Pathology of crystals

THEORY OF DISLOCATIONS. By John P. Hirth and Jens Lothe, 780 pp. McGraw Hill, New York, 1968. $25.00

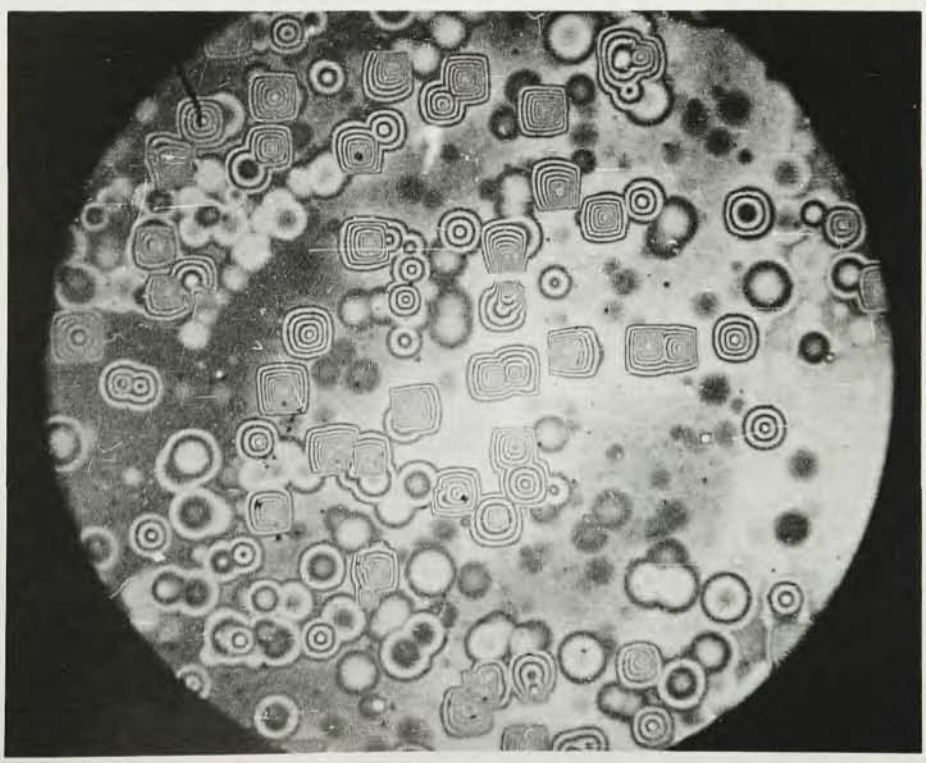
THEORY OF CRYSTAL DISLOCATIONS. By F. R. N. Nabarro. 821 pp. Oxford U. Press, London, 1967. $30.25

by Roman Smoluchowski

The time is ripe for an enterprising science historian to undertake an analysis of the mathematical, philosophical, scientific and even utilitarian development of the theory of dislocations. The story is rich in examples of courageous and imaginative creativity, of complicated and often bitter arguments between proponents and opponents, of debates between the advocates of dielectrical materialism and of bourgeois idealism in science, of big hopes and also big disappointments, of ridicule and of resounding successes. Introduced at the beginning of this century by Volterra in his studies of elastic continua, dislocations remained more or less a mathematical curiosity until 1934 when, thanks to Orowan, Polanyi and particularly Taylor, they acquired a more realistic crystallographic interpretation. Although from then on progress in the theory of dislocations was rapid, not until about the early 1950's did direct observation of dislocations convince conservative and usually "applied" skeptics of the essential correctness of the basic concept. It is interesting to note that at the same time another equally "revolutionary" suggestion, the vacancy mechanism of diffusion long accepted among solid state physicists, was finally replacing the almost untenable interchange mechanism that was vigorously defended by the old guard. Without much exaggeration these two concepts, dislocations and the vacancy mechanism of diffusion, did more to advance our understanding of various atomic solid-state phenomena and of various utilitarian metallurgical facts within the last 20 years than any other factor.

Although the essential qualitative and even some quantitative features of dislocation theory are simple and easy to handle, the more advanced and rigorous aspects are very complicated both mathematically and conceptually. For this reason there was a gap of more than ten years between the appearance of the first two introductory texts by Read and by Cottrell and the more detailed later books by Friedel, by Cottrell, by Weertman and by Hull. This year two new books in this area have been published, one by Hirth and Lothe and the other by F.R.N. Nabarro. A third book by Zorawski deals only with the mathematical aspects of the transition from discrete dislocations to a continuum mechanics point of view and is not discussed here.

