Book Review

Solid State Protonic Conductors I

Edited by J. Jensen and M. Kleitz, published by Odense University Press, 1982; 352 pp.; price U.S. $19.50.

The fuel cell has posed, for many years, a fascination for electrochemists and others interested in increasing the efficiency of electric power generation. A recent review by F. T. Bacon (*J. Electrochem. Soc., 126* (1979) 7C) notes that "the idea of a continuous feed battery is very attractive, and the thought that one might be able to by-pass our old enemy, the Carnot Cycle, in the process of the generation of electrical energy was always in my mind.". Work, started by Bacon in England before the war, eventually led to the successful use, after huge R & D investment, of fuel cells in the Apollo and other American space missions.

Although commercial demonstration plants based on phosphoric acid technology are now being evaluated in the USA, their economics remain uncertain. In the UK, the appeal of fuel cells, coupled with the almost total lack of successful commercial development, has led to a considerable polarisation of views on the merits or otherwise of engaging in R & D on fuel cells and fuel-cell related topics. A similar situation pertains in Europe and few fuel cell development programmes remain intact today. Successful demonstrations may result from the adoption or adaption of the American technology, but a recent review by Kordesch (*J. Electrochem. Soc., 125* (1978) 77C) points out, pertinently, that "the technology of fuel cells has not been supported by basic scientific studies to the extent that we can explain catalyst action or even predict ways to improve electrode kinetics beyond the routine methods of engineering and design optimisation". There is absolutely no doubt that the technology of fuel cells is complex and difficult. Where precious metal electro-catalysts need to be employed, profound problems of catalyst activity, cost, and poisoning inevitably ensue. High-temperature technology, for example, utilising oxide–ion conducting solid electrolytes, offers a way around some of these problems but bring as many others in its train, primarily concerned with materials durability at high temperatures.

One of the most attractive applications of fuel cells is, in principle, for transport, with the direct methanol fuel cell being of particular interest here. Nevertheless, in a recent SERC Appraisal Meeting on Fuel Cells last year (*Rutherford Appleton Laboratory Report RL-82-055)* Glazebrook of Shell pointed out both the bulkiness of fuel cells compared with internal com-

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bustion engines and the basic electro-catalysis short-fall before satisfactory performance could be achieved. At least an order of magnitude improvement is necessary in the catalysis of methanol, and once again it was proposed that more fundamental long-term studies on the catalysis problems might be the most useful way forward, any advances only being probable in the long term. This reviewer believes that such an approach is most appropriate for the UK and European situation, although a proper evaluation of current American phosphoric acid technology should also be made if a favourable demonstration site where both heat and electricity can be effectively utilised can be established.

Nevertheless, new materials or improved materials properties can offer the hope of ways round some of the existing problems and the discovery of protonic conductivity in materials such as the ion-conducting β-aluminas offers, in principle, the prospect of overcoming, at intermediate temperatures, both the electro-catalysis problems of direct methanol and phosphoric acid fuel cells and the high temperature problems of molten carbonate and solid oxide fuel cells. The volume under review aims both to present the case for fuel-cell-related research in Europe, but addressing, particularly, protonic conductors, and also to review the present scientific understanding of proton conductivity in solids.

There are clearly difficulties in attempting to organise a workshop and conference volume along two rather orthogonal themes, the justification for European fuel cell R & D and the science of solid state proton conductors, because neither theme will be fully or rigorously addressed. Additionally, a relative new materials discovery, such as new protonic conducting solids, is always a more appealing base for promoting work in a difficult technological area such as fuel cell R & D, compared with existing technology, because the nasty problems have yet to be encountered.

It is no surprise, therefore, that this volume does not address in great detail the question of where Europe should go in fuel cell research, neither is it an in-depth review of solid-state proton conductors. Although primarily concerned with fuel cell applications, the papers are largely a report of current work on-going in France and Denmark, the countries from which the participants of the workshop were drawn. Only two papers discuss perfluorinated membranes which form the basis of the solid-polymer-electrolyte fuel cells developed by General Electric Company in the 1960's and used in the early American space flight programme. As polymeric based materials are probably one of the more promising avenues for future work in the area, particularly with regard to fuel cell and related technological development, one would have liked to see considerably more emphasis on this topic. Being a snapshot of work in progress, the volume deals mainly with materials of current interest, notably hydrogen-containing β-aluminas and hydrogen uranyl phosphate (HUP)-based materials. Hydrated oxides have been quite extensively studied recently, and there is one paper on hydrated antimonic oxide and also a good review of proton hydrates which can be formed in strong acids. However, one is aware of good work done elsewhere, including

the areas treated in this volume such as β-aluminas and hydrated oxides, that is not discussed in this volume. There is much to be established before we properly understand the origin of the good conductivities in certain β-aluminas and related phases and, unfortunately, the review of hydrogen containing β and β'' aluminas in this volume provides only one, disputed view of the complex structural and compositional issues in this field.

Nevertheless, the last substantial review on proton conduction in solids was written 10 years ago, before the recent discoveries of HUP and of β-aluminas and hydrated oxides. Therefore, a review is certainly timely and the merit of this volume is that it is honest about the reasons why people are interested in such work at the present time. There is great interest in solid state devices as well as in fuel cells and this aspect is covered by a review from the Thomson-CSF Group.

This volume is the only current review of an interesting new field of solid state chemistry and electrochemistry but the comments above on both fuel cell R & D and the science of proton conductivity must be borne in mind when reading it. Nevertheless, it provides a snapshot view of the topics of current interest which will be amplified in future volumes and will be of interest to scientists interested in protonic conductors and solid state ionics in general.

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