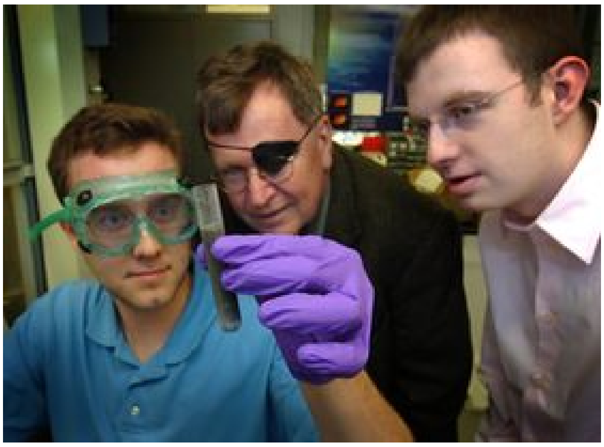
Engineers perfecting hydrogen-generating technology

27 August 2007



Purdue researchers demonstrate their method for producing hydrogen by adding water to an alloy of aluminum and gallium. The hydrogen could then be used to run an internal combustion engine or a fuel cell. The reaction was discovered by Jerry Woodall, center, a distinguished professor of electrical and computer engineering. Charles Allen, holding test tube, and Jeffrey Ziebarth, both doctoral students in the School of Electrical and Computer Engineering, are working with Woodall to perfect the process. (Purdue News Service file photo/David Umberger)

Researchers at Purdue University have further developed a technology that could represent a pollution-free energy source for a range of potential applications, from golf carts to submarines and cars to emergency portable generators.

The technology produces hydrogen by adding water to an alloy of aluminum and gallium. When water is added to the alloy, the aluminum splits water by attracting oxygen, liberating hydrogen in the process. The Purdue researchers are developing a method to create particles of the alloy that could be placed in a tank to react with water and produce hydrogen on demand.

The gallium is a critical component because it hinders the formation of an aluminum oxide skin normally created on aluminum's surface after bonding with oxygen, a process called oxidation. This skin usually acts as a barrier and prevents oxygen from reacting with aluminum. Reducing the skin's protective properties allows the reaction to continue until all of the aluminum is used to generate hydrogen, said Jerry Woodall, a distinguished professor of electrical and computer engineering at Purdue who invented the process.

Since the technology was first announced in May, researchers have developed an improved form of the alloy that contains a higher concentration of aluminum.

Recent findings are detailed in the first research paper about the work, which will be presented on Sept. 7 during the 2nd Energy Nanotechnology International Conference in Santa Clara, Calif. The paper was written by Woodall, Charles Allen and Jeffrey Ziebarth, both doctoral students in Purdue's School of Electrical and Computer Engineering.

Because the technology could be used to generate hydrogen on demand, the method makes it unnecessary to store or transport hydrogen - two major obstacles in creating a hydrogen economy, Woodall said.

The gallium component is inert, which means it can be recovered and reused.

"This is especially important because of the currently much higher cost of gallium compared with aluminum," Woodall said. "Because gallium can be recovered, this makes the process economically viable and more attractive for large-scale use. Also, since the gallium can be of low purity, the cost of impure gallium is ultimately expected to be many times lower than the high-purity gallium used in the electronics industry."

As the alloy reacts with water, the aluminum turns into aluminum oxide, also called alumina, which can be recycled back into aluminum. The recycled aluminum would be less expensive than mining the metal, making the technology more competitive with other forms of energy production, Woodall said.

In recent research, the engineers rapidly cooled the molten alloy to make particles that were 28 percent aluminum by weight and 72 percent gallium by weight. The result was a "metastable solid alloy" that also readily reacted with water to form hydrogen, alumina and heat, Woodall said.

Following up on that work, the researchers discovered that slowly cooling the molten alloy produced particles that contain 80 percent aluminum and 20 percent gallium.

"Particles made with this 80-20 alloy have good stability in dry air and react rapidly with water to form hydrogen," Woodall said. "This alloy is under intense investigation, and, in our opinion, it can be developed into a commercially viable material for splitting water."

The technology has numerous potential applications. Because the method makes it possible to use hydrogen instead of gasoline to run internal combustion engines, it could be used for cars and trucks. Combusting hydrogen in an engine or using hydrogen to drive a fuel cell produces only water as waste.

"It's a simple matter to convert ordinary internal combustion engines to run on hydrogen. All you have to do is replace the gasoline fuel injector with a hydrogen injector," Woodall said.

