Engineering Carbon for Impressive Hydrogen Storage

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(PhysOrg.com) -- University of Missouri researchers recently showed how carbon nanostructures can be engineered to become excellent media for hydrogen storage, work that may be important for the advancement of hydrogen-energy technologies for vehicles and other applications, which have been slow to develop due to the lack of suitable storage materials.

Using a combination of experiement and computer modeling, the group investigated the storage potential of various “nanoporous” carbon materials - carbon that contains tiny vacant spaces with diameters ranging from less than one nanometer to several nanometers.

Nanoporous carbon is a member of a class of materials being targeted as promising storage candidates because they can reversibly store hydrogen, are easy to load with hydrogen, and don't have heat-management issues. Carbon has an edge over other materials because it is both cheap and lightweight, but the low interaction energies between hydrogen molecules and carbon atoms lead to storage capacities that are inadequate at room temperature.

But no material, carbon or otherwise, presently comes close to the 2010 targets that the U.S. Department of Energy (DOE) has set for hydrogen storage at low-pressure, room-temperature conditions, namely 45 grams (g) of hydrogen per kilogram (H2/kg) material for rigid storage materials and 28 g per liter for liquid storage.

“Our work makes the case that it is possible to significantly increase hydrogen storage capacities in carbon materials by engineering the nanopores,” said University of Missouri physicist Carlos Wexler, the study's corresponding researcher, to *PhysOrg.com*.

Wexler and his group learned that the tendency for hydrogen and carbon to bind can be made much more likely by tailoring the material to certain specifications such that the binding energy between the two materials is raised, meaning they bond more strongly. They published their findings in the journal *Nanotechnology*.

Their approach has two key parts. First, it is necessary to engineer the material such that the ratio of its surface area to its volume is very high. This creates lots of surfaces, with lots of nanopores, maximizing adsorption while still using a small amount of material. Here, the researchers created tiny carbon granules (using a method, interestingly, that involves heating ground corncob, an agricultural waste product), which boast approximately 3100 square meters of surface area in a single gram. Further, the tiny width of the pores creates deep potential-energy wells that almost double the binding energy.

Second, they conclude that “doping” the carbon with a small amount of an element can boost the hydrogen-carbon interaction; examples of suitable elements include boron, iron, and nitrogen.

Because nanoporous carbon is a solid storage material, the DOE goal of 45 g H_2/kg applies. The group's experimental results yielded storage capacities of up to 100 g H2/kg at 83 degrees Kelvin (about -310 degrees Fahrenheit) and 20 g H_2/kg at a much more reasonable 303 K (about 86 °F).

“We think this shows that, with some work, it may be possible to meet those DOE goals by 2010,” said Wexler.

More information: *Nanotechnology* 20 (2009) 204026, all-craft.missouri.edu/