

Carbon Nanotechnology Lowers Cost Of Hydrogen Fuel Cell

Florida State University



To keep the world's growing army of cell phone towers constantly powered so mobile phone users can enjoy ubiquitous service, telecommunication providers are scrambling to find viable solutions to supplement unstable power grids or meet new regulations for alternative energy sources in remote areas.

According to a report by Navigant Research, there are approximately [5 million cell phone towers](#) (also called mobile base stations) worldwide, including 640,000 off-grid base stations at the end of 2012, most of which are powered by generators using diesel fuel.

Using nanotechnologies developed at [Florida State University \(FSU\)](#), [Bing Energy](#) hopes its hydrogen fuel cell that features a cutting-edge, high-performance material called buckypaper will become the cell tower power of choice in many countries around the world.

The Hydrogen Fuel Cell

The hydrogen fuel cell (also known as a proton exchange membrane fuel cell or PEM) is similar to the lead-acid battery in that it generates electricity through a chemical reaction. However, unlike a battery, which requires recharging once

its stored energy is consumed, this fuel cell not only keeps producing electricity as long as it has a supply of fuel, but it is also free from the environmental hazards associated with lead-acid batteries.

The basic components of a PEM fuel cell include a channel on one side that allows hydrogen to flow in to the anode electrode, where a catalyst causes the hydrogen to split into positive ions and negatively charged electrons. On the other side of the fuel cell, oxygen flows into the cathode electrode. A membrane in the middle allows only the positively charged ions to pass through to the cathode, while blocking and forcing the electrons to travel to the cathode via an external circuit or load, creating the electrical energy. When the electrons and ions eventually meet at the cathode, they combine with the oxygen to form water, an environmentally safe by-product..

Collectively, the anode and cathode electrodes and membrane form membrane-electrode assemblies, or MEAs.

“The fuel cell is a small stationery unit that consumes the most common element in the universe (hydrogen) to generate electricity, producing a waste product of water,” says R. Dean Minardi, chief financial officer of Bing Energy.

Until now, one of the limitations to the hydrogen fuel cell — whether it is used to power an automobile or as a stationery unit of backup power — has been cost. It’s typically because of it’s expensive platinum or other precious metals that are used to strip the electrons off hydrogen gas in the anode and reduce oxygen to water in the cathode.

As a result, scientists — including James P. Zheng, Ph.D., a professor in the [Center for Advanced Power Systems](#) at FSU — have been searching for ways to lower the cost of the fuel cell by reducing the amount of platinum it requires or finding alternative catalysts.

The Carbon Nanotube and Buckypaper

Zheng knew that his FSU colleagues, Richard Liang and Ben Wang in FSU’s [High Performance Materials Institute](#), had been working with a new material called buckypaper, made from a unique form of pure carbon. Over lunch with his fellow scientists, they theorized that the properties of buckypaper could provide an excellent material for the MEA in the PEM fuel cell.

Depending on how its atoms are bound together, carbon can take on a variety of forms. Arranged in a tetrahedral lattice, carbon atoms form a diamond. But a single layer of carbon atoms arranged in a honeycomb or hexagonal shape results in graphene. Rolled into a cylindrical shape, graphene becomes a carbon nanotube 50,000 times thinner than a human hair.

Although carbon nanotubes occur naturally, they can be created with a carbon source, such as sugar cane or corn with the help of heat and a catalyst. Carbon nanotubes can then be synthesized into a thin film, stacked and compressed to create buckypaper, a conductive material 250 times stronger than steel yet 10 times lighter.

Zheng and his colleagues decided to hire a postdoctoral student in 2007 to test buckypaper for the fuel cell application. Nine months later, the team had a viable proof of concept.

“The gradient structure of the buckypaper improved gas flow and the effectiveness of the catalysts,” says Zheng, who began working with the [Florida State University Office of Commercialization](#) to start the patenting process.

