Objectives

It is generally accepted that the global demand for energy will dramatically rise in the future. Fuel cells are promising as efficient, non-polluting power sources that produce little noise and have no moving parts. The main problem is the high cost of manufacturing the devices, which has largely limited them to a handful of exotic applications.

The objective of the present project is the development and construction of Advanced Polymeric Fuel Cells, which will be able to operate under H₂ and/or methanol fuels. High thermodynamic efficiencies and power densities of the order of 0.5 W/cm² as well as significantly reduced manufacturing cost of the membrane electrode assembly are the main aims of this project. The accomplishment of the above is feasible either by the optimization of both the electrocatalytic performance of the electrode/electrolyte interface or the development of advanced high temperature (150°C-200°C) polymer electrolytes with high ionic conductivity.

Challenges

The ideal fuel for the efficient operation of fuel cells is H₂, which exists, in high quantities in nature as the main constituent of water and organic substances. Conventional Polymer Electrolyte Membrane Fuel Cells (PEMFC) using Pt as a catalyst suffer irreversible damage of the electrocatalytic activity if CO (even at 100ppm) is introduced with the fuel gas. Therefore, the fuel processor should be able to supply the fuel cell with CO free H₂ and so high complexity and instability characterize the system.

In addition, overpotential losses in low temperature fuel cells are due to the activation overpotential developed on the electrode/electrolyte interface. These losses are essentially related to the electrocatalytic activity of the electrodes (both anode and cathode), which either oxidize H₂ or methanol or reduce O₂. This is a severe limitation for the achievement of high thermodynamic efficiency, which for the current state of the art fuel cells lies around 35%. Thus there is great room for improvement of the polarization properties of the anode and mainly the cathode materials.

In order to overcome the aforementioned constraints: (i) new more active and cost effective electrode materials which can be tolerant to CO poisoning even at CO concentrations 0.5-1% with applications in low temperature fuel cells (70-80°C preferably for mobile applications) and (ii) the use of new generation high temperature cheap polymer electrolyte membranes which will permit the cell operation at temperatures above 150°C will be investigated. This latter medium temperature fuel cell is proposed for stationary applications. However due to the high operating temperature (above 150°C) it is quite tolerant to CO poisoning.

Apart from the improved electrocatalytic activity of the new electrode materials, they are more cost effective compared to the existing expensive Pt based electrodes because of both the cheap constituents of the active electrocatalytic phase and their ultra stable properties and long lifetime. This results in greater durability and higher electrocatalytic activity of the fuel cell.

Besides the expected significant improvement of the PEM fuel cell performance we expect that the cost of the membrane assembly will be significantly reduced since the new membrane is a factor of 10 less expensive than state of the art NAFION®. Furthermore, such medium temperature fuel cells are expected to be more cost efficient than their proposed mobile counterparts due to their higher temperature operation and the anticipated zero water drag coefficient for the membranes which result in more simplified controls.

Project structure

The project consortium consists of nine partners. Technical University of Denmark (DK) has expertise in theoretical design of catalysts. Three research organizations with expertise in synthesis and development of electrocatalysts: Max-Planck-Institut für Kohlenforschung (D), Consejo Superior de Investigaciones Científicas (E) and Institute of Chemical Technology (CZ). The Institute of Chemical Engineering and High Temperature Processes (GR) which is also the coordinator of the project, has a great deal of experience in the study and physicochemical characterization of electrochemical systems and spectrochemical characterization of polymeric materials. University of Patras-Greece (GR) and Slovenian National Institute of Chemistry (SI) are
responsible for the synthesis and development of novel polymeric electrolyte membranes. Finally, two industrial partners De Nora Tecnologie Elettrochimiche S.p.A. (I) and FRIGOGLASS S.A. (GR) will further develop and exploit the results achieved and market the product.

**Expected impact**

The successful completion of the project will allow for the production of fuel cells readily accepted by the market (simplified and more reliable fuel processors, reformate gas with marginal changes of composition, fuel cells characterised by constant performance over thousands of hours, reduced investment, more effective cogeneration in the case of stationary applications but still keeping the intrinsic advantages of the membrane fuel cells, and low maintenance cost). The fuel cell system, developed as a result of the programme, will certainly increase the probability of realising the commercial forecasts for fuel cells based on a number of market surveys. Whereas the ability of the EU Industry to compete successfully in the area of the stack technology is already well established (De Nora, Siemens), the field of catalyst production and electrode manufacturing is just in the very first stage of development. For this reason, the success of this project could play a really decisive role to help EU industry to acquire a position of technical excellence in this dynamic area.

**Progress to date**

During the first year of the project experimental and theoretical studies were focused on pre-selection and preparation of new promising electrocatalysts, which can be used on the anode and cathode side of PEM fuel cells. A number of bi- and tri-metallic catalysts were synthesised, mainly according to theoretical predictions, and are now under investigation. The objective is to evaluate their efficiency in association with already existing and utilised materials. The results are encouraging, although a lot remains to be done, in order to refine processes and optimise results (see Figure 3).

Development and synthesis of new alternative polymer electrolytes, using various methods, are now in progress. Promising polymeric materials have been synthesised and characterised. Additionally, modification of already existing polymer blends is under study aiming to increase their ionic conductivity. Based on the above studies, formation of new polymeric membranes, which after optimisation can be tested in a single fuel cell, is underway. As a final point, the integration of the investigation results, into a single PEM fuel cell construction (see Figure 2) and testing of the assembly under real conditions, is the ultimate goal of the first part of this project.

**INFORMATION**

References: ENK5-CT-2001-00572

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Partners:
- Foundation for Research and Technology Hellas (GR)
- Max-Planck-Institut für Kohlenforschung (D)
- De Nora Tecnologie Elettrochimiche (I)
- Institute of Chemical Technology (CZ)
- Consejo Superior de Investigaciones Cientificas (E)
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