the point where CO_2 conversion could be poised for a radical leap forward. Finally, the products that can be made from converted CO_2 run the gamut of advanced materials, including novel ceramics and graphene, for example. The Carbon XPRIZE is built upon the advances of materials science and seeks to propel the field and its potential for solutions even further.

Another one of humanity's grand challenges is to explore what is beneath the ocean. Oceans cover two-thirds of the Earth's surface, and yet we know less than 5% of what is out there, whether it be biological or geological. The primary reason we remain in the dark is because, until now, the technological capabilities to explore the ocean at the scale and speed necessary were not available.

The Shell Ocean Discovery XPRIZE is a USD$7 million competition for the development of technologies to map the deep-sea floor at high resolution and produce high-definition images of the ocean. Embedded within this is a USD$1 million NOAA Bonus Prize to develop pioneering underwater sensors that can autonomously detect and trace a biological or chemical signal to its source.

With these, we hope to usher a new era of ocean exploration through which we expect to find new materials needed to survive and progress as a society. Our limited knowledge of the ocean has already given us additional sources of minerals such as manganese; we have found marine life that can camouflage itself, conduct electricity in seawater, or create its own light source; and we have discovered new compounds for the development of medical cures for Alzheimer's disease, various cancers, and AIDS.

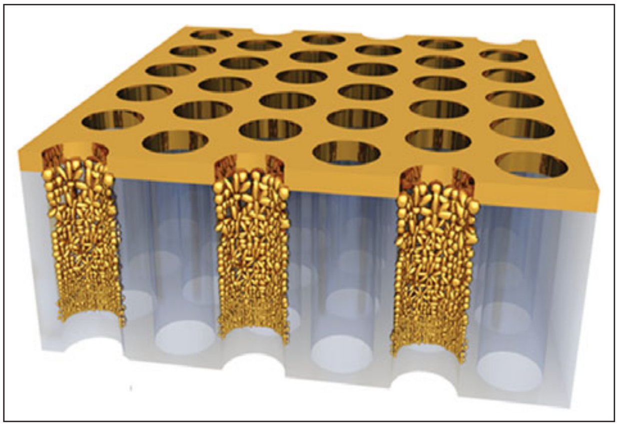
Operating in a water environment has, historically, only been accomplished by the marriage of materials science with engineering. Seawater is a corrosive medium, and the challenges of creating technology that can maneuver electronics on and through water, often under high pressures, has called for innovative approaches. Recent advances in materials are of direct relevance to the solutions for the Shell Ocean Discovery XPRIZE. Graphene, for example, may be used to detect the gas molecules that constitute a chemical signal, paving the way for the novel underwater "sniffing" devices incentivized by the USD$1 million NOAA Bonus Prize. New materials are allowing for the miniaturization of technology and improving optical capabilities, paving the way for multiple small innovations that would map the deep-sea floor and produce high-definition images from the dark ocean environment.

XPRIZE hopes to incentivize anyone to try a new solution and reward the most radical new solutions. But this is just part of a broader trend, one that gives us both hope and an expectation that our biggest challenges can be solved. We have the tools, remarkable scientific knowledge and capacity, big thinkers, and anyone can be a part of the solution.

Gold nanoparticles self-assemble to make efficient broadband plasmonic absorbers

Plasmonic absorbers are gaining significant attention for applications such as photo/thermal detectors, solar energy conversion, and infrared imaging because of their exceptional ability to concentrate electromagnetic energy and trap it into thin layers to generate hot electrons. These absorbers are a determining factor in the performance of the whole system, making their efficiency and bandwidth of absorption crucial. A research team from Nanjing University, China, has now fabricated a broadband plasmonic absorber with average measured absorbance of 99% across wavelengths ranging from 400 nm to 10 μm.

As reported in a recent issue of *Science Advances* (doi:10.1126/sciadv.1501227), Lin Zhou, Yingling Tang, and Jia Zhu from the National Laboratory of Solid State Microstructures, Nanjing University, and collaborators from the University at Buffalo, The State University of New York, as well as the University of Wisconsin–Madison, created their plasmonic absorbers by self-assembling gold nanoparticles on a nanoporous template using a physical vapor deposition (PVD) process. A nanoporous alumina template with pore sizes of 30–400 nm provides a percolated scaffold and is used to control the deposition of the gold nanoparticles during PVD. The size of the gold nanoparticles could be changed by varying the pore size of the nanoporous template and the gas pressure of the PVD system. It was found that the gold nanoparticles were deposited on the surface of the template forming a metallic film, and also on the side walls of the pores as randomly distributed aggregates. The latter creates a gradual size distribution along the deposition path. This random size distribution, as shown in the figure, is critical for efficient and broadband absorption because it generates multiple overlapping plasmonic modes.


Three-dimensional assembly of self-assembled plasmonic absorbers. Credit: *Science Advances.*

The absorption spectra of a bare nanoporous template and two gold sputtered templates with different pore diameters were measured over the wavelength range of 400 nm to 10 μm, and compared to 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."

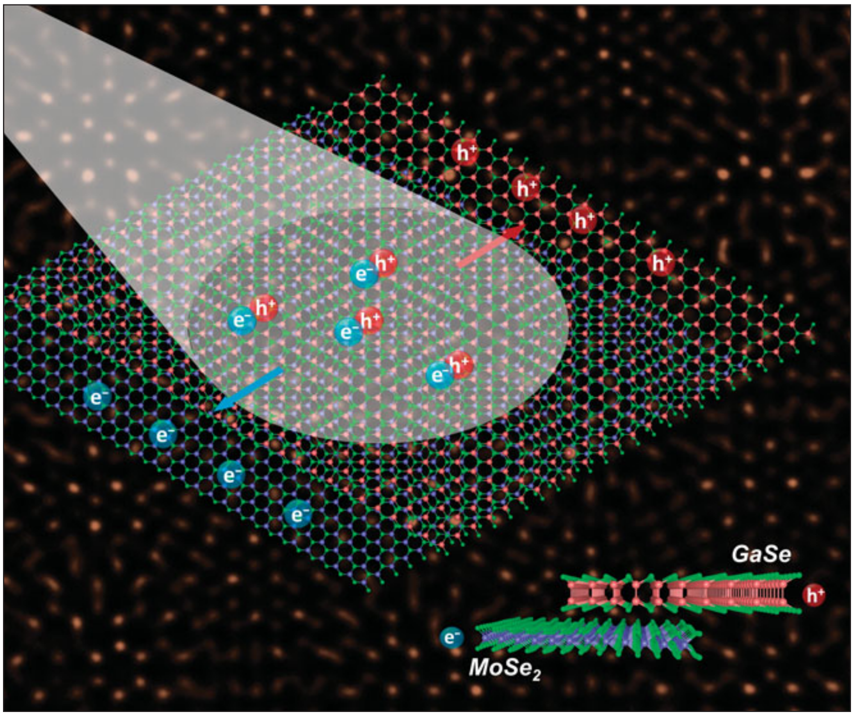
The researchers believe that with more advancements in design and fabrication of different templates along with low-cost plasmonic materials like aluminum, large-scale manufacturing of complex nanoscale architectures will be possible for a diverse set of potential application fields.

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