

New Materials for Fuel Cell Systems

A REPORT OF THE FIRST INTERNATIONAL SYMPOSIUM

The first of an intended biennial symposium, The First International Symposium on New Materials for Fuel Cell Systems, was held at the Montréal Bonaventure Hilton, Canada, from 9th to 13th July 1995. The symposium, which was organised by the *Laboratoire d'Électrochimie et de Matériaux Énergétiques*, École Polytechnique de Montréal, concentrates on the material science of fuel cell systems, rather than on applications. As such, all aspects of the fuel cell system, namely catalyst, electrolyte and fuel processing components were dealt with. The meeting attracted some 120 delegates, including a large number of participants from industry.

The keynote address was delivered by A. J. Appleby from Texas A & M University, who discussed "New Materials for Fuel Cell Systems". He stressed the importance of the electrolyte, since it determines the properties required for the other materials in the system. In practice, only a limited choice of materials is available: strong acids, strong aqueous alkalis, molten alkali carbonates and solid oxides.

Appleby pointed out that there are gaps in the operating temperature ranges of fuel cells due to a lack of suitable electrolytes; for example there is a gap between the upper operating temperature of phosphoric acid fuel cells (PAFCs): 210°C, and the lower operating temperature for molten carbonate fuel cell (MCFC): 625°C; and similarly between the upper temperature for the MCFC: 675°C, and the lower temperature for solid oxide fuel cells (SOFCs): 900°C. The temperature windows, in which fuel cells are operated, are set by their performance characteristics at the lower temperature and by material characteristics (stability and resistance to corrosion) at the upper temperature.

Electrolytes

The proton exchange membrane fuel cell (PEMFC) operates at the much reduced temperatures of 60 to 100°C and has excellent performance characteristics; however, the expense

of the membrane itself – presently costing some \$700/m², is a considerable drawback. At present, the membrane component of a PEMFC fuel cell stack accounts for 20 to 30 per cent of the total cost of the materials. Accordingly, there is a considerable incentive to develop other membrane materials which can be prepared by simpler and less expensive chemistry than the currently used perfluorinated sulphonic acid polymers.

This latter point was discussed further by A. E. Steck of Ballard Advanced Materials, Canada, who described the development of ion exchange membranes beginning with the early work done at General Electric in the 1950s, to the perfluorinated membrane materials presently used in PEMFC, which are manufactured by Du Pont (Nafion) and Dow. Although these materials are noted for their stability and good performance, the current cost is prohibitively high. In order for PEMFCs to be commercially viable for the automotive market, the membrane cost will need to be reduced to between \$50/m² and \$150/m². Steck then went on to describe work being done at Ballard on the development of a low-cost membrane. This third generation membrane, BAM3G, appears close to achieving the goals of performance, stability and cost, which are required for commercialisation of PEMFC.

Fuel Processing

As well as the fuel cell stack, the symposium also dealt with aspects of fuel processing. The keynote speakers in this session were R. Kumar and S. Ahmed from the Argonne National Laboratory, U.S.A., who presented work on fuel processing for transportation fuel cell systems. They discussed the various means of producing hydrogen from fossil fuels (primarily methane and methanol) and described the comparative merits of each, using calculations of overall system efficiency. It was concluded that while all fuel processor designs are driven by some performance criteria, transportation applications

using low temperature fuel cells, especially the PEMFC, set the most demanding constraints. In this case the fuel processing is best served by partial oxidation systems as they appear simpler, compact and more responsive.

Catalysts

Carbon supported platinum, usually in combination with one or more other metals for both anode and cathode reactions, remain the materials of choice for new electrocatalysts for low temperature fuel cells. H. A. Gasteiger and P. N. Ross from the Lawrence Berkeley Laboratories, U.S.A., discussed the differences between platinum-ruthenium and platinum-tin alloys for both methanol and carbon monoxide oxidation, using results obtained with bulk metal samples. It was found that while ruthenium can adsorb both carbon monoxide and water, tin can only adsorb water. Thus in catalytic reactions involving carbon monoxide, platinum-tin displays superior activity.

A complementary piece of work was described by J. Stumper, D. Olligs and U. Stimming from the Institut für Energieverfahrenstechnik, Jülich, Germany, in which the optimum surface composition of platinum and ruthenium in platinum-ruthenium alloys for carbon monoxide electro-oxidation was probed using *in-situ* infrared spectroscopy. Only one type of carbon monoxide species was found on platinum-ruthenium surfaces, suggesting that atomic mixing occurs between platinum and ruthenium at the surface.

The use of platinum-ruthenium catalysts in the form of supported materials was discussed further by M. P. Hogarth, P. A. Christensen and A. Hamnett from Newcastle University, who presented encouraging results, discussed elsewhere in this journal on page 173, of a methanol vapour fuelled PEMFC single cell which achieved a power density of 0.2 W/cm².

The addition of tungsten to supported platinum and platinum-ruthenium catalysts was the subject of several presentations. A. R. J. Kucernak, C. J. Barnett, G. T. Burnstein and K. R. Williams, from Cambridge University, showed that the electrodeposition of "WO₃" onto

platinum and platinum-ruthenium catalysts modestly enhanced the methanol oxidation activity. They also showed that the addition of H₄SiW₁₂O₄₀ to the electrolyte improved the methanol oxidation performance of a supported platinum-ruthenium catalyst. It is likely that the adsorption of tungstic acid from solution onto the catalyst was responsible for the enhanced performance.

The chairman of the symposium, O. Savadogo from the École Polytechnique de Montréal, discussed the potential promotion of supported platinum catalysts, used for oxygen reduction, by H₂WO₄ in both PAFCs and PEMFCs. It was found, especially with low platinum loaded catalysts, that the addition of H₂WO₄ gave enhanced oxygen reduction kinetics for PAFC conditions.

The last session of the Symposium was devoted to new catalysts. Of particular interest was the presentation by N. Alonso-Vante from the Hahn-Meitner Institut, Berlin, who discussed novel ruthenium-based materials for oxygen reduction in acid electrolytes; the semiconducting transition metal selenides of general formula, (Ru_{1-x}Mo_x)_ySeO_z (0.02 < x < 0.04; 1 < y < 3; z ≈ 2y). At present, their oxygen reduction activity is somewhat poorer than platinum, but unlike platinum cathode catalysts they have the advantage of being tolerant to the presence of methanol. The operation of Direct Methanol Fuel Cells usually leads to methanol being transported to the cathode through the electrolyte, where cathode depolarisation takes place. A methanol tolerant cathode catalyst would be a significant technological breakthrough. This was examined further during the poster session with Newcastle University describing work on the sulphur analogues of the selenium material.

In view of the importance of material science to improvements in fuel cell technology, this symposium was a welcomed addition to fuel cell and electrochemical related conferences. It is hoped that the planned 2nd Symposium will take place in 1997. Copies of the proceedings of this symposium are available in North America from COOPOLY l'École Polytechnique de Montréal, and in Europe from Technique et Documentation-Lavoisier, Paris. D.A.L., D.T.