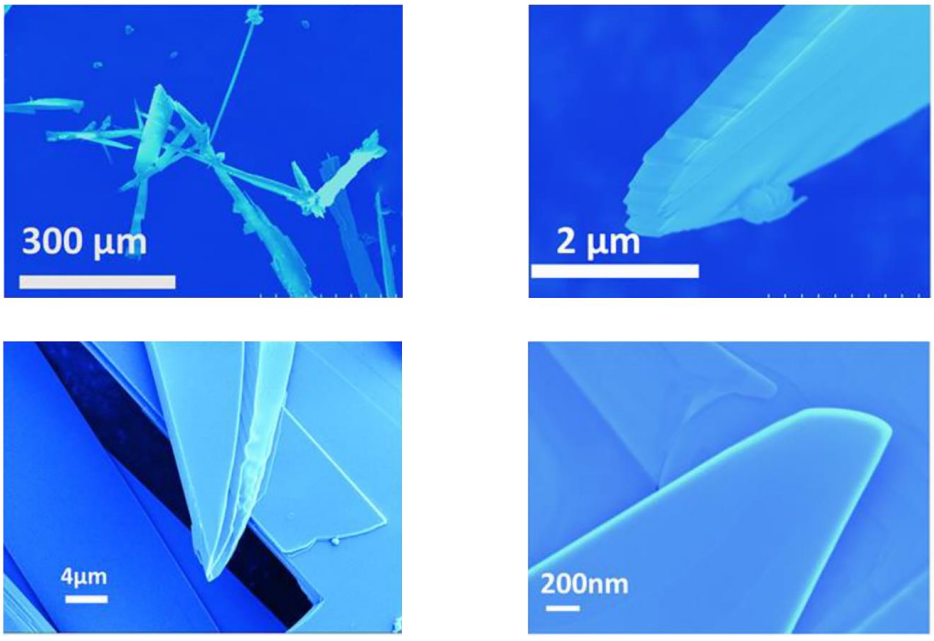
The discovery of Molybdenene – "Metallic" Analogue of Graphene

28 September 2023

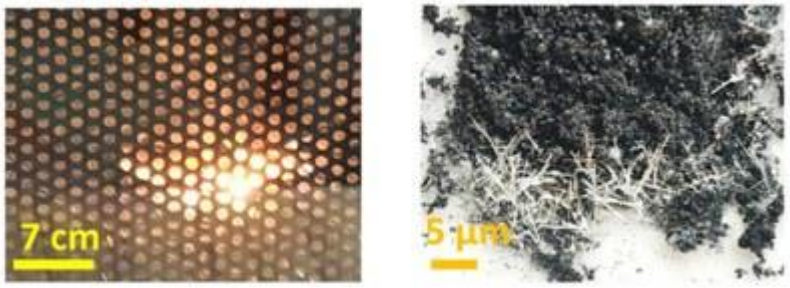
Researchers at the Indian Institute of Technology Patna (IIT-Patna), together with collaborators from Forschungszentrum Jülich, have discovered a new class of 2D materials comprising of just one atomic layer of molybdenum atoms- referred to as “molybdenene”. Analogous to graphene, this new material is mechanically and thermally stable and conducts electricity. While graphene is semi-metallic, the molybdenene is the first metallic 2D material whose free-standing layers could be prepared. Unlike the other recently introduced 2D materials such as phosphorene and germanene, this new material molybdenene is extremely resistant to heat.



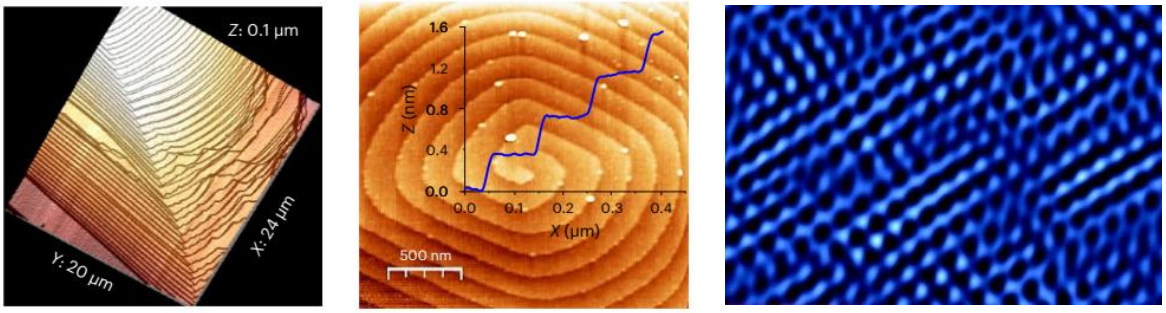
Electron microscope images of the hair-shaped structures, also known as "whiskers", which contain the thin molybdenene layers. Copyright: Sahu, T.K., Kumar, N., Chahal, S. et al., Nat. Nanotechnol. (2023), https://doi.org/10.1038/s41565-023-01484-2

