developed a diagnostic strip and magnetic detector that, together with a smartphone, can diagnose hepatitis B in minutes using magnetically tagged biomarkers.

"It was an exhilarating journey to participate in the XCHALLENGE," Wang says. "The very challenging requirements posed by the XPRIZE Foundation forced us to design our assay and platform for the real world rather than the ivory tower. Being able to highlight novel nanomaterials such as magnetic nanoparticles and giant magnetoresistive (GMR) sensors in this international competition was also very rewarding."

Participants in such challenge prize competitions fund their entries through investors, crowdsourcing, institutional support, corporate sponsorship, philanthropic organizations, or their own wallets. In some cases, finalists receive seed money or a portion of the prize money. Organizers say this funding model provides better returns on their investment since the development costs are widely shared. Competitors in challenge prizes say this model involves more risk, but can lead to deep levels of commitment and productive new partnerships.

Participating in the USD$1 million "H2 Refuel" H-Prize competition has led to new business ventures for SimpleFuel, the only finalist group in an ongoing DOE competition to develop home or community hydrogen refueling systems for fuel-cell electric vehicles. SimpleFuel is a consortium of companies with unique contributions, according to Darryl Pollica, team spokesperson and President and CEO of Ivys Inc., one of the member companies. "Our business arrangement will undoubtedly live beyond the competition as we already have aggressive plans to commercialize the hydrogen refueling appliance after the initial competition demonstration."

Credit for the earliest successful challenge competition usually goes to Britain's 1714 Longitude rewards for methods to determine a ship's longitude while at sea (see *MRS Bulletin* **25** [4], [2000], doi:10.1557/mrs2000.51). The Ansari XPRIZE propelled challenge prizes into the modern spotlight in 2004, when Mojave Aerospace Ventures received a USD$10 million prize for launching a reusable, manned spacecraft into space twice within a span of two weeks. Since then the idea has regained popularity primarily in the United States and Europe.

Challenge prizes based outside of the United States and Europe are difficult to find, but corporations, governments, and foundations across the world are taking notice of their results and showing interest, according to Zenia Tata, executive director of international expansion and global development for XPRIZE. Digital platforms such as NineSigma.com and InnoCentive.com are becoming popular ways to connect visitors worldwide with open challenges from a range of hosts for varying prize amounts.

The rise in challenge prizes has caused a growing interest in studying their effectiveness. Initial reviews by McKinsey & Company and others show that well-designed contests can spur innovation in areas that are beyond the scope of traditional funding mechanisms, but exactly how they will affect the landscape of science research and advancement in the long term remains to be seen.

Connect with open challenges

- ec.europa.eu/research/horizonprize
- www.Challenge.gov
- www.InnoCentive.com
- www.Kaggle.com
- www.NineSigma.com
- www.openIDEO.com
- www.xprize.org

XPRIZE provides incentive for radical breakthroughs in innovation

www.xprize.org

By Paul Bunje, Jyotika Virmani, and Marcius Extavour

We are living in an era of extraordinary disruption. The technological, sociopolitical, and economic changes taking place around the world present innovators with an opportunity to apply groundbreaking research to challenges of worldwide importance.

Technologies on an exponential growth path (such as advanced robotics, ubiquitous sensors, synthetic biology) are rapidly becoming a part of our daily lives. These exponential technologies have the potential to lead to innovative solutions to some of the world's grand challenges. Importantly, many of these exponential technologies critically depend upon advances in materials science. Advanced materials are at the heart of innovative solutions to many of the world's biggest problems and opportunities.

The XPRIZE Foundation relies on the growing power of exponential technologies and revolutionary science to catalyze radical breakthroughs. By offering a suite of incentives, XPRIZE seeks to inspire the world's scientists, technologists, and innovators to tackle seemingly intractable challenges.

"Grand Challenges" are a part of today's dynamic period of disruption. It is now possible for us to not only characterize massive, global threats and opportunities that might affect billions of people, but also to conceive of possible solutions. Listing grand challenges—poverty, climate change, a cure for cancer, total planetary exploration—may sound trivial, but in reality, framing a grand challenge requires understanding the complexity and nuances involved in both defining a

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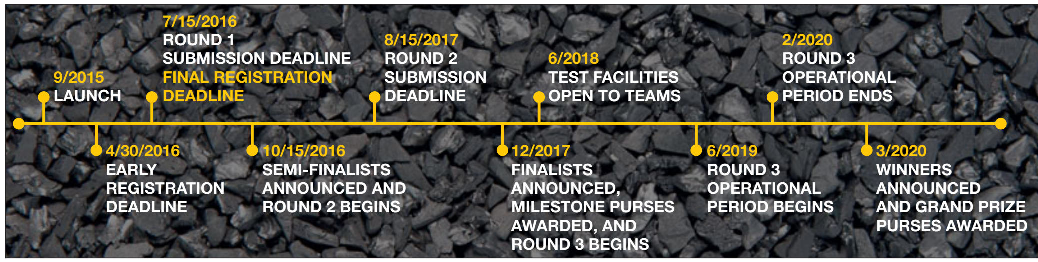
https://doi.org/10.1557/mrs.2016.142 Published online by Cambridge University Press

Grand Challenge: Reimagine CO_2



Grand Challenge: Shell Ocean Discovery

problem and envisioning the characteristics that will define a solution.

