A multi-disciplinary research team led by Young Hee Lee, director of South Korea’s Institute for Basic Science (IBS) Center for Integrated Nanostructure Physics at Sungkyunkwan University (SKKU), has devised a fabrication method for the creation of pure molybdenum ditelluride (Suyeon Cho et al, ‘Phase patterning for ohmic homojunction contact in MoTe2’, Science (2015) vol. 349, no. 6248, p625).

Molybdenum ditelluride (MoTe2) is a crystalline compound that, if pure enough, can be used as a transistor. Its molecular structure is a sandwich made up of one molybdenum atom for every two tellurium atoms. It was first made in the 1960s via several different fabrication methods, but had never been made in a pure enough form to be suitable for electronics.

Not only did the IBS-led team succeed in making MoTe2 in pure form, they were also able to make two types of it — the semiconducting variety 2H (hexagonal) and the metallic variety monoclinic 1T’ (octahedral) of MoTe2 — which are both stable at room temperature.

Making MoTe2 in a pure form was very difficult and was seen by some as a black sheep of the transition metal dichalcogenides (TMD) family and hence ignored. TMDs are molecules that can be made very thin (just several atomic layers thick) and have an energy bandgap that makes them ideal for making electrical components, especially transistors.

A TMD crystal follows an MX2 format: there is one transition metal (where M can be tungsten, molybdenum, etc) and two chalcogenides (where X2 is sulfur, selenium or tellurium). These atoms form a thin, molecular sandwich with the one metal and two chalcogenides, and (depending on their fabrication method) can exist in several slightly differently shaped atomic arrangements.

As electronic devices get smaller there is increasing demand to shrink the size of their logic chips. As the chips approach single or several atom thickness (i.e. two-dimensional), silicon no longer works as well as it does in a larger, three-dimensional scale. As the scale approaches two dimensions (2D), the bandgap of silicon changes (to a higher bandgap than that in its 3D form) and the contact points with metal connections on silicon are no longer smooth enough to be used efficiently in electrical circuits.

This is the perfect opportunity to employ new TMD materials. The IBS research team was able to exploit the two versions of MoTe2 and make one 2D crystal that was composed of the semiconducting 2H-MoTe2 and the metallic 1T'-MoTe2. This configuration is superior to using silicon as well as other 2D semiconductors because the boundary where the semiconducting (2H) and metallic (1T') MoTe2 meet forms an ohmic homo-
MoTe₂ has a bandgap of around 1eV, which is similar to silicon’s bandgap and it allows an ohmic homojunction at the semiconductor–metal junctions. So, MoTe₂ can replace silicon without much change in the current voltage configurations used with today’s silicon technologies.

This presents a solution to several problems that have been a hindrance in the past. By using only one material in the device channel and the metal-semiconductor junction, it is more energy efficient since the joints between the two phases of the MoTe₂ are fused seamlessly, realizing an ohmic contact at the joints. Because 1T’-MoTe₂ is such a good conductor, metal electrodes can be applied to it directly, saving any additional work of finding a way to attach metal leads. This new fabrication technique is a very efficient way of utilizing the available MoTe₂ without any wasted or extraneous parts.

“There are many candidates for 2D semiconductors, but MoTe₂ has a bandgap of around 1eV, which is similar to silicon’s bandgap and it allows an ohmic homojunction at the semiconductor–metal junctions,” says SKKU professor Heejun Yang. So, MoTe₂ can replace silicon without much change in the current voltage configurations used with today’s silicon technologies. The dual-phase MoTe₂ transistor looks promising for use in new electronic devices as demand for components increases for materials that are small, light and extremely energy efficient.

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