

## Hydrogen Sources and Storage Options for Fuel Cells

A major obstacle to establishing the hydrogen economy is the safe and cost-effective storage and transport of hydrogen fuel. One approach is to find a solid chemical material that can hold and then release  $H_2$  as needed. Take metal hydrides, for instance. Formed as a result of metal alloys combining with hydrogen, they release  $H_2$  when subjected to heat. The  $H_2$  combines with  $O_2$  in a fuel cell system to produce electricity. "One drawback of the technology is that most complex metal hydrides operate at too high a temperature. This forces some of the hydrogen to be used up in order to release the remaining hydrogen," says James Spearot, director of General Motors Corp.'s (GM; Detroit, MI; [www.gm.com](http://www.gm.com)) Advanced Hydrogen Storage Program. "Another challenge is that it takes at least 30 min for the hydride to reabsorb the hydrogen."

Against this backdrop, GM and Sandia National Laboratories (Livermore, CA; [www.sandia.gov](http://www.sandia.gov)) have embarked on a 4-year, \$10 million mission to develop a pre-prototype solid-state hydrogen storage tank based on sodium alanate. The objective is to store more hydrogen onboard a fuel-cell vehicle than current conventional hydrogen-storage methods and is more efficient during operation.

Phase 1 of the project involves the design of tanks using thermal and mechanical modeling, controls systems for hydrogen transfer and storage, and external heat management systems that improve the overall energy density compared to traditional heat sources. In Phase 2, a pre-prototype will be fabricated and tested.

Coincidentally, researchers at the Pacific Northwest National Laboratory (PNNL; Richland, WA; [www.pnl.gov](http://www.pnl.gov)) have found that transforming ammonia borane into a nanomaterial allows it to

release  $H_2$  approximately 100 times faster compared to conventional bulk ammonia borane at the required release conditions (temperatures below  $80^\circ C$ ). The scientists first dissolved the solid compound in a solvent and then added the solution to mesoporous silica (6.5-nm pores), which acted as a scaffolding material. "The capillary action of the porous silica pulled the ammonia borane into the pores," explains researcher Tom Autrey. "When the solvent was removed, the pores remained filled with ammonia borane," he continues. The researchers believe the patent-pending process may be reversible.

Taking a conventional fueling approach, scientists at Rutgers Univ. of New Jersey ([www.rutgers.edu](http://www.rutgers.edu)) have created a high-surface-area form of iridium that holds promise as a catalyst for extracting  $H_2$  from liquid ammonia. "By using established processes to bind hydrogen with atmospheric nitrogen into ammonia molecules, we could produce a liquid that is handled much like today's gasoline and diesel fuel. Then, using the nanostructured catalysts, pure hydrogen could be extracted from this liquid as needed by the fuel cell," says research director Ted Madey, a Rutgers' Univ. physics professor.

The nanostructured surface is created by heating a flat surface of iridium in the presence of oxygen. At temperatures around  $300^\circ C$ , the oxygen atoms pull the iridium atoms into a more ordered crystalline structure consisting of an array of pyramids, the faces of which measure 5 nm at their widest point. "Different temperatures create different face sizes," notes Madey. Ammonia molecules nestle into the dips between the pyramids, with the lone pair of electrons on the nitrogen atom bound to the metal surface; this sets the molecules up to shed their hydrogen atoms efficiently.



Sandia National Laboratories engineer Mark Zimmerman integrates a hydride bed with temperature sensors.