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BOOK REVIEW

S. Basu Ed.: Recent trends in fuel cell science and technology

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Despite the somewhat dispiriting observation that fuel cells have been called "the procrastinators' power source" sometime ago in an editorial of a well-known scientific magazine and the repeated (and mostly unfulfilled) claims that major breakthroughs are just around the corner leading into a glorious future for fuel cells, a book describing the "state of the art" from the perspectives of various authors appears to be an adequate and useful endeavor. As impressively introduced by the editor in the preface, the broad range of systems, subjects, and topics related to fuel cells is presented in a collection of 14 review chapters provided by respective experts in the various fields. Multivolume books also prepared riding this wave may be out of financial reach; in addition, they might be too much of a good thing in particular for a reader looking for a brief and comprehensive update.

In a concise introduction by R.K. Shah, an overview dealing with some thermodynamic and kinetic fundamentals, characteristics of the fuel systems currently under development, and some aspects of fuel cell technology is provided. In the second chapter (M. Ramani), experimental methods applied in fuel cell investigations are presented. It is not just a listing of methods; instead, starting from components of interest or aspects of particular importance for a given type of fuel cell, methods are discussed. This sometimes results in a somewhat confusing situation: considerations of performance or structural aspects tend to push aside the methods. In addition, this chapter already nicely illustrates a frequently criticized drawback of edited books: repetitions. This chapter starts almost literally with the same relationship between cell voltage and Gibbs (free) energy, with the reaction equation of a hydrogen–oxygen fuel cell, not a really big problem, only slightly boring. Passing by odd statements like "electrons are rejected through external circuit" (whatever this means), the author continues to fuel cell types and catalysts (just like in the previous chapter), so far nothing new, only electroanalytical techniques. Finally, a chart emerges naming (not describing, discussing, or even evaluating) analytical methods. Excessively detailed descriptions of function and preparation of membrane-electrode assemblies follow. The remainder of this chapter is a repetition of this approach: a rather haphazard collection of fuel cell topics and methods. Depending on the reader's point of view and own expertise and experience, different types of fuel cell will be assumed as being most important and promising. Taking the number of publications and the intensity of public relations efforts, polymer electrolyte membrane fuel cells (PEMFC) are presumably the most popular ones. Consequently, Chapter 3 by K.S. Dhathathreyan and N. Rajalakshmi on this subject is the longest one in the book. It starts very systematically, leaving out all those repetitions of previous chapters; minor confusions like, e.g., the apparently synonymous use of cell voltage and cell potential (on p. 44 and 45) are only minor distractions in an otherwise impressive and helpful contribution. This contribution is almost worth the price of the book. Gas diffusion layers—major components of the fuel cells treated in Chapter 3—embedded in membrane-electrode assemblies are discussed in a small chapter by V.K. Mathur and J. Crawford. Another interesting aspect of PEMFC—humidity and water management—is briefly addressed in Chapter 5 by K. Ito. A possible field of applications of PEMFC is its use in mobile devices. Their size and power demand require small fuel cells only in many