At IIT-Patna in the department of Physics, Molybdenene is synthesized by Tumesh Sahu (under the supervision of Dr. Prashant Kumar) and Nishant

Kumar (under the supervision of Dr. Alpana Nayak) using a simple kitchen microwave, in which a mixture of molybdenum sulphide (MoS_2) and graphene is heated to incandescence at a temperature of around 3000 degrees Celsius. In the reaction driven by the microwave electric field, finely branched hair structures were formed in which the tapered molybdenene layers (also called "whiskers") can be found.



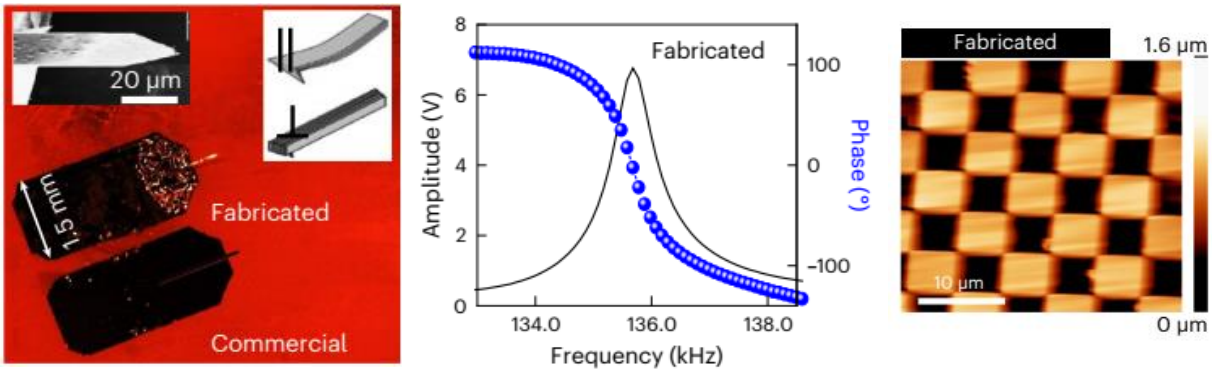
Hair-shaped structures of molybdenene (right) are formed in the microwave (left). Copyright: Sahu, T.K., Kumar, N., Chahal, S. et al, Nat. Nanotechnol. (2023), https://doi.org/10.1038/s41565-023-01484-2



AFM topographs and high-resolution electron microscope image of the molybdenene surface. Copyright: Sahu, T.K., Kumar, N., Chahal, S. et al., Nat. Nanotechnol. (2023), https://doi.org/10.1038/s41565-023-01484-2)

Applications: Researchers at IIT-Patna have already been able to develop some practical scientific applications for molybdenene. Thanks to its stability and excellent electrical and thermal conductivity, it is ideally suited as a cantilever for atomic force microscopy (AFM). Imaging using fabricated cantilevers show that molybdenene offers various advantages over commercial cantilever and tip materials. Because of its thin, flat shape,

and metallic character, the materials can be used as-prepared, just by carefully bending the end to make a tip. Being self-reflecting, there is no need of coating and it is capable of providing particularly good protection against wear and tear or unwanted interference signals.



Atomic Force Microscope cantilever fabrication (left) and imaging of a standard calibration grid (right). Copyright: Sahu, T.K., Kumar, N., Chahal, S. et al, Nat. Nanotechnol.(2023),https://doi.org/10.1038/s41565-023-01484-2

Molybdenene could be also used, for example, as a coating for electrodes to make batteries even more powerful and robust," explains Prof. Ilia Valov at Jülich. The researchers expect that the material can be an interesting candidate for catalysts to accelerate chemical reactions because the freely moving electrons in the 2D sheets can accumulate on the two sides of the molybdenene.

Similar to graphene , due to its special 2D structure, molybdene is also expected to exhibit special electromagnetic effects that could enable groundbreaking innovations in the field of quantum technology.

Original publication

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