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Improving Fuel Cells for Cars

A new method for making ultrathin materials could lead to better fuel cells.

By Kevin Bullis

A new method for making materials just a few atoms thick could pave the way to automotive fuel cells that use readily available fuels instead of hydrogen, which is difficult to produce and store. The new fuel cells would be smaller, lower-temperature versions of solid-oxide fuel cells (SOFCs), which were originally developed for use in stationary applications such as power plants. Startup Sienergy Systems (http://www.sienergysystems.com/) , based in Quincy, MA, was founded to bring the fuel cells to market. Last week the company announced half a million dollars in early-stage funding.

The synthesis method, developed by Harvard professor of materials science Shriram Ramanathan, produces high-quality solid-oxide electrolytes that are about 25 nanometers thick--about a thousandth the thickness of the electrolytes used in conventional SOFCs. The thinner electrolyte allows the fuel cells to run at about 300 ºC--much cooler than the 800 to 1,000 degrees typical for SOFCs. The lower temperatures could lead to lower costs and make it much easier to package the fuel cells for use in vehicles and portable generators.

Several major automakers are developing fuel cells, but they're proton-exchange-membrane fuel cells that can run only on hydrogen, says Harry Tuller, a professor of ceramics and electronic materials at MIT who is also developing lower-temperature SOFCs. Hydrogen has a number of drawbacks. It must be derived from sources such as natural gas or water, a process that consumes energy and typically releases carbon dioxide. What's more, it's a diffuse gas that's difficult to store, and there isn't an extensive infrastructure for delivering it.

Solid-oxide fuel cells could offer a better alternative. They can run on hydrogen but also on natural gas, diesel, and other liquid fuels. Running directly on natural gas cuts out the energy-wasting middle steps of producing and compressing hydrogen for distribution and storage.

The main problem with solid-oxide fuel cells has been that they operate at extremely high temperatures that require expensive materials, make startup times slow, and make the cells difficult to package for portable applications. That has led a growing number of researchers worldwide to investigate ways to lower operating temperatures. Some, such as Tuller and Fritz Prinz, a mechanical-engineering and materials-science professor at Stanford University, have demonstrated prototype SOFCs that operate at only a few hundred ºC. An MIT spinoff called Lilliputian Systems is also developing SOFCs for portable applications, although it's not clear whether the company has produced a low-temperature cell. Ramanathan, who has also demonstrated basic fuel cells that operate between 300 and 500 degrees, hopes that his method for synthesizing oxides could lead to cells that work well at temperatures as low as 200 degrees.

The best thing about Ramanathan's method may be that it works at room temperature. Typically, making oxides with the sort of crystal structure that yields high performance also requires high temperatures. Ramanathan's method essentially uses the energy in ultraviolet photons to replace thermal energy: the ultraviolet light creates oxygen radicals that react with metals to form oxides. The low operating temperature permits better control over the material's structure and can improve the interfaces between layers in a fuel cell, such as the junction where the electrolyte meets electrodes, says Evgeni Gusev, director of research and development at Qualcomm MEMS, in San Jose, CA. "Usually you have to apply high temperatures," he says, "which create a lot of damage."

That damage can include the interpenetration of neighboring materials, whose electronic properties change as a consequence. Contaminants at interfaces can also make a big difference, Tuller says. In his work, he has shown that good interfaces can make fuel-cell performance a thousand times better.

So far, Ramanathan has assembled only rudimentary fuel cells to demonstrate the feasibility of his methods. Over the next year, he will develop prototypes made of stacks of fuel cells, which will be able to produce more power. Having demonstrated that he can make high-quality electrolytes, he's now focusing on using his technique to make high-quality oxides for electrode materials. Another challenge, for Ramanathan as well as for other researchers, is combining improved materials into a complete package that produces large enough amounts of power.
