simulated results to investigate the possible mechanism of absorption. The sample with the larger pore diameter of D = 365 nm showed an average measured absorbance of about 99% in the visible-near-infrared regime (400 nm to 2.5 μm) and greater than 99% in the mid-infrared regime (2.5–10 μm). "We are very excited about this work, particularly because this is the darkest metal reported so far," says Zhu, who is the chief investigator. "A combination of extraordinary absorption with other properties of metals can open up tremendous opportunities, such as photocatalysis, sensing, and desalination."

These plasmonic absorbers were tested for use in solar steam generation and demonstrated over 90% conversion efficiency at a solar irradiation of 4kW/m^2. Shanhui Fan from Stanford University says, "This is innovative work demonstrating an important application in energy technology of nanophotonic concepts. I look forward to seeing this scaled up into a practical system."

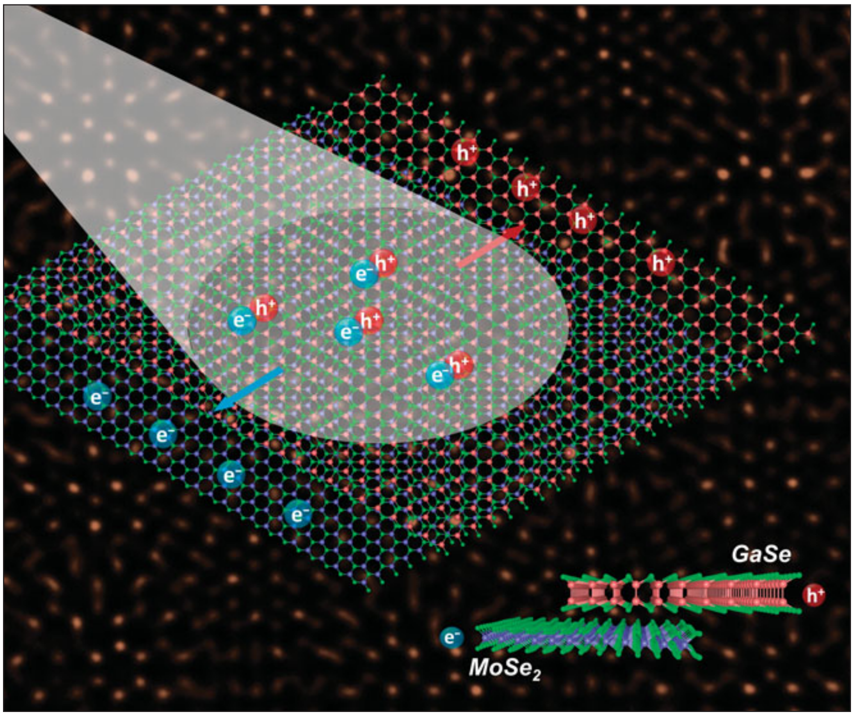
The researchers believe that with more advancements in design and fabrication of different templates along with low-cost plasmonic materials like aluminum, large-scale manufacturing of complex nanoscale architectures will be possible for a diverse set of potential application fields.

Rachana Acharya

Epitaxial misfit van der Waals heterostructures unlock new family of materials

The engineering of materials with "properties-by-design" has spurred the creation of van der Waals (vdW) heterostructures that are based on the stacking of two-dimensional (2D) materials of varying compositions. These layered structures, held together by weak vdW forces, often show optoelectronic properties that are radically different from their individual building blocks. Typical synthesis of vdW heterostructures relies on large-scale chemical vapor deposition (CVD) or mechanical stacking of single 2D flakes.

Recently reported in *Science Advances* (doi:10.1126/sciadv.1501882), Kai Xiao, a staff scientist at Oak Ridge National Laboratory (ORNL), and postdoctoral researcher Xufan Li, along with other co-workers from ORNL, Vanderbilt University, and Beijing Computational Science Research Center, presented the first known attempt to grow a misfit layer heterostructure containing GaSe and $MoSe_2$ through a two-step CVD synthesis. The 2D heterostructures were fabricated by first reacting Se vapor with MoO_3 to form monolayer $MoSe_2$ crystals on SiO_2/Si or fused quartz substrates. Once deposited, the as-synthesized $MoSe_2$ (*n*-type) was then used to template the controlled growth of *p*-type GaSe to form a vertical misfit bilayer with no interfacial contamination.



Light drives the migration of charge carriers (electrons and holes) at the juncture between semiconductors with mismatched crystal lattices. These heterostructures hold promise for advancing optoelectronics and exploring new physics. The schematic's background is a scanning transmission electron microscope image showing the bilayer in atomic-scale resolution. Credit: Oak Ridge National Laboratory, US Department of Energy. Image by Xufan Li/Chris Rouleau.

Despite considerable success, "current CVD methods to directly grow 2D material heterostructures are limited to materials with similar lattice constants and/or crystal structures," says Xiao of the Center for Nanophase Materials Sciences at ORNL. "It is a big challenge to put together two 2D materials with a large lattice-constant mismatch, but we are able to overcome this limitation with vdW epitaxial growth to create novel vdW heterostructures based on lattice-mismatched materials. This opens the door to new families of functional 2D materials for applications in photovoltaics, LEDs, transistors, and memory devices."

