Experimental nanosheet material marks a step toward the next generation of low-power, high-performance electronics

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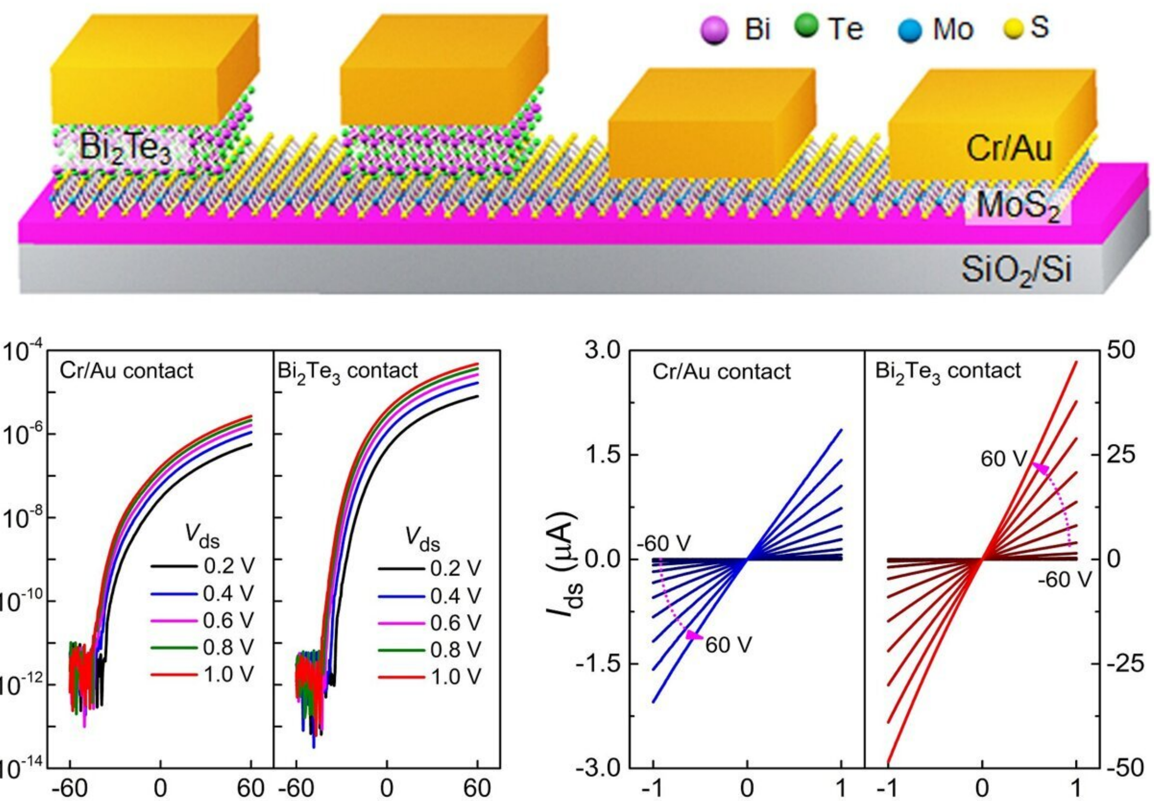

The Bi_2Te_3 nanosheets with high conductivity were grown on MoS_2 as van der Waals contacts, leading to a high-performance MoS_2 FET. Credit: Nano Research, Tsinghua University Press

A team of researchers in China have developed a high-conductivity material that could greatly reduce contact resistance and Schottky barrier height within critical parts of electronic and optoelectronic microchips, paving the way for computer and digital imaging components that consume less power relative to their performance than existing chipsets.

The material, molybdenum disulfide (MoS_2) is so thin that it falls into a classification of two-dimensional. That is, it is grown in sheets extending in two directions, X and Y, but virtually immeasurable on a Z axis because the material is often only a single molecule or atom in height.

The team, led by Professor Dong Li and Professor Anlian Pan, College of Materials Science and Engineering at Hunan University, published their findings in *Nano Research*.

In the article, "Epitaxial van der Waals Contacts for Low Schottky Barrier MoS_2 Field Effect Transistors," the authors emphasize how 2D materials have attracted tremendous attention due to their abundant and tunable electronic states and diverse optical, electronic, and mechanical properties, which make them promising building blocks for future high-performance electronic and optoelectronic devices, such as transistors, photodetectors, and light-emitting diodes.

The experiment was an effort to address. "The performance of a 2D semiconductor transistor mainly relies on the microscopic connections among components within a chip, and the quality of those connections depends ultimately on the material used in these contact points, which are always metals achieved by thermal evaporation, limiting the performance of 2D materials-based transistors," Li said.

In an effort to develop a higher-performing contact point, Li's team employed Bismuth Telluride (Bi_2Te_3), a highly conductive metalloid and semimetal in combination with semi-conducting MoS_2. Growing these metalloid nanosheet crystals together as a hybrid yielded initially promising results.

"Attempts in recent years to achieve epitaxially grown semiconductor contacts have succeeded in laboratory settings, but weren't likely candidates for being scaled up to the level that would be needed to manufacture chips and other devices," Li said.

"Most of these methods put forward strict requirements for material preparation and strict fabrication and are hardly compatible with further manufacturing processes in integrated circuits. The realization of high-quality semiconducting 2D materials and excellent contact at the same time is critical for reliable device applications."

The process of fabricating this experimental van der Waals contact involved vertically stacking MoS_2 and Bi_2Te_3 in a two-step synthesis process. As the growth of MoS_2 monolayer, molybdenum trioxide (MoO_3) powder and sulfur powder were placed at the center and upper stream of the furnace, respectively, and a piece of Silicon dioxide (SiO_2) substrate was placed downstream of a quartz tube.

For the second step growth of the Bi_2Te_3 nanosheet, the Bi_2Te_3 powder and the as-grown MoS_2 nanosheets were placed at the center and downstream of the quartz tube, respectively. After 5 minutes of growth, MoS_2/Bi_2Te_3 heterostructures were obtained.

The researchers observed that the growth temperature and gas flow rate during the growth process could influence the thickness and nucleation sites of the Bi_2Te_3 nanosheets.

The team used a variety of electrical and imaging techniques to observe the appearance and conductive performance of the hybrid nanosheets and found that the new contact method greatly outperformed gold contacts, which are useful as a baseline measurement because of how common gold is in chip manufacturing.

The new contact method was tested at different ambient temperatures and maintained good performance at room temperature—a key milestone in making MoS_2/Bi_2Te_3 semiconducting contact method a good candidate for future commercial viability.

"Combining the multiple advantages, the epitaxial van der Waals Bi_2Te_3 contacts provide a new strategy for the application of 2D MoS_2 in future optoelectronic devices," Li said.

"Now that we've established the functionality of Bi_2Te_3 contacts in a controlled laboratory setting, the next steps will be to continue to investigate and optimize this method, with the hope that this new technology can eventually be adopted for widespread use in more powerful, lower energy consumption electronics."

More information: Huawei Liu et al, Epitaxial van der Waals contacts for low schottky barrier MoS_2 field effect transistors, *Nano Research* (2022). DOI: 10.1007/s12274-022-5229-y

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