References

1 R. L. Fleischer, *J. Mater. Sci.*, 1987, **22**, 2281

2 R. L. Fleischer, in "Proc. Int. Symp. on Intermetallic Compounds," ed. O. Izumi, Japan Inst. Metals, Sendai, 1991, p. 157

3 H. J. Frost and M. F. Ashby, "Deformation Mechanism Maps," Pergamon, Oxford, 1982

4 R. L. Fleischer and R. J. Zabala, *Metall. Trans.*, 1990, **21A**, 1951; *ibid.*, 2709

5 R. L. Fleischer, C. L. Briant, and R. D. Field, *Mater Res. Soc. Symp. Proc.*, 1991, **213**, 463

6 R. L. Fleischer, R. D. Field, K. K. Denike and R. J. Zabala, *Metall. Trans.*, 1990, **21A**, 3063

7 R. L. Fleischer, R. D. Field, and C. L. Briant, *Metall. Trans.*, 1991, **22A**, 129

8 R. L. Fleischer, R. D. Field and C. L. Briant, *Metall. Trans.*, 1991, **22A**, 403

9 R. L. Fleischer, *ISIJ Int.*, 1991, **31**, 1186

10 D. W. McKee and R. L. Fleischer, *Mater. Res. Soc. Symp. Proc.*, 1991, **213**, 969

11 K.Aoki and O.Izumi,*Jpn.Inst.Met.*,1979,**43**,1190

12 R. L. Fleischer, *J. Mater. Sci. Lett.*, 1988, **7**, 525

13 R. M. Waterstrat, L. A. Bendersky, and R. K. Kuentzler, *Mater. Res. Soc., Symp. High-Temp. Ordered Intermetallic Alloys V*, Boston, 1992

Platinum Utilisation in Fuel Cell Electrodes

Due to its ability to provide much higher power densities, the proton exchange membrane fuel cell is the leading fuel cell contender for power generation in both vehicular and stationary applications in the 5–500 kW range. The proton exchange membrane cell operates below 100°C and uses a solid film of immobilised fluorocarbon ion-exchange membrane as electrolyte. This provides a more rugged unit and faster start-up from room temperature than other types of fuel cell. Recent Californian State regulations calling for 2 per cent of all new vehicles to be zero emitting by 1998, the percentage increasing to 10 by 2003, has renewed interest in the development of this clean and efficient power generation system.

A Commercialisation Requirement

One of the major impediments to the wider commercialisation of currently available proton exchange membrane fuel cell technology is the high platinum content of the electrocatalyst used to catalyse the hydrogen oxidation and oxygen reduction reactions. With loadings of around 4.0 mg Pt/cm^2 on each electrode, the platinum cost is over $300/kW. To achieve commercial success catalyst costs may have to be reduced by a factor of around 50, while maintaining the high power outputs.

In conventional fuel cells, relying on the diffusion of the liquid electrolyte into the electrode, it is possible to utilise nearly all the platinum catalyst in the porous electrode to catalyse the electrochemical reactions. Proton exchange membrane cells make use of a solid polymer electrolyte and up to now high platinum utilisation has been difficult to achieve; hence the current prohibitively high loadings of platinum catalyst required.

Two recent publications, one from the Los Alamos National Laboratory (M. S. Wilson and S. Gottesfeld, *J. Electrochem. Soc.*, 1992, **139**, (2), L28–30) and the other from Physical Sciences Incorporated, of Massachusetts (E. J. Taylor, E. B. Anderson and N. R. K. Vilambi, *J. Electrochem. Soc.*, 1992, **139**, (5), L45–46), describe the preparation of new, extremely low platinum loading, high performance proton exchange membrane fuel cell electrodes. The Los Alamos group describe a new "thin film catalyst" in which catalyst layers are cast directly onto the solid electrolyte membrane from inks consisting of carbon supported platinum catalyst mixed with a solubilised form of Du Pont's Nafion ion-exchange membrane. During tests, electrode assemblies with platinum loadings of 0.13 mg/cm^2 gave 2 A/cm^2 at 0.6 V, which is comparable with current state-of-the-art technology. The approach adopted by Physical Sciences Inc. involves preparing a gas diffusion electrode from uncatalysed carbon into which the soluble form of Nafion is impregnated. Finely dispersed platinum particles are then electrodeposited from a commercial platinum plating bath, apparently only into regions of the electrode having both ionic and electronic conductivity. Electrodes containing 0.05 mg Pt/cm^2 generated currents which again are comparable with state-of-the-art technology.

The high performance of these new electrodes with such remarkably low levels of platinum is attributed to better utilisation of the platinum. If these laboratory performances can be realised when scaled-up into practical fuel cell stack systems, they may indeed provide a major breakthrough in the advancement to commercialisation of the proton exchange membrane fuel cell system. At the very least they amply demonstrate the technical feasibility of achieving significant platinum cost reductions. G.A.H.