THE Ames Laboratory

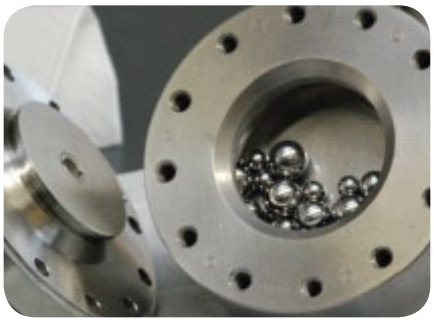
Creating Materials & Energy Solutions

The quest for an efficient solid-hydrogen fuel

Nanotechnology and a unique 'mechanochemical' refining process may hold the keys to putting hydrogen cars on the road

We all know that solids are denser than liquids. So all else being equal, a solid fuel should pack more energy than its liquid equivalent. But if your fuel of choice happens to be hydrogen, you've got a big problem. Hydrogen will only revert to solid form at temperatures below -259 °C, and it has to be chilled to below -250 °C before it transforms into a liquid. Even if you took hydrogen gas and compressed it, the low-energy density would mean your car would need an elephant-sized gas tank just to reach your next vacation destination.

But suppose you could create a solid hydrogen fuel that was able to exist at room temperature? And what if that solid hydrogen contained roughly as much energy as the liquid variety? The prospect has led many scientists to investigate ways of making room-temperature solid hydrogen fuel. One of them is Vitalij Pecharsky, a researcher at the U.S. Department of Energy's Ames Laboratory.



This specially constructed ball mill allows Ames Laboratory researchers looking into solid hydrogen storage to mechanically combine materials under a high-pressure hydrogen environment to boost the amount of hydrogen the materials can store. The technique, called mechanochemical processing, could pave the way for hydrogen-fueled cars.

For several years now, Pecharsky and his Ames Lab team have been on a quest to create a solid form of hydrogen that mimics the hydrogen content of methane, itself a burnable fuel. Methane molecules contain four hydrogen atoms that encapsulate a single carbon atom. This simple atomic structure does not allow methane to give up its hydrogen atoms easily through heating or by other means. Any viable hydrogen fuel would need to do otherwise – release hydrogen easily.

But Pecharsky's team wants its solid hydrogen fuel to have other attributes as well. Specifically, the researchers hope to design their material so it can be recharged with fresh hydrogen atoms after the old ones have been spent – which is to say, they want a fuel that's recyclable.

Variable energy milling

Unfortunately, materials that meet the Ames Lab team's requirements don't exist in nature. They must be specially fabricated using precursors that are themselves exotic. The Ames Laboratory researchers have set their hopes on so-called light-metal alanates, borohydrides, amides, and imides. These materials already posses a total hydrogen content above 10 percent by weight.

Hydrogen filling-stations may look similar to today's gas stations, but the fuel they dispense and the way that fuel is consumed by vehicles will be vastly different.

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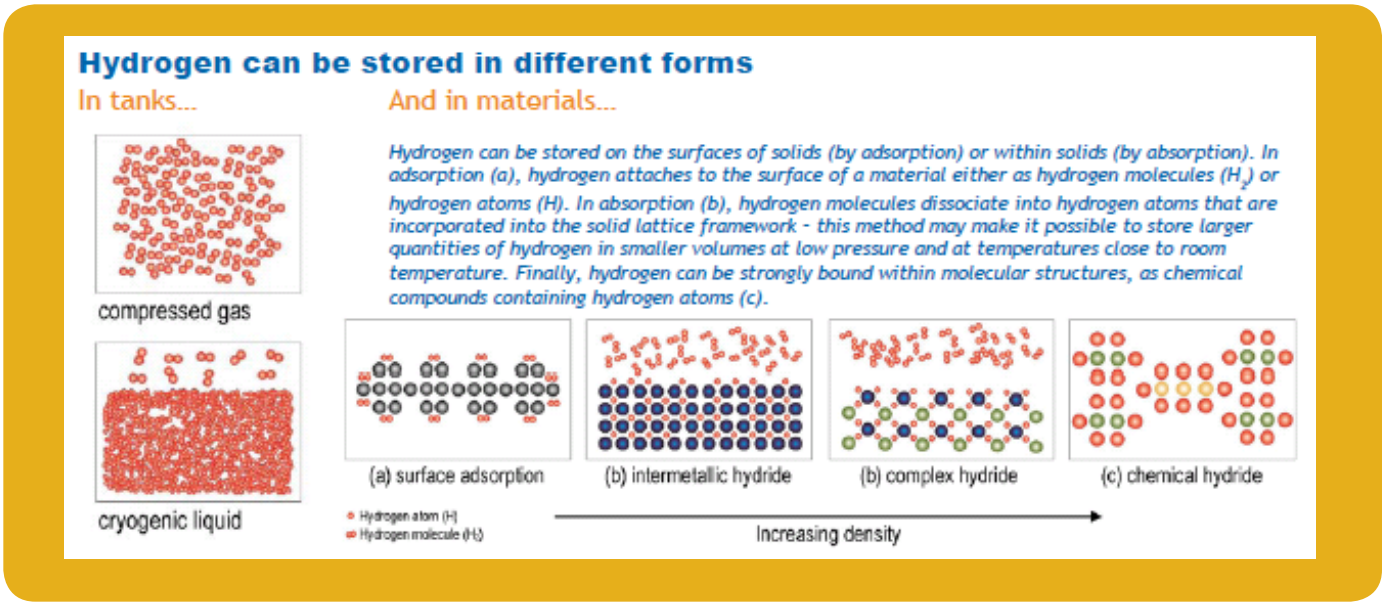

Given hydrogen's light weight – it's the simplest element on the periodic chart – that may sound like a lot. However, it's still not sufficient to put hydrogen cars on the highway. "If you have a material that holds 10 percent hydrogen by weight," Pecharsky notes, "then to store 5 or 6 kilograms of hydrogen you need 50 or 60 kilos of a solid, or 120, 130 pounds—which is comparable to the weight of a conventional fuel tank."

The trick will be to add even more hydrogen atoms to the 10-percent-by-weight substances. The team plans to do this with a process that uses something called variable energy milling to modify both the structure and properties of hydrides, and potentially, to make them easily rechargeable with hydrogen.

The process works like this. Some combination of the aforementioned materials will be reduced to nano-sized particles, measuring just billionths of a meter each. The small size makes it easier to add the needed extra hydrogen atoms.

The fine powder mixture is next placed in a hardened steel vial along with steel balls. The vial is vigorously shaken. This acts to transfer energy into the materials. In addition, the rigorous mixing actually alters the materials' crystallinity, provides mass transfer, and eventually – it is hoped – combines the materials and hydrogen gas into new fuel-ready compounds.

Tomorrow's filling stations

The Ames Lab group plans to mill various combinations of hydrides until they uncover the one that works best as a fuel. At some point in the future, this novel material could well become the fuel source for a hydrogen-powered car. The final product might be a powder or even a solid, removable block.

Once in the tank, it'll be warmed or agitated slightly. This will allow the hydrogen atoms to be released in the form of a gas. The gas in turn might then be converted into electricity via a fuel cell or simply burned by the engine.

When the material gives off most of its hydrogen atoms, it can be removed so new hydrogen atoms can be added – using the same milling process – so the material may be reused.

Years from now, this recycling process might conceivably take place right at the filling station. Alternately, you might exchange fuel tanks for your hydrogen car the way people now exchange propane cylinders for gas barbeque grills. Either way, your vehicle will be powered by a non-polluting fuel that will never run out.