

International Fuel Cell Workshop

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The first International Fuel Cell Workshop was held at the Tokyo Institute of Technology, Japan, on 16th September 1989. This meeting was supported by The Fuel Cell Committee of the Electrochemical Society of Japan, and the International Society of Electrochemistry. The workshop co-chairmen were Drs. Masahiro Watanabe and Paul Stonehart. Dr. Ken-Ichiro Ota of Yokohama National University, Japan, acted both as workshop secretary and as moderator for the molten carbonate presentations, while the steering group consisted of representatives from various Japanese fuel cell companies.

At this International Fuel Cell Workshop, emphasis was placed only on technical aspects of the various fuel cell technologies actively under development worldwide, leaving business, marketing and strategy discussions to other fuel cell meetings, such as the Fuel Cell Seminars held in the U.S.A. Due to the limited time available, only problems and solutions relating to the electrochemistry and fuel cell stacks were addressed, leaving the technicalities of fuel processing and power conditioning to be considered at another time and place.

To encourage an exchange of views and to allow newer workers to meet established practitioners of fuel cell technologies, attendance was limited to 130 people actively involved in the furtherance of fuel cell technologies.

The published Proceedings for the meeting also differed from the usual formats, in that each of the speakers was asked to provide only a single page giving the title, authors and affiliations, and then a detailed extended abstract. In addition, every slide or overhead projection used was reproduced in the Proceedings, thus members of the audience had a full and complete record prior to the presentations, and could therefore annotate their copies as the meeting progressed.

Following the chairmen's introductions, two

overview speakers, Yoshiki Kurihara of the Moonlight Project Promotion Office (MITI) Japan, and Graham Hagey of the U.S. Department of Energy, outlined their respective national programmes. These addresses considered the strategies for integrating government funding of these technologies with the private sector. Existing and projected funding levels were defined, for each of the technologies, as was industrial support; the aim being to establish an active fuel cell industry which could satisfy the various national needs for electric energy production. In addition, estimates were placed on the status of the relevant technologies, as viewed by these government agencies.

Phosphoric Acid Fuel Cells

The first presentation concerning phosphoric acid fuel cell (PAFC) technology was given by Dr. Hansraj C. Maru from the Energy Research Corporation. Their fuel cell design operates under atmospheric pressure at a temperature of 200°C, with a demonstrated lifetime of 30,000 hours and a decay rate of 3 mV/1000 hours. This can be compared to a pressurised stack operated by Westinghouse Corp., which has a 16,000 hours life and a decay rate of 7-8 mV/1000 hours. The goal for the decay rate of the pressurised stack is

4mV/1000 hours. Principal concerns are improvements in catalyst support stability, by substitution of more stable carbons; understanding and control of localised corrosion of the bipolar carbon plates; and improved electrolyte management, where it is seen that periodic additions of electrolyte reduce the voltage decay rate. It is clear that electrolyte starvation in the electrodes is a significant cause of the observed cell decay.

The Johnson Matthey cathode alloy development programme was discussed by Lindsay Keck. A large number of binary and ternary metal alloy combinations of the first row transition elements with platinum were examined, but without specifics as to the exact compositions. Although there was a significant scatter in the performances of these catalysts for oxygen reduction, it was felt that all of the elemental combinations were equivalent in performance, but reproducibly better than platinum alone, although it was not divulged which alloys were preferred by Johnson Matthey. The view was expressed that the alloys had not only demonstrably higher performance than platinum, but also greater stabilities against dissolution or corrosion.

Speaking for Fuji Electric Corporate Research and Development Ltd., Dr. Masahiro Sakurai outlined the critical aspects of reducing fuel cell costs by improving the power density through lowering the component count, improving cell performance and lifetime by reducing both sintering and flooding of the electrodes, and increasing the reliability. He presented a detailed evaluation of all of these critical factors, and made the point that only by close collaboration and supportive interaction between the component makers and the suppliers of catalysts and carbon materials, will rapid progress be made to solve the technical problems. Most usefully, the PAFC power plants tested in Japan were listed.

Sanyo Electric Co. Ltd., was represented by Dr. Masahiro Ide, who discussed the key technologies relating to their air-cooled PAFC. The status requires high activity cathode electrocatalysts, with low internal resistance in the

cell and uniform temperature distribution. It is important to have long life with simple control systems and a small component count. For small units, 5 kW, methanol is a suitable fuel. With a 220 W demonstration unit, co-generation is important to improve the all round economics.