“There are 50 to 60 patents in the United States on Dr. Zheng’s buckypaper work,” says John Fraser, executive director of the FSU Office of Commercialization. “Dr. Zheng is a super star at FSU, and we have high hopes for him and this technology.”

Initial funding for FSU buckypaper-based fuel cell research came from the U.S. Army and was followed by support from the [FSU Research Foundation Gap Grant Program](#), which provided \$50,000 to help scale the invention for commercialization, and the U.S. Department of Energy.

Startup Company Bing Energy

In 2010, FSU entered into an exclusive licensing deal with Bing Energy, a spinoff company led by Richard Hennek, to create PEM fuel cells with MEAs made with buckypaper. Hennek relocated the company from California to Florida to be closer to Zheng, who serves as technical adviser to the company, and received \$300,000 from the [Florida Institute for the Commercialization of Public Research](#) to help develop the technology.

“FSU’s Office of Commercialization has been extraordinarily helpful,” says Minardi. “We wouldn’t be here if it weren’t for that office.”

At the company’s new Tallahassee headquarters, Bing began its buckypaper-based MEA production.

“We embed platinum in the buckypaper as the anode, but it requires 70 percent less platinum and performs the same [as a fuel cell made without buckypaper],” says Minardi. “The MEA looks like a furnace filter with platinum on the filter fibers to provide a reactive surface.” The large decrease in the amount of platinum that needs to be mined is another environmentally significant improvement of the buckypaper technology.

Each fuel cell requires a number of MEAs stacked together, depending on the amount of energy that needs to be generated. Today there are 15 employees in Tallahassee working to produce 300 MEAs during each eight-hour shift — a number that will soon grow to several thousand per shift when the facility is semi-automated.

Once completed, the MEAs are sent to the company’s second facility in Ragao, China, just outside Shanghai, for final production. Zheng, a native of Shanghai, worked with Chinese authorities to establish an enterprise zone for the factory and a dormitory. Thirty-five employees in Ragao place end caps around the MEAs, affix aluminum hoses and pipe-fittings, and finally, place the unit inside a box cabinet to create the final fuel cell product.

Powering China Telecom’s Cell Towers

The first commercial application of Bing’s fuel cells will be in China, where they will replace lead-acid batteries in isolated cell phone towers owned by [China Telecom](#), an international telecommunications company. The PEM fuel cell will be placed at the foot of each cell tower in a rain-proof metal locker with a 5-foot tall steel cylinder nearby to hold the hydrogen fuel.

“China Telecom needs backup power desperately,” says Minardi. “They have a very unstable grid and the country is trying to ban acid batteries. It’s the same situation in India, which is seeing significant telecom industry growth.”

China Telecom’s off-grid cell phone towers, each with a 3-kilowatt generator, will require the electrical output of 40 hydrogen fuel cells.

The Market for Stationery Fuel Cells

Smaller, lighter, quieter, lower environmental impact, and lower cost are just a few of the advantages Bing Energy says it offers with its new PEM fuel cell.

“There’s a sweet spot in the market for distributing stationery fuel cells to replace existing battery or diesel backup power,” says Minardi.

He says even cell phone towers that are connected to an electrical power grid need backup power when the grid goes down, a common occurrence in developing countries.

“ There are 1.3 million cell towers in China alone, and they all are converting to this technology.

R. Dean Minardi

Minardi says Bing's fuel cell stacks up well against other energy alternatives, such as lead-acid batteries (which are being phased out in China due to environmental waste issues) and diesel-powered generators. While batteries need to be constantly charged, diesel powered generators require a significant amount of fuel and frequent maintenance — and both will last only 18 to 60 months before they will need to be swapped out for new equipment. Conversely, he says Bing's fuel cells have no emissions, fans or pumps and have a 20-year lifecycle.

“The durability of our fuel cell and low platinum usage is being embraced by the market,” he says. “There is a place in the energy world for distributed hydrogen power.”

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