Electronic Processes in Non-Crystalline

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Abstract

TEN YEARS ago our theoretical understanding of electrons in non-crystalline materials was rudimentary. The classification of materials into metals, semiconductors, and insulators was based on band theory, and band theory starts from the assumption that the material is crystalline. According to band theory, an insulator is a material with an energy gap between the conduction and valence bands, and a transparent insulator is one in which the gap is greater than the quantum energy of visible light. Ordinary soda glass is an insulator and transparent; a gap seemed to exist, but we did not know how to describe the gap. Even now we do not know how to calculate it, but the concepts that we have to use are fairly clear.

Key words: Key1, Key2, Key3

Introduction

explanation of the electrical properties of liquid metals, put forward in 1960. This was a weak-interaction theory, the effect of each atom being treated as small. The success of this theory prompted investigations of what happens when the interaction is large, as it must be when an energy gap exists. The keys to our present understanding have been the principle of Ioffe and Regel (1960) that the mean free path cannot be less than the distance between atoms, and the concept of localization introduced by Anderson in his paper 'Absence of diffusion in certain random lattices', published in 1958. In a sense, our book is written around these two themes.

We have built a theoretical edifice on them, and since mathematical rigour is anything but easy in this subject we have not hesitated to guess at the approximate solutions of problems that at present are unsolved. Our aim is to suggest models that can be compared with experiment. We have chosen the experimental material, too, with a view to comparing it with our theory and our conjectures. Thus we have given a rather full account of what is known in October 1970 about the electrical and optical properties of certain amorphous semiconductors, in particular silicon, germanium, chalcogenide glasses, and selenium, which we think relevant. We have said much less about conduction in glasses containing transition-metal ions as they would in our view fit better into a book about polarons.

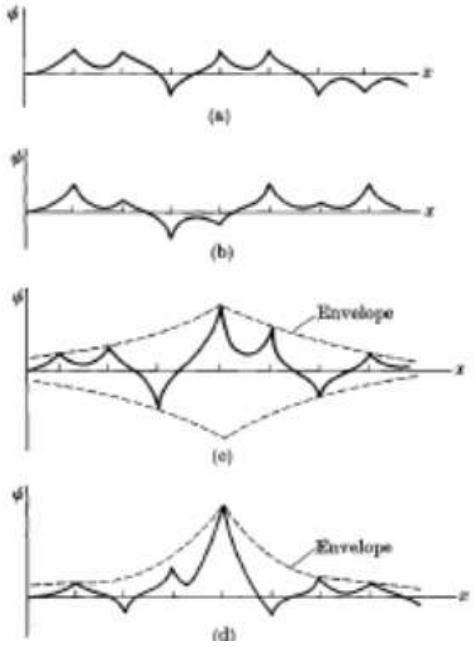
Materials and methods

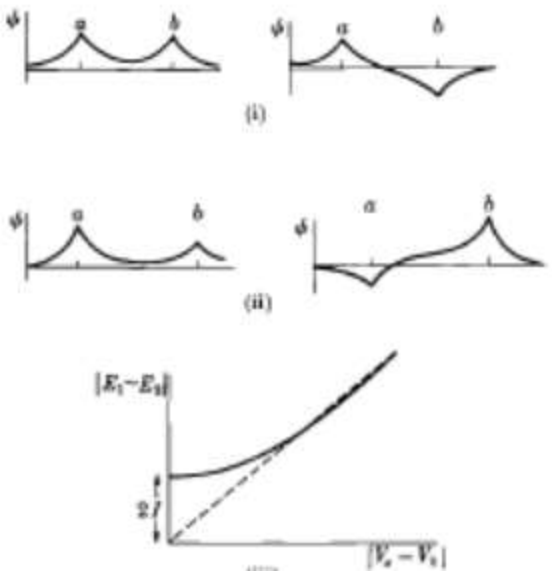
Our chapter on impurity conduction is not meant to be exhaustive; we include it because impurity conduction is the most fully understood process of conduction in a random field. We have said

rather little about the phenomenon of switching, fearing that anything we could-write would be out of date too quickly.

Results and Discussion

which a mean free path such that *kL*< 1 is impossible. With the potential energy illustrated in Fig. 2.1 and no disorder, *ka = TT* in the middle of the **Fig. 2.2.** Form of the wavefunction in the Anderson model: (a) when L~a; (b) when states are just non-localized *(E^EC);* (c) when states are just localized *(E&Ec)i* (d) strong localization. band. The loffe-Regel rule then means that the shortest possible mean free path arises when the wavef unction loses phase memory in going from atom to atom, so that instead of (2.26) it has the for





Conclusion

suggests that there should be random fluctuations of the amplitude (as well as of the phase) of *i//* in going from well to well, and that as *Vo/B* increases, these fluctuations become larger (Fig. 2.2(b)). This undoubtedly occurs. However, if *V0/B* is very large, one would expect intuitively that the wavefunctions for each isolated well would be little perturbed by all the other wells, and so would fall off exponentially with distance as in Fig. 2.2(c) and 2.2(d). The important questions are: Does this in fact occur, an if so at what value of *Vo/Bt* To answer this question, Anderson took the potential of Fig. 2.1(b) and asked the following question. If at time *t* = 0 an electron is placed on one of the wells, what happens at f-»oo? Is there a finite probability at the absolute zero of temperature that the electron will have diffused to large distances or does the chance that an electron will be found at a large distance *r* vary as exp(-2ar), in which case there is no diffusion? Anderson found that there is no diffusion if *V0/B* is greater than a constant that depends on the co-ordination number z. This means that, if *Vo/B* is greater than this constant, all the wavefunctions for an electron in the system are of the type shown in Fig. 2.2(c), decaying with distance *r* from the neighbourhood of some well *n.*

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