Dr. Michael B. Cutlip from the University of Connecticut, U.S.A., was the last speaker to talk on PAFC. He gave a dramatic presentation of his theoretical modelling programme which is used to evaluate all diffusion and kinetic losses in the porous PTFE bonded fuel cell cathode under real operating conditions. It was shown that exact agreement was obtained with the experimental cathode performance curves using the computer modelling programme with six independent variables. Significant losses were due to gas-phase diffusion in the porous carbon backing paper—for electrode structures with low gas-flow rates (or high gas-utilisations); but at high gas-flow rates the major losses in performance were due to ionic conductivity within the electrode structures. Similar diagnoses were made for anodes using various inlet and outlet gas mixtures; and finally a model of the total cell stack was shown, demonstrating an ability to predict optimum catalyst partitioning between the anode and cathode electrodes in the stack to achieve maximum performance.

Molten Carbonate Fuel Cells

Presentations on molten carbonate fuel cells (MCFC) were led by Dr. Len Marianowski from the Institute of Gas Technology in Chicago. In his presentation, he showed that feed of the gas to the fuel cell stack was important, as was the gas distribution to the individual cells. The approach used was to develop an internal manifold system to provide uniformity of gas distribution and minimise thermal gradients, especially for use with a coal derived feedstock. Most importantly, additions of carbonate electrolyte must be considered, and the approach taken by the Institute of Gas Technology eliminates carbonate pumping and transfer in the manifold gasket, and also

matching and mating of the gas manifolds due to stack height changes during thermal cycling.

An estimation of the lifetime-limiting factors for the MCFC were presented by Dr. Toshiaki Murahashi of the Central Research Laboratory, Mitsubishi Electric Corp. He described lifetime experience of 4000 hours in 1988, and observations that nickel oxide (cathode catalyst) dissolution, electrolyte migration, and electrolyte losses were significant problems that needed to be overcome. Dissolution of the nickel oxide produces nickel ions in solution, which are reduced to nickel dendrites and precipitate in the matrix close to the anode. Over time, this produces an electrical shorting of the cell which gives rise to loss of voltage and an increase in carbon dioxide content in the anode exhaust. Electrolyte migration produces flooding in the electrode structure at the negative end of the cell stack.

The presentation of MCFC status for Hitachi Ltd., was given by Dr. Keizou Ohtsuka. At the start of his talk he emphasised the status of scaling up the electrodes and cell sizes from 3600 cm² electrode sizes in 10 kW stacks containing 32 cells, to 10,000 cm² electrodes in 100 kW stacks. It is anticipated that the large size electrodes will be incorporated into 1000 kW stacks in the 1992–1995 time frame. Anode sintering is identified as a lifetime-limiting problem, and the additions of magnesium oxide to the nickel anode retards sintering and densification over 8000 hours on test. In order to reduce corrosive dissolution of the matrix, additions of aluminium and yttrium are used.

The concluding review of MCFC status was given by Dr. Minoru Hosaka of Ishikawajima-Harima Heavy Industries. An impressive display was given for the preparation of large size electrodes, cell components and related production technologies to go well beyond 10,000 cm² cell sizes. At the 10,000 cm² cell size the average cell voltage over 2000 hours was 0.703 V at 150 mA/cm², producing 9.5 kW from a 9 cell stack at 50 per cent fuel utilisation. This was despite one low performing cell in the stack, removal of which improved the average stack voltage to 0.74 V. Tape casting for the

matrix was shown for 100 cm x 2000 cm sheets with extremely small thickness deviation of not more than ± 25 micrometres over the whole sheet. This is important, so that uniform temperature distribution and reaction rate across the cell are achieved. Electrodes are manufactured and sintered in sizes up to 100 cm x 200 cm. Automatic welding of the cell hardware is also provided. Problem areas are maintenance of close tolerances for the pore distributions of the electrodes and matrices, quality control of thicknesses of the cell components, control of the temperature distributions in the cell, and prevention of gas cross-leaks in the cells due to matrix tile cracking.

Solid Oxide Fuel Cells

Future solid oxide fuel cell (SOFC) research plans were presented by Dr. Yoshihiro Ohno from the Japanese Government's Electrical Technical Laboratory in Ibaraki. Cell component fabrication is carried out by either acetylene flame spraying for the electrodes (LaCoO₃ and NiO), or plasma spraying for the solid oxide electrolyte (yttria stabilised zirconia). Gas permeation is identified as a critical problem, since the electrodes require large sized powders for good gas permeation, but the electrolyte requires fine powders for densification. In addition to the problems of gas permeation, temperature cycling of the cells requires good matches for the coefficients of linear expansion for all the components to prevent thermal cracking.

