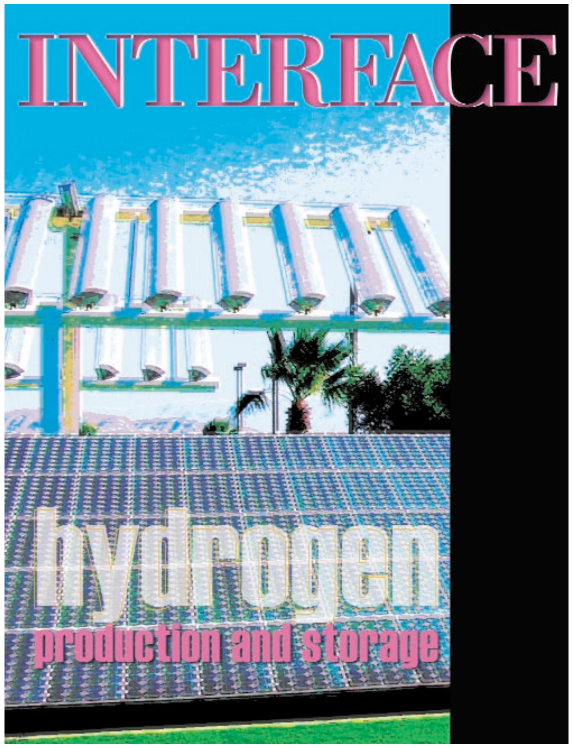
Electrochemistry and the Hydrogen Economy

by J. A. Turner

Hydrogen is a hot topic in our society today. Issues relating to hydrogen run the gauntlet from energy, economics, and the environment to foreign and domestic policy. The vision of the widespread production, storage, distribution, and use of hydrogen as an energy carrier is often termed, "the hydrogen economy." This vision can offer energy security for the nation, provide enormous environmental benefits for our cities and towns, and increase the reliability, "dispatchability," and quality of our electric power system. Hydrogen can provide the energy storage for intermittent renewables like photovoltaics and wind, as well as be utilized as a transportation fuel.



Hydrogen also may provide the link between the fossil energy we use today and the renewable energy we will use tomorrow. Today, hydrogen is produced mainly through steam-methane reforming. In this process, natural gas (methane) is reacted with steam, ultimately producing CO_2 and hydrogen. The hydrogen is then used to make ammonia for fertilizer, in refineries to make reformulated gasolines, and in the chemical, food, and metals industry. Worldwide, approximately 40 million tons of hydrogen are produced and used each year, with the U.S. accounting for about 9 million tons of that. Hydrogen can also be made from coal in a gasification process where the coal is reacted with steam. Because the United States has large reserves of coal, this is being seriously considered for future hydrogen production. In a carbon-constrained world though, this is likely to require carbon sequestration, a technology that still has many problems to solve.

Three articles in this issue of *Interface* cover only a few of the areas of active research relating to a future hydrogen economy.

In the future, the ideal hydrogen production process will use energy from renewable resources such as wind or sunlight, to split water into hydrogen and oxygen via electrolysis. The first article entitled, "Hydrogen Economy Based on Renewable Energy Resources" — contributed by Mark Williams, *Interface's* editor "Raj," and this writer — discusses some of the approaches that can be taken. The vision and benefits of the hydrogen economy are presented as well as the challenges in producing hydrogen from these resources. Commercial technology, particularly electrolyzers, now exists that can implement part of this system, but much remains to be done to realize the full potential of hydrogen produced by renewables. Since 1943, the Industrial Electrolysis and Electrochemical Engineering (IE&EE) Division of ECS has been contributing to this area.

In the second article, "Hydrogen Production from Fossil Fuels with High Temperature Ion Conducting Ceramics," Eric Wachsman and Mark Williams discuss significant issues relating to ceramic membranes and the technologies where they could be applied. This is an area where electrochemistry can combine with conventional catalytic processes to greatly improve chemical yields and to generate electricity with much higher efficiencies than current technologies can achieve. Whether for purely ionic transport, as needed in solid oxide fuel cell applications, or for mixed electronic-ionic transport in separations applications, these ceramic membranes would not only contribute to the efficient utilization of our large fossil fuel resources as a chemical feed stock for hydrogen and electricity generation, but also allow for subsequent CO_2 capture and sequestration. The High Temperature Materials Division of ECS has been contributing to this area since 1921, and Mark is one of the members-at-large in this Division.

Fuel cell vehicles represent a holy grail of a clean, zero-emission transportation system. However, storing hydrogen on-board these vehicles presents a significant challenge. For specifications and performance commensurate to what we have today, these vehicles must be able to store at least 5 kg of hydrogen and be filled in 5 minutes or less. While advanced carbon fiber tanks can store hydrogen safely at pressures up to 750 bar, over 10% of the energy in the hydrogen is lost during the compression step. Lower-pressure systems for hydrogen storage would significantly advance the commercialization potential fuel cell vehicles and, in turn, the development of an infrastructure for hydrogen generation and distribution.

In the third article, "Hydrogen Storage and Its Limitations," Giselle Sandi covers some of the key technological barriers that face hydrogen as a fuel for transportation. Nanostructured materials continue to be a fruitful area for exploration, particularly with various forms of carbon. Also featured prominently is the area of theory and computation. Advanced computing technologies have enabled theorists to make even greater contributions toward predicting material properties and enhanced understanding into the electronic and atomistic processes that govern chemical reactions. Developing the electronic materials and materials processing techniques that make advanced computing possible is an area in which the Electronics Division of ECS has been contributing since its inception in 1931.

The research budgets for hydrogen and fuel cell related R&D are growing, with the U.S. Department of Energy (DOE) funding for hydrogen and fuel cells more than doubling in the last three years. The recent call for proposals from the DOE Office of Science Hydrogen Fuel Initiative represents the start of a new expanded program with many opportunities for the scientific community. Electrochemists are at the forefront of this technology, with their fingerprints on everything from electrolyzers to batteries to fuel cells. Now is a great time to be an electrochemist. ■

About the Author

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