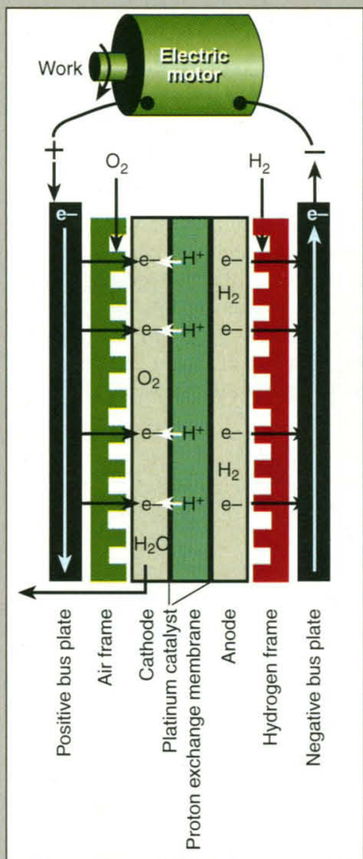
Company Aims to Give Fuel Cells a Little Backbone

ELKTON, MARYLAND—The future of electricity generation might be housed in an unassuming green box perched on a table in a conference room here at W. L. Gore and Associates. It may not look like much, but the toaster-sized metal container, which lets out an occasional hiss from the hydrogen gas seeping through its innards, can generate enough power to run a television and a VCR.

The device is a prototype fuel cell that converts bottled hydrogen gas and oxygen from the air into electricity and water. For decades fuel cells have eked out a small but vital niche in the energy world, performing tasks such as powering spacecraft and remote field stations. Now these electrochemical power packs are on the verge of penetrating a mass market, as automakers are gearing up to unveil in the next decade cars equipped with fuel cell engines (see main text). Companies like H Power of Belleville, New Jersey, which built the model on display here with parts from Gore, are hoping to put fuel cell generators into our homes someday—giving us independence from the power grid at very little environmental cost.

But before fuel cell–makers can challenge utility companies for our business, they must first lower the price and ratchet up the power of their devices. A crucial part of the strategy is to improve the membrane that lies at the heart of the machines. "The membrane technology is directly related to what power you can get out," says Tom Zawodzinski, a fuel cell researcher at Los Alamos National Laboratory in New Mexico.

In hydrogen fuel cells, membrane assemblies do the heavy lifting, serving as catalyst, electrode, and chemical separator. As hydrogen gas streams into a fuel cell, it meets a catalytic electrode, usually platinum or some other precious metal. The catalyst strips electrons from the hydrogen atoms, leaving only hydrogen ions—protons—behind. These protons diffuse through a barrier called a proton exchange membrane, while the electrons flow out of the fuel cell, via the electrode, to an external circuit. Once the protons reach the other side of the membrane, they huddle around the other electrode, hungry for electrons that would allow them to react with oxygen to make water. The chemical reaction pulls electrons through the circuit, a flow of electricity that supplies power for appliances (see diagram).



In the ion's den. In this PEM fuel cell, a catalyst strips electrons from hydrogen; the resulting protons diffuse through a membrane and help draw the electrons through a circuit to perform work.

The challenge for engineers is to make membranes impermeable to hydrogen and oxygen, while conducting protons efficiently. An early breakthrough came in the 1960s, when DuPont created fluoropolymers (like Teflon, which had been developed during the 1940s) that happened to have just the right chemical properties to work in fuel cells. One polymer, comprised of sulfonic acid groups strung on a fluoropolymer backbone, turned out to be an excellent proton exchange medium. This material, sold under the trade name Nafion, is well suited for fuel cells, because protons are happiest when swimming among the highly acidic sulfonic groups. "It is basically a plastic version of battery acid," says Zawodzinski. One drawback, however, is that the Nafion membrane must be saturated with water to work well. And because soggy objects usually swell and become weak, Nafion membranes end up thick. That's not good, because any membrane hinders the flow of protons. So the challenge for fuel cell designers was to make the thinnest possible membranes.

Five years ago, Jeff Kolde and Bamdad Bahar, two chemical engineers at Gore, realized they could make a better membrane if they combined a proton-conducting material like Nafion with the company's well-known Gore-Tex membrane, a water-repelling mesh, permeable to gases, that's used in everything from mountaineering parkas to synthetic blood vessels. When the duo first described their idea to fuel cell experts, Bahar recalls, "people told us we were crazy." Gore-Tex membrane is an insulator, skeptics said, so how could the material turn an ion-exchange membrane into a better conductor? Yet the same polymer structure that gives Gore-Tex membrane its strength and porosity also helps hold the ion exchange membrane together, like reinforcing bars in a concrete wall. By embedding the proton conductor into the open spaces between the rebars, Bahar and Kolde thought they could make a better membrane: one that could absorb water without becoming soggy. Their colleagues encouraged the duo to give it a try in a small trailer behind the company's building.

The early results were promising. Kolde and Bahar found they could make the fuel cell membranes extremely thin, which increased the flow of protons through the membrane as much as 10 times. When they sent the membrane to a fuel cell designer in late 1994, they got a surprising call a few days later. "He said he'd melted the wires on his fuel cell," Bahar says. Delighted with the power output—and with happy customers—Bahar and Kolde have since moved from the trailer to a new state-of-the-art building, where they are part of a global fuel cell membrane team.

Gore and other companies have plenty of challenges left to solve before fuel cells can compete on the market. One is making the cells less choosy about their diet. "Fuel cells like every fuel, as long as it's hydrogen," jokes Zawodzinski. To use gasoline or methanol, a device called a "reformer" must break the hydrocarbons down to hydrogen. Reformers, however, tend to produce traces of carbon monoxide, which locks up active sites on the metal catalysts. "Carbon monoxide poisoning can be alleviated by running at higher temperature," which drives off the CO, says Zawodzinski. But the necessary heat would evaporate the water in a fuel cell. Either cells must be run under high pressure to keep the water from boiling, or a novel nonaqueous membrane must be developed.

Technical hurdles are one thing, says Zawodzinski: "The showstopper is cost." According to studies by the consulting firm of Arthur D. Little Inc. in Cambridge, Massachusetts, fuel cells, which now run about $3000 per kilowatt, won't penetrate power markets until they come down to about $1500 per kilowatt. Until Gore and other companies can slice into that differential, it may be a while before you can watch your favorite soap opera even when the rest of your neighborhood is plunged into darkness by a power outage.

—DAVID VOSS

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