Solid Polymer Electrolyte Fuel Cells

Recent advances in solid polymer electrolyte fuel cells (SPEFC) were described by Dr. Supramaniam Srinivasan of Texas A & M University. In particular, he addressed the progress that had been made in reducing the platinum metal loading at the electrodes. SPEFCs are capable of high current densities with pure hydrogen as the fuel, but due to the temperature limitations of the polymer electrolyte, the cells are not able to operate above

80°C (atmospheric) or 95°C (4–5 atmospheres) without drying out the membrane. This means that noble metal catalyst poisons, such as hydrogen sulphide and carbon monoxide, cannot be tolerated at any level. With pure hydrogen, however, the reaction rate for dissociation of the hydrogen molecule on platinum is so high that very little platinum is required, and electrodes can be formed with the platinum catalyst close to the SPE surface. Improvements in the conductivity and water retention of the SPE are produced by using the lower equivalent weight (more sulphonic acid groups per polymer molecule) Dow membrane, rather than the DuPont Nafion membrane. By identifying problems and applying various solutions, it is possible to reach a cell potential of 0.62 V at 2000 mA/cm² at 95°C and 5 atmospheres pressure with pure hydrogen and oxygen.

Alkaline Fuel Cells

The final speaker of the meeting was Dr. Pehr Björnbohm from the Royal Institute of Technology, Sweden, who described fundamental systems and technology results relating to alkaline fuel cells (AFC). Here, comparison of system studies for alkaline fuel cells

with the carbon dioxide rejecting electrolyte systems of PAFC, MCFC and SOFC indicate that AFCs may be cost competitive, even after the cost of carbon dioxide removal. Fundamental studies were done of the individual electrode and cell operations, separating the various ohmic and diffusional characteristics which can then lead to efficient operation.

It was unfortunate that the date of this meeting coincided with that of the Grove Fuel Cell Symposium in London, England (*Platinum Metals Rev.*, 1989, 33, (4), 169–177) effectively excluding many possible attendees from Europe, while retaining many prominent fuel cell personalities in Japan. Nonetheless this first International Fuel Cell Workshop represented a powerful demonstration of the state-of-the-art for fuel cell technology.

The Proceedings of the Workshop have been published, and are available from the organising committee, First International Fuel Cell Workshop, c/o Laboratory for Electrocatalysis for Fuel Cells, Faculty of Engineering, Yamanashi University, Takeda 4–3, Kofu 400, Japan; or from Stonehart Associates Inc., PO Box 1220, Madison, CT 06443, U.S.A.; price U.S.\$75.00.

A Novel Device for Energy Conversion

News of an interesting new fuel cell concept, using thin-film devices for energy conversion, was presented at the Grove Anniversary Fuel Cell Symposium by Dr. C. K. Dyer of Bell Communications Research (1), and further details have since been published (2, 3). The devices consist of two platinum electrodes deposited on either side of very thin (<50 μm) gas permeable and ion conducting membranes.

One electrode in the fuel cell is deposited on an impermeable support, such as quartz. The membrane separator is applied, and an upper porous electrode is then laid over it. When this upper electrode is exposed to hydrogen and oxygen or air mixtures, a potential of up to one volt is observed between the electrodes, and currents of 2 to 3 mA/cm² may be drawn.

Lower performances are achieved using electrode pairs of palladium/platinum, palladium/palladium and platinum/nickel, with open circuit voltages of 740 mV, 450 mV and 600 mV,

respectively. Significantly, using methanol vapour as a fuel in pure oxygen, up to 640 mV can be obtained at atmospheric temperature and pressure, with platinum electrodes.

Although specific power levels are relatively low (1 to 5 mW/cm²), each assembly is extremely thin, and hence power densities of 100 W/kg of fuel cell are presently obtainable, and 1000 W/kg appears possible.

The author foresees simply constructed, inexpensive fuel cells, operating on mixed fuel/oxidant gases fulfilling a range of functions from replacing high-use batteries, to new applications in information processing.

D.S.C.

References

- 1 C. K. Dyer, "The Grove Anniversary Fuel Cell Symposium", London, September 1989, published in *Platinum Metals Rev.*, 1989, 33, (4), 169
- 2 C. K. Dyer, *Nature*, 1990, 343, (6258), 547
- 3 T. E. Mallouk, *ibid.*, 515