XPRIZE uses an incentive prize model to challenge anyone to solve a grand challenge. This model capitalizes on the millions, if not billions, of potential solvers in the world and enables the demonstration of novel approaches. An XPRIZE includes an objective set of criteria that teams have to achieve; it empowers an independent judging panel of leading experts to evaluate the solutions, and allows anyone the opportunity to demonstrate solutions in real-world environments.

Previous XPRIZE challenges have opened space exploration to private interests around the world (the Ansari XPRIZE), advanced hyper-efficient automobiles (the Progressive Automotive XPRIZE), and led to a quadrupling in the rate of oil spill cleanup technology in just over a year (the Wendy Schmidt Oil Cleanup XCHALLENGE).

Less than a year ago, the Montana-based winners of the Wendy Schmidt Ocean Health XPRIZE demonstrated unprecedented performance and cost gains for measuring the pH of the oceans—the critical first step in combating ocean acidification, a devastating environmental grand challenge in the making. These winners and the other five finalists all relied on a suite of technologies, science, and engineering to demonstrate a diversity of ways of measuring ocean chemistry in harsh environments. Unsurprisingly, advances in materials science were at the heart of many of these breakthroughs, including embedded chemical sensors, optode sensing, and high-pressure microfluidic or potentiometric systems.

XPRIZE recently launched two new prizes that tackle two grand challenges: the carbon dioxide emissions that drive climate change, and our poor ability to properly explore the oceans that make up the majority of our planet's surface.

The NRG COSIA Carbon XPRIZE is a USD$20 million global competition to incentivize technologies that convert CO_2 emissions into valuable everyday products, such as building materials and alternative fuels. Teams from around the world will compete for more than 4.5 years and through three increasingly difficult rounds of competition. Teams will have the opportunity to use the flue gas coming from either a coal-fired power plant or a natural-gas-fired power plant as a feedstock. The winning teams will convert the largest quantity of CO_2 from actual flue gas into one or more products with the highest net value. Judges will take into account production costs, market prices of product(s) produced, and market volumes of product(s) produced.

After proceeding through a technical submission evaluation and then a lab-scale demonstration, 10 finalists will utilize two new test centers—one adjacent to a coal-fired plant and the other to a natural-gas plant—and demonstrate their solutions at scale.

The Carbon XPRIZE is built to catalyze breakthroughs in carbon conversion, to showcase the ability of new approaches to utilize CO_2 instead of allowing it to escape into the atmosphere. Converting carbon dioxide is a part of a broader effort to mitigate CO_2 emissions using carbon capture, utilization, and storage (CCUS). CCUS technologies have the potential to become a major player in climate change mitigation, especially if they enable a responsible way to reduce the amount of carbon dioxide emitted from electricity generation.

However, CCUS is not without challenges, and has been dismissed by some critics as too expensive, too risky, and too enabling of the continued use of fossil fuels. The Carbon XPRIZE is intended to inspire and enable radical new solutions. This includes materials that help capture and purify carbon dioxide, materials that can enable immobilization (and thus transportation and/or storage) of CO_2, and materials involved in the complex process engineering throughout the system.

For carbon conversion, only incredibly advanced catalysts and related process materials can enable a change in the thermodynamics associated with converting CO_2 into other materials. Conventional wisdom has been that CO_2 conversion is too expensive and energy-intensive to thrive in markets dominated by fossil hydrocarbon feedstocks. But an emerging set of technologies and policies, based on advances in materials in particular, may shift the energetics and cost curves to

https://doi.org/10.1557/mrs.2016.142 Published online by Cambridge University Press

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.

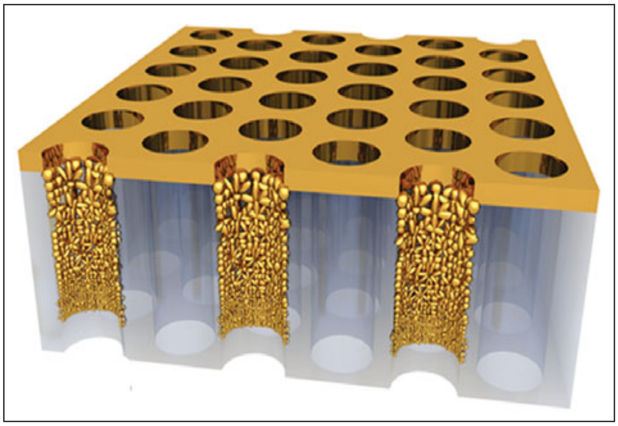
Operating in a water environment has, historically, only been accomplished by the marriage of materials science with engineering. Seawater is a corrosive medium, and the challenges of creating technology that can maneuver electronics on and through water, often under high pressures, has called for innovative 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

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