugal force to separate materials by density. To do this, he and his group added the material to a centrifuge tube along with a gradient of water-based solution. Upon

centrifugation, the denser species move toward the bottom, creating layers of densities within the centrifuge tube. Graphene sorts into single layer sheets toward the top, then bilayer sheets, trilayer, and so on. Because graphene has a relatively low density, it easily sorts compared to higher density materials.

"If I use the exact same process with molybdenum disulfide, its higher density will cause it to crash out," Hersam said. "It exceeds the maximum density of the gradient, which required an innovative solution."

Hersam needed to take the inherently dense material and effectively reduce its density without changing the material itself. He realized that this goal could be achieved by tuning the density of the molecules used to disperse MoS2. In particular, the use of bulkier polymer dispersants allowed the effective density of MoS2 to be reduced into the range of the density gradient. In this manner, the sheets of MoS2 floated at layered positions instead of collecting as the bottom of the centrifuge tube. This technique works not just for MoS2, but for other materials in the transition metal dichalcogenides family.

"Now we can isolate single layer, bilayer, or trilayer transition metal dichalcogenides in a scalable manner," Hersam said. "This process will allow us to explore their utility in large-scale applications, such as electronics, optoelectronics, catalysis, and solar cells."

**More information:** *Nature Communications*, www.nature.com/ncomms/2014/141 … full/ncomms6478.html

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