Fuel cells and hydrogen energy
Working towards a clean hydrogen energy society

Fuel cells

Fuel cells present a number of advantages, advantages which include the fact that even compact fuel cells provide high power generation efficiencies, that it is possible to attain even higher levels of usage efficiency when used in conjunction with heat, and that in the ideal case they use only hydrogen as fuel and produce no carbon dioxide emissions, and they are accordingly viewed as a highly promising technology for ensuring the effective use of energy and helping to prevent global warming.

Of the many different types of fuel cells which exist, polymer electrolyte fuel cells (PEFC) can be produced in compact form because they use fluorinated polymer films as electrolytes for carrying hydrogen ions and use electrocatalysis to make it possible for them to be operated at relatively low temperatures of about 80°C, and they are viewed as a promising type of fuel cell which can be used in a wide variety of applications including automobiles stationary power systems in homes and officies or portable devices. Long term durability and system cost are the issues to be addressed for the real use of PEFC. In the AIST, research on the cause of degradation of PEFC and searching for new inexpensive and high performance electrolytes and catalysts are being performed mainly in Kansai Center. In order to use these fuel cells in high-added-value portable devices, research and development work is also being performed mobile power generation systems which would consist of a combination of compact fuel cells, fuel storage systems, and compact, high-performance secondary batteries.

Solid oxide fuel cells (SOFC) operate at high temperatures near 1000°C and use ceramics made from yttria stabilized zirconia or other oxygen-ion conducting materials as electrolyte, and in addition to providing high power generation efficiencies of over 50 percent, they provide a number of other advantages such as that their design is simple and robust and that fuel can be easily converted to hydrogen within the high-temperature fuel cell. Hybrid systems where the high-temperature exhaust gas from the SOFC is used to drive a power generator provide the highest overall efficiency in the power generation systems. Over the past few years, a number of prototype SOFC systems with capacities of several hundreds of kilowatts have been created, and work has also been done to develop systems which shorter startup times or more compact systems with operating temperature of under 700°C. At AIST, in addition to developing technologies for accurately evaluating the performance of SOFC systems nearly ready for the market, we are also doing research on low-operating-temperature materials for compact SOFC systems on methods to use a wider range of fuels and on hybrid systems. Figure 1 shows a view of a compact, low-temperature (tubular) SOFC together with the electrode pattern used in performing a detailed analysis of the behavior of oxygen ions.

Hydrogen

Just as with electric power, hydrogen is a secondary energy source which can be used to store and transport energy, and it has many advantages like the fact that it provides high energy densities per units mass, that it produces only water vapor when burned, and that the electrolysis of water or fuel cells may be used to both convert hydrogen to electric power or do the reverse. Fuel cells are one of the most important possible uses for hydrogen. It is expected that the amount of hydrogen which is required to the government targets for the introduction of PEFC systems by 2010 (targets calling for their use in 50 thousand fuel-cell automobiles and 2.1 gigawatts of capacity in fixed power generation systems) can be met by using the hydrogen produced as a byproduct in the making of steel and other processes, and the important issues which must first be addressed are finding ways of storing, transfering, and supplying hydrogen at high densities. While the first generation of fuel-cell automobiles will be equipped with high-pressure gas tanks (with pressures from 30 to 70 MPa), there is a need to develop materials which would be able to hold large amounts of hydrogen within a small volume, and current targets call for the development of materials capable of holding from 5 to 6 percent of their own weight in hydrogen. To achieve this goal, a great deal of work is being performed at AIST. Completely new types of materials are being produced by using many different types of methods, and analyses of the nanoscale structures of these materials are being performed. Figure 2 shows an alloy with a body-centered cubic lattice structure which achieves high levels of hydrogen storage together with a view of a fuel-cell automobile built using this material.

In order to reach the target of getting 5 million fuel cell automobiles onto the road by 2020 and achieve the long term objective of creating a hydrogen-energy-based society using larger quantities of hydrogen, it will be necessary to ensure safety in the use of hydrogen, and to find ways of producing large amounts of hydrogen from renewable energy resources. AIST is also conducting research on these subjects.

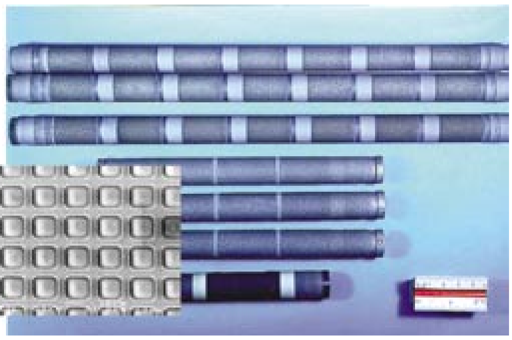

Fig. 1 SOFC (tubular type) developed by AIST, and electrode pattern on planar SOFC for ion dynamics analysis

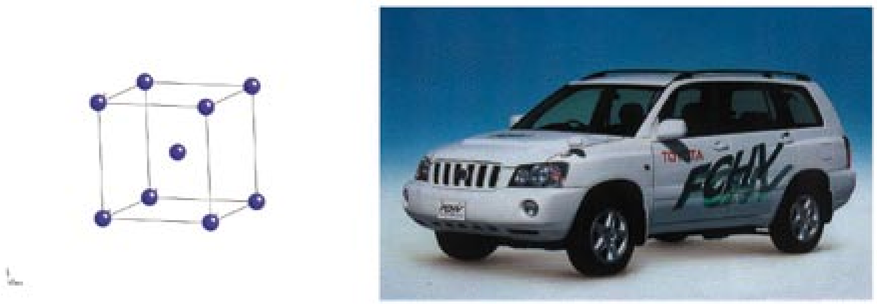

Fig. 2 An alloy with body centered cubic structure which achieved high density hydrogen storage, and fuel cell vehicle with it