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cases; thus, microfuel cells again based on PEM technology may become a promising development. They are treated by S. Venugopalan. Alkaline fuel cells (those were the cells successfully employed in space missions at the beginning of the long and tortuously winding road of fuel cell development until today) operating with alcohols and borohydrides are reviewed by A. Verma and S. Basu in Chapter 7. The whole range—from electrocatalysts beyond cell components to complete cells—is covered. Unfortunately, reasons for unwanted humor are included: On p. 178, cell voltages are listed. Starting with fairly decent 0.85 V, suddenly the cells go berserk with cell voltages up to 39 or 500 V, presumably a mix of volts and millivolts—but hardly a welcome feature. R.S. Choudhury describes the state of the art of phosphoric acid fuel cells. Once considered to be the most promising candidates for commercialization, apparently, it has become silent around these cells. (The fact that the reviewer has stopped counting the typing errors in Fig. 9, p. 200, is certainly not the reason). This appears to be due mostly to the fact that currently complete systems are under actual testing, hardly subjects of research papers or newspaper headlines. Nevertheless, this chapter provides a timely overview. Molten carbonate fuel cells combining numerous advantages from the point of materials science with the major drawback of employing an utterly repulsive electrolyte have made promising but unspectacular progress on various aspects as reviewed in Chapter 9 by H. Ghezel-Ayagh et al. Starting from the fundamentals and containing a brief historical background, the state of the art is described including all relevant aspects. Presumably, as a surprise to most readers (including the author of this review), a short contribution by J.F. Cooper describes direct conversion of carbon as derived from coal in fuel cells. This goes back to the initial idea of W. Ostwald, but years ago the idea—attractive as it might be—disappeared from sight. Even the optimist will feel after reading this report that still much needs to be done in order to make this principle into a working device. Solid oxide fuels (SOFC) are the subject of the two following chapters. Principles, designs, and the state of the art are briefly reported in Chapter 11 by R. Bove; materials science of SOFC is the topic of Chapter 12 by R.N. Basu. After some repetition of the previous chapter (this feature is almost typical of this book), a broad overview of solid oxides, their properties, their preparation and handling, and finally their use in SOFC is provided. The term "trend" featuring prominently in the book's title appears indeed in a figure caption (Fig. 21 on p. 313), but the reviewer has no idea about the meaning, in a plot without labeled axis terms and acronyms are happily mixed—but to what avail?

Fuel cells will always deliver DC voltages, and the actual numbers are in the volt or even millivolt range (those funny excesses mentioned above should not be pursued further). Thus, cells are connected to stacks, and stacks are somehow connected into larger units. Still, a DC voltage will be delivered. Connection to the grid (except for the highly unlikely case that a DC voltage consuming application is sitting nearby) is possible only after conversion and/or transformation into a suitable AC voltage. Thus, a chapter on power conditioning appears to be a logical component in such a book. Unfortunately, most electrochemists will hardly enjoy this; even the reviewer with some background in power electronics was quickly lost when trying to read and understand this Chapter 13 by S.K. Mazumder. In the final chapter, S. Basu attempts to indicate future directions. After some general considerations regarding efficiencies and the way this topic is publicly discussed, he evaluates arguments to be considered when selecting a fuel cell for a particular application, speculates about cost developments, and offers some general assumptions and conclusions. Perhaps, this is as close as possible to the "trend" term in the title of this collection.

The book is lavishly illustrated. Unfortunately, many figures escaped the scrutinizing eye of the editor. Beyond stunning observations (time axis on Fig. 28, p. 37 (somehow the numbers start anew in every chapter) goes to negative times—a fascinating proposition—or simply missing axis labels in Fig. 27, p. 242), many figures are crowded, carelessly drawn, or just studies in grayscale and extremely low resolution. References are provided in formats the various authors preferred personally—a rather unusual feature at Springer who is otherwise very meticulous with referencing. Sometimes, gross errors (e.g., on p. 216 or p. 161 with an utterly nonsensical assignment) indicate a considerable lack of care. This unfortunately applies to the text also; for unknown reasons, language polishing was overlooked. A reference in the text to a cyclic voltammogram in a figure actually showing a Tafel plot (p. 175) is more than a simple nuisance—it is almost typical. In conclusion: the book is one of those apparitions published with disconcertingly growing frequency based on a marriage of convenience between a publisher eager to jump on the bandwagon of a popular subject and an editor eager to publish something in this field (as he honestly admit he rather preferred to write the book not exclusively by himself. His claim that he sought contributions from world experts sounds impressive, but somewhat surprisingly most of them are his countrymen, just a coincidence?). The present reviewer has been (and still is) in the fuel cell business for a few decades already—but he would be lost when asked for trends in this area (beyond the obvious easily concluded one from numbers of patents or publications). Apparently, this book fares not better—so why the promising title? Beyond some well-done review or overview chapters, it is making only a rather minor enhancement of any library.