Some physical properties of some amorphous semiconductors

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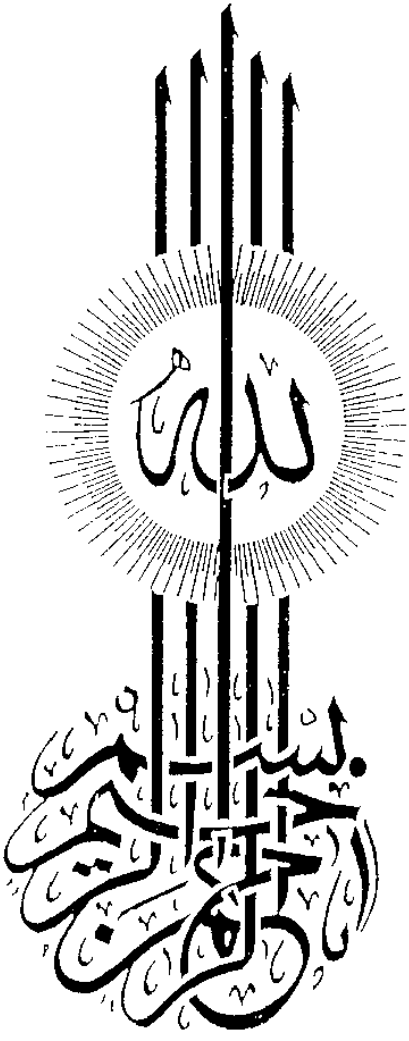
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INTRODUCTION

Introduction:

The interest of dealing with a binary system is to supply a parameter x, that one can vary continuously, leading to different measurable effects. From this point of view, the $Ge_x\ Se_{1-x}$ system is very attractive, since it allows the formation of glasses in the range $x = 0$ to about $x = 0.42$. Furthermore the variation of x induces significant changes in the aptical properties as well as in the electrical properties.

Therefore , we found it worth to investigate some physical properties of the $Ge_x\ Se_{1-x}$ solid solutions in thin film form in the range $x = 0.05$ to $x = 0.30$. Such investigation includes the film structure, the optical propesties, the electrical properties and the I-V characteristics of the $Ge_x\ Se_{1-x}$ /Si heterojunction.

Accordingly, this work represents:

1. Structural investigation of the $Ge_x\ Se_{1-x}$ solid solutions in thin film form including the effect of the Ge content in the range $0.05 \leqslant X \leqslant 0.30$

2. Investigation of the optical constants and the absorption spectra of the $Ge_x\ Se_{1-x}$ thin films including,

   (i) The dependence of the refractive index n, the absorption index k and the absorption coefficient $\propto$ on the film thickness as well as the Ge content.

CHAPTER I

LITERATURE REVIEW

1-1. Structure of amorphous S.C:-

The amorphous solids have no atomic structure with no long range periodicity. Despite the absence of long- range order,there still exists a significant amount of short range order determined by the chemical bonding in the structure. A great deal of work has been done to investigate the nature of the short-range order in amorphous solids, by x-ray and electron diffraction (1) techniques Radial distribition Function for crystalline and amorphous phases of silicon (2), arsenic (3) and selenium anong many others suggest the conclusion that the nearest neighbor separation and coordination are identical in corresponding crystalline and amorphous solids.

An important concept arising out through the structural work is the continuous random network. This ideal amorphous structure represents a fundamental concept on which most the oretical considerations are based. It is realized that the structures prepared experimentally are far from continuity.

An important effect (4) of long-range disorder is that the wave vector is not a good quantum number in the absence of periodicity. Thus K is nu longer convened in optical transitions. This has an important beneficial advantage for solar cell technology, since all amorphus S.C. are strong absorbers of photons with energy exceeding the opticaltransitions. This has an important beneficial advantage for solar cell technology, since all amorphous remiconductors are strong absorbers of photons with an energy above the optical gap, this is why a 1 μm amorphous silicon film absorbs as much visible light as a 50 μm sample of crystalline silicon.

As a result of long-range periodicity in crystalline solids, the density of electronic states is characterized by sharp band edges. Introducing disorder, the periodic potential will be disturbed, the scattering will be enhanced and the mean free path of the carrier is reduced, so sharp band edges could not exist. Theoretical work (5,6) suggests that the band structure of amorphous semiconductor is not very different to that in similar crystalline materials except for the splitting of a tail of localised states below the conduction band and above the valence band.

1-2. Models of semiconductors:-

The first concept, equally valid for crystalline and for non - crystalline materials, is the density of states, which may be dinoted by $N(E)$. The quantity $N(E)\,dE$ denotes the number of states in unit volume available for an electron of given spin direction with energies between E and $E+dE$. As in crystalline solids, the states can be occupied or empty and $N(E)\ f(E)\ dE$ is the number of occupied states per unit

The propagation of an electron, hence the current, is then partly limited by collisions with or scattering by (as it is called)- these imperfections. In collision the electron is scattered from one well defined state or wave function into another. In a glass the difficulty is that the states between which scattering may occur are so readily defined. Moreover, it is not easy to define just what constitutes on imperfection in the disordered structure of a glass. Quite apart from structural imperfections, howevers the perfect periodicity of the crystal lattice is also disturbed by thermal vrbrations of atoms about their normal lattice sites and an electron may also be scattered by collisions with these thermal vibrations or phonons.

