A technique to produce patterned transition metal ditelluride layers for 2-D devices

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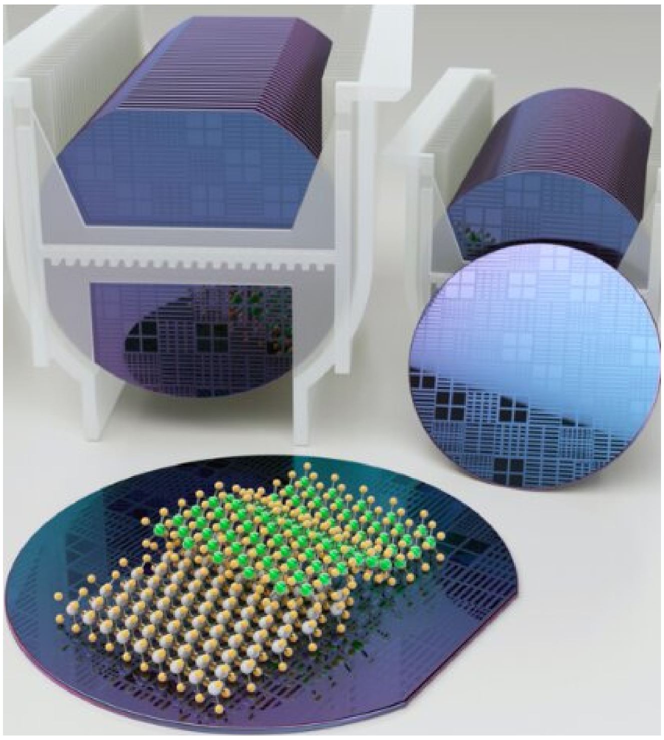

Figure depicting the patterned 2D transition metal ditellurides grown by the researchers on large-area wafers. Credit: Song et al.

Researchers at Ulsan National Institute of Science and Technology (UNIST) in South Korea have recently introduced a method to produce thin and patterned transition metal ditelluride films to be integrated in 2-D metal semiconductors. Their synthesis technique, presented in a paper published in *Nature Electronics*, could mitigate the challenges associated with the high contact resistance of existing electronics based on 2-D materials.

Since the discovery of graphene, a material with highly desirable properties for the development of electronics, other 2-D layered materials with similar characteristics have attracted substantial attention. These materials include transition metal chalcogenides, such as tungsten ditelluride and molybdenum ditelluride (WTe_2 and $MoTe_2$).

These transition metal ditellurides are a class of transition metal chalcogenides that exhibits unique and extraordinary electrical and optical qualities. They have shown great promise for the development of several technologies, including quantum computers, transistors and phase-transition memories.

"Most studies using 2-D transition metal ditellurides have exclusively exploited the mechanical exfoliated flakes from the bulk single crystals, which hinders the practical applications of the materials," Prof. Soon-Yong Kwon, one of the researchers who carried out the study, told TechXplore. "What's more, the defects at the interface between metal and semiconductors can trigger the contact issues (including the Fermi-level pinning) which generally lower the carrier injection efficiency of the nano-electronic devices based on 2-D materials. We tried to solve these contact problems using the metallic 2-D transition metal ditellurides with low work function."

The new approach to synthesize transition metal ditellurides devised by Prof. Soon-Yong Kwon and his colleagues entails the use of a tellurium-rich eutectic alloy as a gas source that triggers nucleation and the growth of the crystals. Using this method, the researchers were able to grow 4-inch scale 2-D transition metal ditellurides over a short period of time (approximately 10 minutes), at a relatively low temperature of 450^{o}C. Remarkably, the process can also be adapted to create wafer-scaled thin films with a variety of different structural patterns.

"We applied the 2-D transition metal ditellurides films as electrical contacts to inject carriers into 2-D semiconductors, such as molybdenum disulfide," Seunguk Song, one of the researchers wo carried out the study, said. "We found that such electrical devices followed the ideal law for the carrier injection (i.e., Schottky-Mott theory), which had a substantial advantage in controlling the efficiency of the electrons' flow at the interface."

Prof. Kwon, Song and their colleagues used films synthesized via their method to build electrical contacts and integrated them into existing 2-D semiconductors. The resulting devices were found to outperform devices based on other analogous 2-D metallic materials, exhibiting a lower contact resistance and a higher performance.

"The key point of our production method is to provide the large amount of tellurium vapor constantly to the transition metal precursor in order to promote their chemical reaction." Song said. "This is particularly important because the chemical activity between W and Te is very low, generally challenging in its successful growth. To mitigate this problem, the precursor of a Ni_xTe_y alloy film was selected as a Te source."

In the films synthesized by the researchers, the compound Ni_xTe_y continually provides and recaptures Te vapors, as Ni_xTe_y is in a liquid-like phase at a growth temperature that is higher than the alloy's melting point (aka eutectic point). This process ultimately averts the scarcity of Te frequently observed during powder-based chemical vapor deposition processes.

"By transferring 2-D MoS_2 crystals onto the 2-D patterned $(W,Mo)Te_2$ thin film, we could simply fabricate the vertically contacted heterostructures," Prof. Kwon said. "These 2-D/2-D metal-semiconductor junction transistors had tunable Schottky barrier heights that depended on the work functions of $(W,Mo)Te_2$ owing to the absence of interface issues. This enabled us to get the lowest Schottky barrier height for the transistor based on monolayer MoS_2 among the other reported studies using 3-D or 2-D metal contacts."

The study could have important implications for the future development of electronics based on 2-D materials. Most notably, the synthesis approach introduced by Prof. Kwon, Song and their colleagues could open up the possibility of controlling some types of polarity in 2-D semiconductors by enabling the production of new 2-D metals with different work functions.

"In nature, there are other variety of 2-D metals with interesting physical properties, but their high-quality, large-area growth is still rare," Song said. "Based on the synthetic approaches for these novel 2-D metals, we now plan to study 2-D/2-D heterostructures and device integrations."

More information: Seunguk Song et al. Wafer-scale production of patterned transition metal ditelluride layers for two-dimensional metal–semiconductor contacts at the Schottky–Mott limit, *Nature Electronics* (2020). DOI: 10.1038/s41928-020-0396-x

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