

## Book Review

### *Lithium Batteries. New Materials, Developments and Perspectives*

Edited by G. Pistoia, published by Elsevier Science BV, Amsterdam, 1994, 494 pp., Dfl. 425.00, ISBN 0-444-89957-X.

One day, about twenty years ago, I was suddenly confronted by a rather excited battery man of my acquaintance demanding to know if I believed that lithium batteries were rechargeable. My off-the-cuff reply was to the effect that given the right electrolyte I believed recharging to be possible at low rates but not many times. In the unlikely event of a similar situation arising at the present time I would refer the questioner to this excellent book which, in eleven chapters contributed by individual or group authors, gives an account of the research and development work that has been carried out, and is in progress, in the preparation of materials for use in batteries, and in the production of several types of battery.

The opening chapter briefly surveys the development of secondary lithium batteries during the past twenty years starting from early cells with intercalation compounds as positive electrodes and metallic lithium, or lithium alloy, anodes; the problems with such metallic anodes are considered, and lithium-ion (rocking-chair) batteries employing carbon anodes are introduced. The advantages of carbon electrodes are discussed and the chapter then considers the many types of carbon, including petroleum coke, available, their structures, the effect of structure on intercalation and on electrochemical behaviour with the objective of determining the most suitable type for cell use. Graphite appears to be the most promising material but has not yet been tried extensively. In addition, the effects and possible advantages of additives to the carbon are considered and the possibility of special carbons being developed for use in lithium cells is suggested.

The second chapter follows on naturally from the first in discussing actual electrodes based on intercalation of materials into carbon and graphite hosts. Starting from carbon polyfluoride ( $CF_n$ ) and carbon lithium ( $Li_xC_6$ ) already used commercially in primary lithium batteries and secondary lithium-ion batteries respectively, various materials are reported on with respect to their probable behaviour, method of

preparation, structure and finally their electrochemical performance in liquid and polymer (poly(ethylene oxide)) electrolytes. The chapter concludes with a short report on a study of the lithium passivation film which, obviously, is of vital importance in determining the stability and self-discharge behaviour of the electrode.

In subsequent chapters liquid and solid (polymer) electrolytes for lithium batteries are discussed. A brief, but informative, review of the physical chemistry of solution structure is followed by a detailed report on the chemistry and electrochemistry of several groups of solvents; the conductivity advantage obtained with some mixed solvents is also briefly mentioned. The factors of importance in selecting the lithium salt (solute) are discussed and many of the possibilities developed are described. Cost considerations are a barrier to the commercial use of some materials, but at least two liquid electrolytes are in production and cells using them have given good cycle lives. The nature of the interfacial film obtained with different electrolytes is reviewed, and the effects of additives to the electrolyte and the possible mechanism of these effects is also discussed.

The use of solid (polymer) electrolytes brings the additional problems of thermal and dimensional stability, of adhesion to the electrode surface and of mechanical strength; to resist internal cell pressures and the effects of changes in electrode morphology. In addition, they have to be produced as thin films which can be readily handled. Two classes of polymer electrolytes are discussed, those with and those without plasticizers (liquid solvents); the plasticizers are of benefit in improving conductivity. A wide range of polymers is considered, including some with inorganic backbones. Their properties and ways of modifying them are reviewed together with methods for their production. Again good cycle lives have been obtained, but there is an upper temperature limit of about 50 °C to their use. Cathode degradation and reactions at the electrode/electrolyte may be life-limiting factors.

Low temperature, below 100 °C, preparation in solution by chemical and electrochemical methods of high performance insertion compounds for secondary batteries is the subject of one of the chapters on cathode materials. This approach appears to be of advantage

in the development of new materials and in the improvement of the electrochemical performance, life and capacity, of known materials. A further benefit appears to lie in the possibility of obtaining materials in various physical forms.

A second chapter has a similar aim, the search for high voltage cathodes for lithium-ion batteries, and relates behaviour of materials in use with their structures. From this chemical compositions likely to give good performance are proposed. The method of preparation of some of these materials is then considered together with their voltages and stability. Some examples of cell performance are also given.

A related chapter discusses intercalation in two- and three-dimensional oxides, again with the objective of obtaining highly oxidising cathode materials. The amount of intercalation and the reversibility of the intercalation process are discussed for several materials together with the changes taking place; considerable attention is given to the structure of the materials. Layered spinel and  $V_2O_5$ -type materials are considered to have considerable promise.

Battery development is the subject of four chapters, the longest of these deals with the application of thin-film technology to the production of microbatteries which could be integrated with microcircuits. The advantages of thin-film technology are discussed, and the performance required from thin-film cells is then described. The several methods of depositing films on chips are given together with their relative advantages and disadvantages. The properties of several electrochemically active films are given and finally some microbatteries are described and the results obtained with them are given.

A historical review of implantable power sources is followed by a more detailed account of the development, design, testing and quality assurance of implantable lithium batteries for cardiac pacemakers. Further developments for batteries to power apparatus to detect

and correct other heart conditions are reported on together with work in which an implantable secondary battery is used as an emergency backup to an external, larger, battery used, for example, for movement control.

The development of small primary and secondary batteries for the commercial market is described. These batteries use an aluminium–manganese–lithium alloy negative and a lithiated manganese dioxide cathode, the preparation of which is described.

The theoretical and practical aspects of the design of large primary batteries using liquid, thionyl chloride or sulfur chloride, cathodes is discussed and a comparison made with other high power systems.

Finally, there is a twelfth, one might almost say rogue, chapter on the development of solid-state sodium batteries. The problems are similar to those with lithium batteries but with the added disadvantages of lower melting point and greater softness of the metal. The passivation layers formed on sodium are not so favourable to battery use as those on lithium and, of course, the energy density obtainable is lower. Nevertheless, one low rate primary cell has been developed and since sodium is cheaper than lithium and readily available in large quantities, sodium batteries could perhaps, for some applications, become the poor man's answer to the lithium battery.

An impressive feature of this book is the very extensive list of references, up to and in some case including 1943, to each chapter. A penalty for such up-to-date publication is that it has not been possible to check the English which in some places is a little confused but not confusing.

In short, there is something in this important book for all persons who have an interest in lithium batteries; persons with battery-powered implanted cardiac devices will be greatly reassured to learn of the testing and quality control applied to the batteries.

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