The atomic structure of the bilayer heterostructures was characterized by scanning transmission electron microscopy, and the images exhibited repeating Moiré patterns, which hinted at long-range superlattice order. Investigation

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of the properties of the $GaSe/MoSe_2$ misfit heterojunction showed efficient charge separation at the interface, which demonstrated strong coupling despite the 13% lattice mismatch, as revealed by photoluminescence quenching of the $MoSe_2$. The *p–n* junction also showed a gate-tunable photovoltaic response, with the photoresponsivity ranging from 5.5 mA/W to 25.3 mA/W with increasing gate voltage.

"This vdW epitaxial growth method opens up a whole new family of heterostructures because you no longer need to worry about lattice matching at the unit cell," comments Dave Johnson, an expert in misfit layer heterostructures at the University of Oregon. "The synthesis of heterostructures via vdW epitaxy, or other approaches, will change the way we think about materials optimization and enable the design of materials by actually modifying the identity, sequence, and nanoarchitecture of the heterostructured solid so that you can selectively tune device performance."

This epitaxial growth protocol is not only limited to 2D semiconductors, but is predicted to also be accessible to both 2D metals and insulators. Despite this promise, the challenge will lie in tuning the growth temperature and pressure for each individual material in order to address problems with interfacial contamination, diffusion, and evaporation. If these conditions can be met, the synthesis of vdW misfit heterostructures will unlock a realm of materials that have not yet been explored, and will allow the selective tuning of materials' properties based on its epitaxial building blocks.

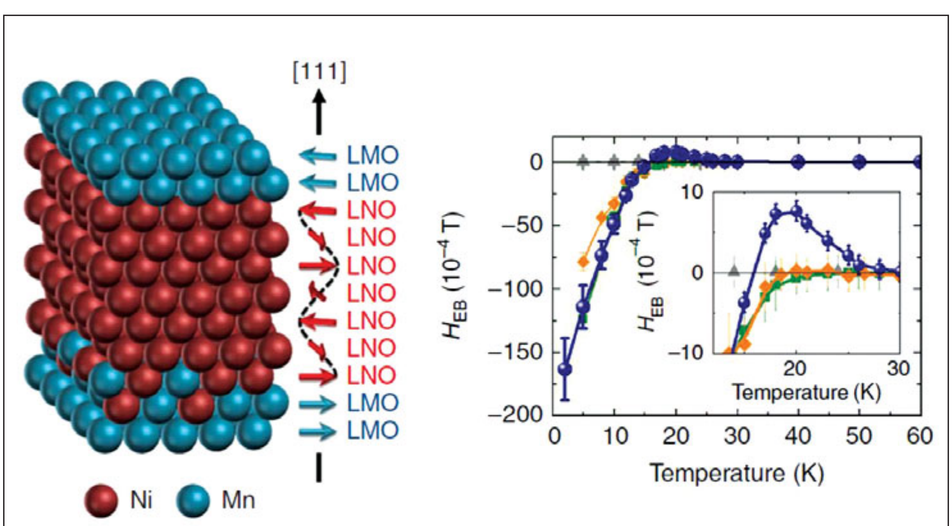
Tyler W. Farnsworth

Magnetic phenomena from the confines of a nonmagnetic material

There have been many recent advances in the synthesis, manipulation, and study of complex atomic-scale structures and interfaces. Among these, understanding the fundamental changes in physical properties in areas of reduced dimensionality has played an important role and has led to improvements in spintronics, digital memory, and transistor technologies. A study from the University of Geneva, Switzerland, published in a recent issue of *Nature Communications* (doi: 10.1038/ncomms11227), demonstrates the complex evolution of magnetic phenomena occurring at the interfaces in multilayered perovskite oxides.

The researchers focused their efforts on [111]-oriented superlattices of $LaNiO_3$ (LNO)/$LaMnO_3$ (LMO). M. Gibert, the lead author, states "We focused on interface engineering, studying new properties that emerge at the interfaces of these oxide materials."

At low temperatures, most materials in the LNO family of perovskite nickelates are both electrically insulating and antiferromagnetic. However, LNO is known to be both metallic and nonmagnetic at all temperatures. Researchers have shown that growing thin epitaxial LNO films in the [111] direction in between layers of LMO can promote a dimensionality-induced insulating character as well as antiferromagnetic ordering of the magnetic moments. As Gibert describes it, "LNO in these specific conditions behaves more like all the other nickelates." Furthermore, by restricting the LNO layer to only 7 monolayers (ML), they were able to promote a number of complex temperature-dependent exchange coupling phenomena.



Model of the magnetic arrangement of 7-monolayer $LaNiO_3$ in the $LaNiO_3/LaMnO_3$ superlattice. The exchange bias sign reversal is exclusively observed for the superlattice with 7-monolayer LNO (blue), that is, not for 5-monolayer LNO or 8-monolayer LNO. Credit: *Nature Communications*.

In a layer this thin, the LNO monolayers were found to couple antiferromagnetically to each other creating a 4-unit-cell stack that equates to a net zero magnetic moment, just like the rest of the perovskite nickelates. However, if only 7 ML of LNO are sandwiched between the LMO layers, the 4-unit-cell sequence is unfinished and the magnetic moments at the ends of the LNO layer (at the interfaces) are pointing in opposite directions; see Figure. Since the LMO layer couples ferromagnetically (parallel) to the LNO layer by a charge-transfer mechanism, successive LMO layers are then

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