The U.S. Department of Energy has set a goal of developing alternative fuels that possess a "hydrogen mass density" of 6 percent by the year 2010 and 9 percent by 2015. The percent mass density of hydrogen is the mass of hydrogen contained in the fuel divided by the total mass of the fuel multiplied by 100. Assuming 50 percent of the water produced as waste is recovered and cycled back into the reaction, the new 80-20 alloy has a hydrogen mass density greater than 6 percent, which meets the DOE's 2010 goal.

Aluminum is refined from the raw mineral bauxite, which also contains gallium. Producing aluminum from bauxite results in waste gallium.

"This technology is feasible for commercial use," Woodall said. "The waste alumina can be recycled back into aluminum, and low-cost gallium is available as a waste product from companies that produce aluminum from the raw mineral bauxite. Enough aluminum exists in the United States to produce 100 trillion kilowatt hours of energy. That's enough energy to meet all the U.S. electric needs for 35 years. If impure gallium can be made for less than $10 a pound and used in an onboard system, there are enough known gallium reserves to run 1 billion cars."

The researchers note in the paper that for the technology to be used to operate cars and trucks, a large-scale recycling program would be required to turn the alumina back into aluminum and to recover the gallium.

"In the meantime, there are other promising potential markets, including lawn mowers and personal motor vehicles such as golf carts and wheelchairs," Woodall said. "The golf cart of the future, three or four years from now, will have an aluminum-gallium alloy. You will add water to generate hydrogen either for an internal combustion engine or to operate a fuel cell that recharges a battery. The battery will then power an electric motor to drive the golf cart."

Another application that is rapidly being developed is for emergency portable generators that will use hydrogen to run a small internal combustion engine. The generators are likely to be on the market within a year, Woodall said.

The technology also could make it possible to introduce a non-polluting way to idle diesel trucks. Truck drivers idle their engines to keep power flowing to appliances and the heating and air conditioning systems while they are making deliveries or parked, but such idling causes air pollution, which has prompted several states to restrict the practice.

The new hydrogen technology could solve the truck-idling dilemma.

"What we are proposing is that the truck would run on either hydrogen or diesel fuel," Woodall said. "While you are on the road you are using the diesel, but while the truck is idling, it's running on hydrogen."

The new hydrogen technology also would be well-suited for submarines because it does not emit toxic fumes and could be used in confined spaces without harming crew members, Woodall said.

"You could replace nuclear submarines with this technology," he said.

Other types of boats, including pleasure craft, also could be equipped with such a technology.

"One reason maritime applications are especially appealing is that you don't have to haul water," Woodall said.

The Purdue researchers had thought that making the process competitive with conventional energy sources would require that the alumina be recycled back into aluminum using a dedicated infrastructure, such as a nuclear power plant or wind generators. However, the researchers now know that recycling the alumina would cost far less than they originally estimated, using standard processing already available.

"Since standard industrial technology could be used to recycle our nearly pure alumina back to aluminum at 20 cents per pound, this technology would be competitive with gasoline," Woodall said. "Using aluminum, it would cost $70 at wholesale prices to take a 350-mile trip with a mid-size car equipped with a standard internal combustion engine. That compares with $66 for gasoline at $3.30 per gallon. If we used a 50 percent efficient fuel cell, taking the same trip using aluminum would cost $28."

The Purdue Research Foundation holds title to the primary patent, which has been filed with the U.S. Patent and Trademark Office and is pending. An Indiana startup company, AlGalCo LLC., has received a license for the exclusive right to commercialize the process.

In 1967, while working as a researcher at IBM, Woodall discovered that liquid alloys of aluminum and gallium spontaneously produce hydrogen if mixed with water. The research, which focused on developing new semiconductors for computers and electronics, led to advances in optical-fiber communications and light-emitting diodes, making them practical for everything from DVD players to television remote controls and new types of lighting displays. That work also led to development of advanced transistors for cell phones and components in solar cells powering space modules like those used on the Mars rover, earning Woodall the 2001 National Medal of Technology from President George W. Bush.

Also while at IBM, Woodall and research engineer Jerome Cuomo were issued a U.S. patent in 1982 for a "solid state, renewable energy supply." The patent described their discovery that when aluminum is dissolved in liquid gallium just above room temperature, the liquid alloy readily reacts with water to form hydrogen, alumina and heat.

Future research will include work to further perfect the solid alloy and develop systems for the controlled delivery of hydrogen.

Source: Purdue University