AMORPHOUS AND LIQUID SEMICONDUCTORS

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Edited by

J. Tauc

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Preface

Solid state physics after solving so successfully many fundamental problems in perfect or slightly imperfect crystals, tried in recent years to attack problems associated with large disorder with the aim to understand the consequences of the lack of the long-range order. Semiconductors are much more changed by disorder than metals or insulators, and appear to be the most suitable materials for fundamental work.

Considerable exploratory work on amorphous and liquid semiconductors was done by the Leningrad School since the early fifties. In recent years, much research in several countries was directed to deepen the understanding of the structural, electronic, optical, vibrational, magnetic and other properties of these materials and to possibly approach the present level of understanding of crystalline semiconductors. This effort was stimulated not only by purely scientific interest but also by the possibility of new applications from which memory devices in the general sense are perhaps the most challenging.

The research met with serious difficulties which are absent in crystals. The theorists have to learn how to live without the Bloch theorem, without the mathematical simplicity introduced by symmetry and long range order; they have to struggle with inhomogeneous systems and with contradictory and changing experimental results. The experimentalists in turn are plagued with the difficulty of mastering the reproducible preparation of materials, with experimental data curves which are typically less structured and sharp (how much nicer it is to have graphs with sharp peaks than very broad bands), and with the vague generalities and loosely defined concepts of the present theories. Therefore the progress has been slow and most of the fundamental questions are still open to discussion. It reminds one of the situation in which semiconductor research was during the thirties.

Nevertheless, just as the basic ideas for the understanding of crystalline semiconductors were available in the pre-germanium era, very probably most of the present interpretations have a sound foundation and will survive as basic concepts for the future more detailed and better founded work. The recent book on the Electronic Properties in Non-crystalline Materials by Mott and Davis presents an ingenious attempt to correlate the observed electronic effects in disordered solids on the basis of a few concepts derived from some theoretical considerations and generalized with a sharp physical intuition.

In our book we do not try to give a unified picture of the field. A few experts in the field were invited to discuss their respective subfields. They were asked to describe the basic methods, their merits, limitations and achievements. This approach is hopefully useful for readers working or intending to work in the field. Of course, each contributor necessarily includes some of his personal preferences in the interpretation and meaning of his results. Actually these views are not too diverging, but no attempt was made to unify them.

A large class of amorphous solids – glasses – have been studied extensively over many decades from the point of view of their thermodynamical and structural properties. The first two chapters deal with this aspect which is considered essential for any deeper understanding of the nature of the amorphous state. The inherent metastability of the amorphous state compared to the crystalline state is responsible for many discrepancies in the experimental results. It should be understood not only for improving the reproducibility of the measurements but also because the control of the structural parameters is the heart of such applications of amorphous semiconductors which cannot be produced by devices constructed of crystalline materials. Indeed, most kinds of memory devices are based on the ability of glasses to exist in different structural states.

The third chapter is an introduction to the theoretical treatment of the electronic states in highly disordered systems. This chapter briefly summarizes some of the basic ideas of an important theoretical school in this field. It starts with simple consideration but later difficult fundamental problems are treated in a rather sophisticated way.

After dealing in some detail with the optical and transport properties of amorphous semiconductors, we include a chapter on some of their applications in practical devices. We believe that it is of general interest to the reader to learn about the physical principles of various devices based on amorphous semiconductors. It should also be a stimulating reading on a field whose future depends much on further ingenuity in applied research. This remark does not mean that a deeper understanding of the fundamentals should be underestimated. It is well known what a difference it made in the crystalline semiconductor technology in the fifties compared with the thirties.

The last chapter deals with liquid semiconductors. They are closely related to amorphous semiconductors but have many interesting new features.

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