Hirth's and Lothe's book is divided into four parts: dislocations in isotropic continua, dislocations in crystalline structures, interactions with point defects, groups of dislocations. The part dealing with dislocation–point-defect interactions comprises more than half of the book. The treatment is elegant, thorough, detailed, and the various mathematical deductions are unusually complete, which is a very valuable feature from the point of view of skeptical readers. The book abounds also in numerous helpful diagrams and illustrations. Some of the mathematical and diagrammatical symbolism is rather difficult to handle, but the reader will become accustomed to it. The book stresses crystallographic aspects of dislocations, their various interactions and topologically intricate constructs rather than the effect of dislocations on various physical properties. Actually the only area of application of the dislocation theory that is treated at length is the main concepts of the mechanical behavior of solids in particular metals. It is surprising not to find any reference to the interesting fact that the critical shear stress, on the (211) planes of body-centered cubic lattices is asymmetric. The recent observation that dislocations in alkali halides can actually dissociate was probably made too late to be included. In general the effect of dislocations on electronic properties and vice versa of electrons on dislocations as well as the optical



DISLOCATION ETCH PITS that appear on the surface of a lithium fluoride crystal.

and magnetic effects are essentially omitted. The influence of dislocations on physical properties or, in other words, the true *physics of dislocations* is admittedly a very difficult field in which progress is still dishearteningly slow and is obtained often by hindsight. A most welcome aspect of the book are excellent exercises and problems discussed in the text or appended at the end of chapters. The subject index is only fair although better than in the earlier books on dislocations. The printing and the general appearance of the book are excellent.

Nabarro's book shows clearly that it is written by a physicist for whom the dislocation theory and its analytical, topological and theoretical details are only a tool for understanding physical phenomena and not a goal in themselves. For this reason the mathematics is rather restrained and the symbolism not too cumbersome. Besides chapters that deal with the usual fundamentals of stationary and moving dislocations, the role of point defects, the structure of grain boundaries, etc., there are excellent chapters on interaction of dislocations with surfaces, electrical effects, magnetic effects and dislocation optics. There is also a useful chapter that discusses the geometry of generalized noneuclidean spaces and dislocated lattices in tensorial formalism, which play an important role in the present attempts to develop a continuum theory of dislocations. Sections of various chapters deal with such topics as the role of dislocations in oxidation processes, in catalysis and even in apparently remote fields such as zoology, botany and geophysics. Unfortunately the various aspects of work-hardening and of fracture are not considered in detail because "it is not at present clear which mechanism predominates in any given situation." The book has an unusually large number of references, mostly from before 1966. There are no problems attached, and the subject index, though good, could stand improvement.

Both these books, which are, in fact, complementary, will serve well the research man and the student, Hirth's and Lothe's as a rigorous and quite mathematical treatment of the subject and Nabarro's as a source of insight into the rich variety of associated physical phenomena.

An historical footnote: The very important Frank–Read source of dislocations that removed one of the major obstacles in the early stages of the dislocation theory was invented in Pittsburgh around 1951 in the wee hours of the morning in a beer establishment affectionately called "the Greeks." May the future progress in this very important field be made under equally pleasant circumstances.

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Broader spectrum

PHOTOIONIZATION PROCESSES IN GASES. By Geoffrey V. Marr. 282 pp. Academic Press, New York, 1967. $12.50

by Bruce W. Shore

Increased study of ultraviolet spectroscopy, motivated by research in plasma physics and by the possibility of rocket and satellite observations of solar and stellar spectra, has provided much new information during the dozen years since the subject of photoionization was summarized by Gerhard Weissler.[1] New observations of photoionization have been made, many by Geoffrey Marr and his students at the J. J. Thomson Physical Laboratory, University of Reading, England. New computations have been reported; many use the quantum defect theory. And a better understanding of resonance features, such as autoionizing lines, has developed. Thus a survey of observational and computational results would appear to be appropriate. One such survey, written by James Samson,[2] was published last year. The present monograph enlarges the subject matter of Samson's review, filling in background to provide a broader, self-contained introduction for the nonspecialist.

As with Samson's review, the approach here reflects the author's research activity as an experimentalist although the topics show a nice balance between theory, experimental methods, numerical results and applications. Although Samson provided numerous tables of absorption coefficients and detailed plots of autoionizing features, Marr has confined himself to graphs of absorption coefficients.

The author begins with a brief review of the conventional quantum theory of radiation absorption and emission and summarizes the several common approximate methods for computation. Although the discussion is too brief to give a real understanding, the references are adequate for that task. Next the author reviews common laboratory arrangements for measuring photoionization and mentions the broadening of spectral lines and the lowering of the ionization potential caused by neighboring ions, atoms and electrons in the absorption source. The author then presents, in graphical form, experimental and theoretical photoionization cross sections for numerous atoms and molecules. He summarizes some of the observations of autoionization and the theoretical approach of Ugo Fano.[3]

As one might hope of a monograph on photoionization, the topics of predissociation, preionization, and photodetachment are discussed. In addition, the author discusses the opacity of the terrestrial atmosphere for ultraviolet radiation. Perhaps surprising is a discussion of those electrical discharge phenomena in which photoionization is "a significant process in their

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