In the Black-Wilson theory of crystalline solids, the allowed energies for an electron are divided into bands. In an insulator or intrinsic semiconductor, a fully occupied valence band does not overlap an empty conduction band. There is a band of forbidden energies, in which the density of states is Zero, and fermi energy lies in the gap as shown in fig (1-a) i.e most treatment of nonmetallic materials ascribe the gap to the crystalline structure.

Ziman(7), Klima and Mc Gill(8), illustrate how the gap can occur. If E_1 and E_2 are the energies of the atomic states from which band, are formed, the gap will not less

than $E_2 - E_1 - Z (J_1 + J_2)$.... (2)
where Z is the coordination number, and J_1, J_2 are the maximum overlap integrals in the two bands. Such treatment would certainly be appropriate for an amorphous covalent material Also the calculation given by weaire(9) and Heine(10) shoved that the gap must appear if there is no dangling bands.

Cohen, fritzsche and Ovshinsky(11), introduced two states to the gap by postulating an overlap of both the conduction and valence band known as in Fig(1.b). The tail of the conduction band would consist of donors and that of the valence band would be of acceptors. Thus the higher acceptor states would give up an electron to the lower donors, producing positivcly charged donors and negative acceptors. The overlapping bands will moreover lack the Fermi energy near the middle of the band. At high temperature the material will behave like an intrinsic semiconductor, but since $N(E_f)$, finite at low temperature current, it will be carried by electron at the Fermi energy.

Davis and Mott(12,13) deduced, from their measurements on chalcogenide glasses with low optical absorption coefficient in the infrared that there might be a peak in the density of states in the middle of gap. This might occur by assuming that, there are no states in the gap when the co-ordination number is preserved. states may be introduced by " dangling bonds " whether there are some voids on the surface or simply unsaturated bonds in the body of the glass.

The dangling bond may provide a donor below the middle of the gap and an acceptor above it, but the disorder and particularly random fields due to the change cavities, give a range of energies for both, so that the two bonds overlap, In Fig (1-c) it is eazy to illustrate the disorder structure, including impurities accommodating themselves so that all the electrons are taken up in bands. Also, the structure defects play a more effective role than impurities do in controlling the conductivity of amorphous semiconductors.

Therefore it seems clear that , Fermi level lies near the middle of the band gape, it is uncertain, whether for a given amorphous semiconductor the conductivity is intrinsic as extrinsic. (By intrinsic we mean that the position of the Fermi level is controlled by the densities of states in the conduction and valence bands). In such a situation the Fermi level moves (linearly with tenperature, to keep the total concentration of excited electrons equal to the holes. It should be noted however that even in this case, If the range of localized states at the edge of say, the valence band is smaller than that in the conduction band, the number of holes excited below E_v will exceed the number of electrons, excited above Ec, and the material may behave as p-type semiconductor.

Fig(2..a,b) illustrates the model of the density of states N (E) and the mobility μ (E) , where the region in which the mobility drops rapidly from extended to localized states discribed as a mobility edge. The densities of localizid states from the valence and conduction bands can be high and very brood, but it still possible that the electronic behaviour will be determined by the behaviour of the relatively small number of carriers, in the high- mobility nonlocalized states.

Thus, the determining feature is a mobility gap rather than a density of state gap. That is the energy difference (E_c-E_v) which defines the mobility gap.

1.3. Electrical conductivity:

The change in electrical properties is more significant at the transition from amorphous state to crystalline state.(14). Amorphous allays behave as intrinsic semiconductors over a wide range of temperature. The electrical conductivity of most chalcogenide glasses is less sensitive mobility one considers fast jumps between neighbouring sites and obtains.

$$\mu = \frac{1}{6}\left[\frac{ea^2}{Kt}\right] V \quad \ldots\ldots\ldots\ldots\ldots(10)$$

where a is the interatomic spacing and v is the jump frequency. A more exact analysis of the transport just above E_c is based on the so- called random model(18,19) in which the extended wavefunctions are represented as a linear combination of atomic wavefunctions which have no phase relation from one site to the next.

1.4. Optical Properties:-

The band gap in amorphous semiconductors plays an important role in their electrical and optical properties.(18) The optical obsorption in the chalcogenide glasses defines an energy gap between the valence band and the conduction band. It is well known that the optical gap of chalcogenide glasses strongly depends on their composition. On the short wavelength side of the spectrum the transparency is limited by the electronic fundamental absorption band. The fundamental edge is observed in amorphous semiconductors although its shape is often quite different from that occuringin crystals. chalcogenide glasses have such edge in the near infrared region. They will be transperent between the