Hawai‘i Natural Energy Institute Research Highlights

Advanced Materials

Two-Dimensional Materials for Thin Film Manipulation

OBJECTIVE AND SIGNIFICANCE: The objective of this project is to develop methodologies to facilitate the manipulation of thin films utilizing two-dimensional (2D) interfacial layers. This approach has the potential to facilitate the physical transfer of high-efficiency devices, such as photovoltaics, from their original substrates to novel platforms, including clothing, vehicles, and buildings.

BACKGROUND: Monolithic integration—the process by which solid-state devices are made by sequentially depositing layers of materials on top of each other—is used in all commercial thin film-based technology. Despite its wide acceptance, however, monolithic integration presents two major limitations.

First, process compatibility is a challenge since the deposition of each layer must not damage the previously deposited underlying layers. As such, the thermal, mechanical, and chemical compatibility between layers and their deposition processes restricts materials selection, limiting the adoption of promising materials. Second, monolithic integration almost always leads to the formation of additional phases at the interface of two materials. The electronic and chemical properties of interfaces also generally differ significantly from those of a simple combination of the two constituting layers, which impacts device performance.

An integration scheme that combines materials regardless of their nature, while preserving or even enhancing their intrinsic performance, could revolutionize the manufacturing of technologies that rely on material stacking, including photovoltaic (PV) devices. Such an integration approach, using 2D materials for thin film manipulation, is being developed in this program.

PROJECT STATUS/RESULTS: HNEI and the University of Nevada, Las Vegas have partnered with the Lawrence Livermore National Laboratory and National Renewable Energy Laboratory to develop 2D material-assisted thin film exfoliation, focusing on the chalcopyrite class (e.g., $Cu(In,Ga)Se_2$, CIGSe) and transition metal dichalcogenides (e.g., MoS_2 and $MoSe_2$).

In this work, we use the so-called *metal-mediated exfoliation* (MME) process to isolate MoS_2 monolayers from commercial bulk crystals (Figure 1a). Theory suggests a certain degree of electrical charge transfer in the topmost MoS_2 layer when placed in contact with a metal, such as gold, which polarizes and produces a van der Waals-like interaction at the metal/MoS_2 interface greater than that of the bulk crystal.

The MME process begins with template stripping of a gold metal layer from its substrate using temperature release tape (TRT). The gold tape is then immediately brought into contact with a MoS_2 crystal. The gold tape (and its MoS_2 monolayer) is then separated from the crystal and pressed to a target substrate (Figure 1b). Finally, the TRT is removed with heat and the gold layer chemically etched, leaving being the MoS_2 monolayer attached on the new substrate (Figure 1c).

Current efforts are focused in increasing the size of isolated MoS_2 monolayers (currently 5 mm × 5 mm) to facilitate integration into novel optoelectronics devices with interfacial properties controlled down to the atomistic level.

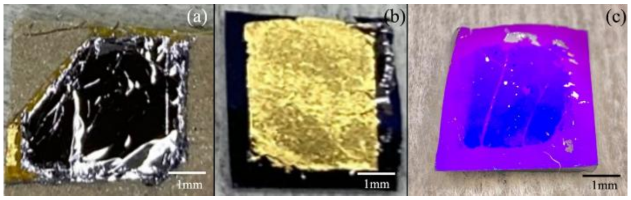

Figure 1. HNEI's MME process for MoS_2.

Results of this work, "**Periodically Strained 2D Materials for Tunable Optoelectronic Applications**," was presented at the 2024 Electrochemical Society PRiME Meeting.

Funding Source: U.S. Department of Energy

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Last Updated: November 2025