

## **Solid Oxide Fuel Cells (SOFCs) – Highly Efficient Future Energy Converters**

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“Energy is the very lifeblood of today’s society and economy”, has been stated by Loyola de Palacio, Vice President of the European Commission and Commissioner for Transport and Energy, and Philippe Busquin, Commissioner for Research, in the special report *Hydrogen Energy and Fuel Cells – a Vision of Our Future* of the European Commission. The worldwide demand for energy is steadily growing very rapidly, and an increase in power generation in the next decades will be based on a well balanced distribution between fossil, nuclear and renewable resources.

The exploitation of fossil energy carriers will - without doubt - strike limits. Moreover, millions of tons of greenhouse gases and other pollutants are emitted and cause ecological problems, and the amount will even increase in the future. Therefore, power generation has to be more efficient.

Fuel cells have a significantly higher efficiency and have lower emissions compared to conventional energy conversion devices based on combustion. Fuel cells are “direct” converters of chemical energy into electrical energy, without the intermediate steps of generating heat and mechanical energy as necessary in conventional heat engines. This means that their efficiency is not limited by the Carnot barrier.

There are many types of fuel cells, which mainly differ in their temperature of operation. Among them, polymer electrolyte membrane (PEM) fuel cells operate at practically ambient temperature conditions, and there are already niche markets where the PEM fuel cell technology has been established. Nevertheless, the cost per Watt of power is the limiting factor, because the membrane and the electrode materials are expensive and the power density still needs to be increased. Ceramic high-temperature fuel cells or solid oxide fuel cells (SOFCs) operate at the highest temperatures, around 700 – 1000°C. These temperatures are high enough to convert oxygen and hydrogen into water and energy without any special catalyst for the electrochemical reaction. Moreover, carbon monoxide (CO) is converted to carbon dioxide (CO<sub>2</sub>) and desorbed from the hot surface of the SOFC electrodes. Thus, carbon monoxide is not a poison for the SOFC. This is especially advantageous when using, for example, methane instead of hydrogen as a fuel: due to the catalytic activity of the SOFC anode methane is reformed to CO (or to CO<sub>2</sub> in the case of a water gas shift reaction or an electrochemical oxidation) and hydrogen.

The developments during the past years proved that - from the technical point of view - fuel cells are very promising candidates for future energy conversion. However, the system reliability is the most crucial parameter for any SOFC application. Reliability covers lifetime (i.e. low degradation), robustness against thermal cycling as well as emergency shut-downs, trouble and operator errors. The second key parameter is the cost (per kW) of the system in order to come to the market.

By building smaller or larger units, the power can be easily adapted to the demand. This aspect makes them highly feasible for larger stationary power plants, for decentralized power

generation as well as for mobile applications. They can also play an important role in transition strategies from fossil feedstock to renewable energy carriers and to hydrogen, also encompassing future biomass-derived, carbon-based fuels.

Many achievements of today are based on the research and development of novel materials, which is also true for fuel cells. In the recent years, Indian and German researchers have made common research on materials for fuel cells at the same eye level (e.g. Al Daroukh 2003; Arul Raj 2004; Zahid 2006; Basu 2004).

A future common research and development can help to establish the same scientific and technical level of knowledge on fuel cells in Germany as well as in India. This enables Germany and India to decide independently which detailed technology concept might be suitable for which country, and how to cooperate best for gaining as many synergies as possible.

#### **References:**

Al Daroukh, M.\*; Vashook, V. V.\*; Ullmann, H.\*; Tietz, F.; Arul Raj, I.\* (2003): Oxides of the  $AMO_3$  and  $A_2MO_4$ -type: structural stability, electrical conductivity and thermal expansion. In: *Solid State Ionics*. vol. 158, pp. 141-150.

Arul Raj, I.\*; Nesaraj, A. S.\*; Kumar, M.\*; Tietz, F.; Buchkremer, H. P.; Stöver, D. (2004): On the Suitability of  $La_{0.60}Sr_{0.40}Co_{0.20}Fe_{0.80}O_3$  Cathode for the Intermediate Temperature Solid Oxide Fuel Cell (ITSOFC). In: *Journal of New Materials for Electrochemical Systems*. vol. 7, pp. 145-151.

Zahid, M.; Arul Raj, I.\*; Fischer, E. V.; Tietz, F.; Serra Alfaro, J. M. (2006): Synthesis and investigations on the stability of  $La_{0.8}Sr_{0.2}CuO_{3-\delta}$  at high temperatures. In: *Solid State Ionics*. vol. 177, pp. 3205-3210.

Basu, R.N.; Tietz, F.; Wessel, E.; Buchkremer, H.P.; Stöver, D. (2004): Microstructure and electrical conductivity of  $LaNi_{0.6}Fe_{0.4}O_3$  prepared by combustion synthesis routes. In: *Materials Research Bulletin*. vol. 39, pp. 1335-1345.