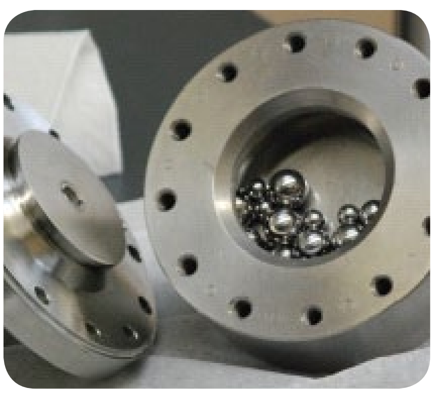
THE Ames Laboratory
Creating Materials & Energy Solutions

Solving the Solid Hydrogen Storage Riddle

Ames Laboratory research uses a novel refining process to add hydrogen to metal hydrides

Hydrogen's energy density is highest when the element exists as a solid. But freezing hydrogen requires temperatures below about 14 K. Creating a room-temperature-stable, solid hydrogen fuel by combining it with other materials has been aptly described as one of the grand challenges of science. For several years now, a team led by Vitalij Pecharsky, a senior scientist at the U.S. Department of Energy's Ames Laboratory, believes they are on the right path to success. The group's aim is to create a storage medium with an energy density equal to that of hydrogen in liquid form. That would be sufficient to make hydrogen a viable fuel for vehicles. Secondly, Pecharsky hopes his material's atomic structure will possess some of the characteristics of methane, whose four hydrogen atoms encapsulate a single carbon atom. This structure may allow certain novel compounds to give up their hydrogen atoms easily, through moderate heating or by other means. As a final goal, Pecharsky's team wants to design a material which can be recharged with fresh hydrogen atoms, each time the old ones have been dislodged and used up.



This specially constructed ball mill allows Ames Laboratory researchers looking into solid hydrogen storage to mechanically combine metal hydrides in a high-pressure hydrogen environment to boost the amount of hydrogen the materials can store. The technique, called mechanochemical processing, could help make hydrogen-fueled cars a reality.

Materials that fit the bill don't exist in nature. They must be specially fabricated using precursors that are themselves exotic. The Ames Lab team has set its sights on light-metal alanates, borohydrides, amides, imides and their derivatives. These materials already posses a total hydrogen content above 10 percent by weight. The goal will be to add even more hydrogen atoms.

A key enabling technology for this research is something called mechanochemical processing. The technique uses mechanical energy to

Hydrogen filling-stations may become as common as gasoline stations today.

forcibly combine different materials. Ames Laboratory researchers successfully applied mechanochemical processing to complex hydrides in 2002. This earlier work demonstrated that variable energy milling was able to modify both the structure and properties of hydrides and potentially allow the hydrides to take on additional hydrogen atoms.

Small advantages

Before the hydrides are placed in the milling device, they will make use of another technique pioneered

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at the Ames Laboratory called nanostructuring. Victor Lin, an Ames Lab chemist. developed a way of using the nanoscale pores in a self-assembling polymer as "molds" to precisely control the size of particles fed into the milling process.

Smaller particles are advantageous because they possess higher surface energies, and surface energy may be a decisive factor in shifting a material's thermodynamic equilibrium. Lowering the size of particles to a few nanometers also reduces the distances over which the mass transport takes place, thus improving the kinetics – the rate at which reactions take place – of complex hydride-hydrogen systems.

Once rendered into nanoscale particles, the materials are next placed inside a hardened steel vial along with steel balls. The vial is vigorously shaken. This causes mechanical energy to be transferred into the system, while it also alters the crystallinity of the solids, provides mass transfer, and eventually allows hydrogen gas to be added in a high-pressure environment.

Other methods of adding hydrogen to hydrides exist. But they rely on solvents. And the Ames Laboratory group contends that processing these materials without the use of solvents is important because once a material is dissolved, its structure fundamentally changes, and with it, perhaps, the material's ability to efficiently add and release excess hydrogen atoms.

The team plans to synthesize various combinations and sizes of materials in order to find a mixture with an optimal hydrogen content. Scanning and transmission electron microscopy, solid-state nuclear magnetic resonance, and X-ray powder diffraction are among the techniques the team will use to test the novel materials they create.

As the group's work progresses through these early stages, it's impossible to know what form the material will take when it goes into the fuel tank of a hydrogen-powered car some years from now. Perhaps it will be a fine powder or solid block. Similarly, the hydrogen atoms released from the material in the form of a gas may then be converted into electricity via a fuel cell or simply burned by the engine. When the material runs out of hydrogen it can be removed from the tank so hydrogen can be re-added, while a fresh batch of the hydrogen-laden material is placed in your vehicle.