lished and a concise account is given of the structure of the atom and the consequent build-up of the periodic table. There follows a description of the quantum theory of interatomic and intermolecular interactions, and of the basic types of chemical bond. This introductory information is well presented, although much of it may already be familiar to readers of this type of book.

Crystals are introduced by a consideration of the symmetry of atoms, molecules and crystals, and crystal chemistry; the forces of interaction between particles, which lead to the formation of crystals, and the electron theory of crystals, which is fundamental in determining and explaining crystal properties, also receive very adequate treatment. The book concludes with a detailed consideration of the many properties of crystals which are of particular interest in solid-state physics and materials science.

In a work of this type it is inevitable that certain aspects of the subject tend to be omitted, and in *Crystal Physics* this applies to the optical and thin film behaviour of crystals. The book, which is exceptionally well produced, is based on a series of lectures given by Dr. Zhdanov to postgraduate students some ten years ago, and although written primarily for research workers it is unfortunate that few references to original papers are given and that the subject-matter is apt to be out of date regarding the most recent advances in this field.

Problems are given at the end of most chapters and these are solved by the author in an appendix to the book. In view of a shortage of comprehensive books on this topic it should prove extremely useful as a source of information and an introduction to more advanced reading.

D. T. TURNBULL

# PLASTIC FLOW AND FRACTURE —A COMPREHENSIVE APPROACH

## The Strength, Fracture and Fatigue of Materials

By Takeo Yokobori. Translated by Shigeru Matsuo and Michiko Inoue. Edited by John D. C. Crisp. Pp. 372. (Groningen: P. Noordhoff, Ltd., 1965.) 48.50 D.fl.

*THE Strength, Fracture and Fatigue of Metals* is a deceptively slim volume, since it contains in its 372 pages the distilled observations and theories of most of the leading workers in the field of fracture during the past 50 years. References are made to more than four hundred authors and a similar number of papers or books on the subject.

In spite of the lapse of 10 years since the original Japanese edition was published, this translation can still fulfil the aims of the author in providing a comprehensive correlation of the many aspects (atomistic, microstructural, macroscopic and statistical) present in the investigation of the problems of yielding, plastic flow, fracture and fatigue.

The early part of the book, after some general considerations including comments on scatter and rate processes, briefly introduces the dislocation theory. Many readers not familiar with this concept might prefer to have this chapter expanded but references give the reader access to original work.

Yielding, the theory of plastic flow, and fracture are next considered in the sequence of their normal occurrence. Some six types of fracture are described and the following chapters deal with four of them—brittle fracture, ductile fracture, fatigue fracture and creep fracture. The section covering creep fracture is limited in extent but in his preface the author promises a further book devoted to that topic.

Nearly half the book is concerned with fatigue. The various stages of fracture are described and later the theories are examined in the light of these observations. Much of this forms a useful critical review, but since the object of the book is to provide a fundamental approach to a much wider subject it is unfortunate that the earlier topics are not so adequately covered.

In collating work from diverse fields there have obviously been problems of reconciliation of the symbols and terms used. In most cases this appears to have been satisfactorily accomplished though some additional definitions at the end might be helpful. In the fatigue section some confusion appears to remain in the use of the terms 'range of stress' and 'amplitude' and also in the condition of 'understress' when related to coaxing.

Some of the correlation from theory to practice appears to be based on limited evidence as presented, but nevertheless it bears out a point made towards the end of the book that "in order to develop the solid state physics . . . in a proper way, it is necessary to give physical and microstructural meanings to the probabilistic factors".

J. F. ALDER

# THE FUEL CELL

## An Introduction to Fuel Cells

Edited by Keith R. Williams. Pp. xiv+329. (Amsterdam, London and New York: Elsevier Publishing Company, 1966.) 90*s*.

OF recent years, interest in the production of electrical energy by means of fuel cells has been stimulated both by the recognition that we are approaching the limits of efficiency of heat engines in respect to the temperatures permissible in their working parts, and also by the demands for a generator suitable for space research in which financial considerations play but a minor part. This interest has been reflected in the appearance of a large number of articles and a few monographs on various aspects of the subject.

Under the too modest title of *An Introduction to Fuel Cells*, Dr. Williams has presented us with a volume that is remarkable not only for the completeness of the systematic survey of the various types of fuel cells and the theories as to their mode of operation, but also for the clarity of presentation.

The types of fuel cells available are conveniently grouped into those operating at ambient temperatures and under suitable pressure up to 200° C, fused salt electrolyte cells with working temperatures of 350°–800° C, and finally those with high-temperature solid oxide electrolytes. As might be anticipated, cells with aqueous or fused salt electrolytes have received most attention.

From an operational point of view, fuels and oxidants both soluble in the electrolyte are the simplest, and these include such substances as ammonia, hydrazine and methyl alcohol as fuels and hydrogen peroxide or chlorates as oxidants. It is those cells in which gaseous fuels, especially hydrogen and gaseous hydrocarbons, and air as oxidant are used which are of most interest.

It is clear that the conversion of hydrogen to protons at the electrode surface involves a series of steps, any of which may be rate-determining, dependent on the conditions of operation, and the separate factors such as gaseous diffusion, concentration and activation polarization, chemisorption as well as the magnitude of exchange currents are now reasonably well understood, although the picture is by no means complete. On the other hand, our knowledge of the *modus operandi* of the oxygen electrode is far less satisfactory, for the reaction which involves conversion of oxygen into hydroxyl ions is more complex than is the case for hydrogen. It would appear from experiments on catalytic oxidation that surface oxides are first formed; these can be reduced by water, which in turn is converted into hydroxyl ions. Frequently equations involving two electron transfers are used. It seems preferable to regard the transfer as proceeding by steps of single electron transfer, that is, $O^{2-}{}_2 \rightarrow O^{-1}{}_2 +$