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SOME OPTICAL AND ELECTRICAL PROPERTIES OF MERCURY TELLURIDE THIN FILMS

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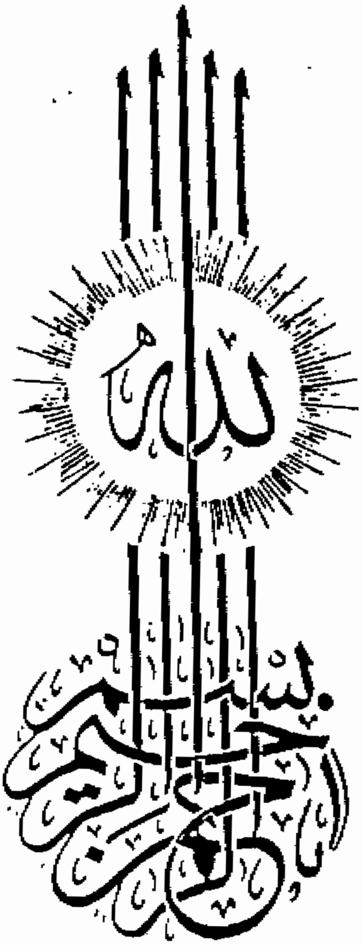

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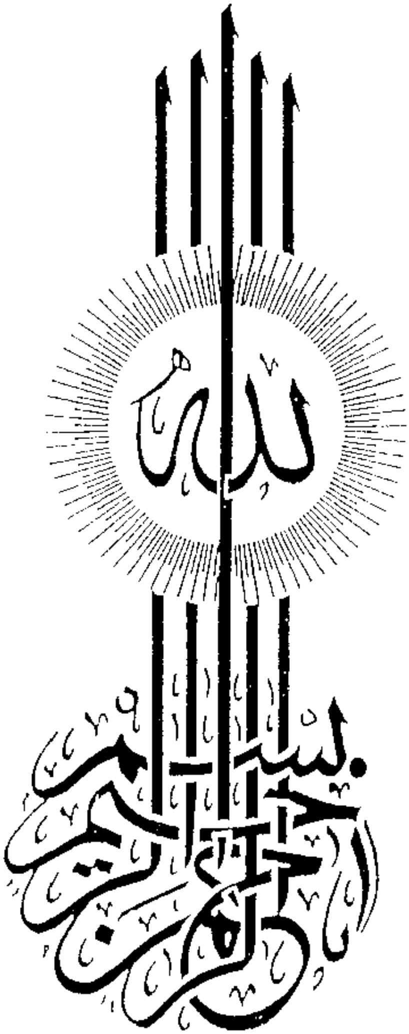
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ABSTRACT

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Thin mercury telluride films of different thicknesses were prepared in vacuum of 10^{-5} Torr by thermal evaporation onto glass substrates. The substrate temperature was that of room temperature (25-35^{o}C) during the deposition process.

The structural investigation of HgTe thin films includes both x-ray and electron microscope diffraction techniques. It was found that such films were polycrystalline having zinc blende structure. The (111) plane of the crystalites shows a preferable orientation parallel to the substrate surface. The degree of orientation as well as the size of the individual crystallites were influenced by the film thickness and the temperature of annealing.

Throughout the dark resistivity measurements of the HgTe thin films, it was found that such films have semimetallic behaviour. Therefore the mean free path (ℓ_o) of the free carriers , and the bulk resistivity (ρ_o) were determined not only at room temperature but also at different elevated temperatures. The thermal activation energy was also determined for HgTe films before and after annealing.

The optical constants (the refractive index n, the absorption index k and the absorption coefficient α) of HgTe thin films were determined in a wide spectral range of 400 - 2000 nm.

Finally, HgTe/n-Si heterojunction was prepared. Throughout the I-V characteristics of such junctions, the series resistance R_s, the shunt resistance R_{sh} and the activation energy ΔE were calculated. It was found that R_s, R_{sh} and ΔE are dependent on the HgTe film thickness. The output powers of the HgTe/n-Si heterojunctions were also calculated.

INTRODUCTION

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The investigation of thin semiconducting and metallic films is of great interest, since it could be used in the solution of a whole series of practical problems (photosensitive layers, resistances, semitransparent contacts,...etc). Apart from this, a careful analysis of the properties of thin films may be useful in explaining of certain aspects of the theory of solids.

Materials which have a high mobility of electric current carriers have been chosen to start with. A high mobility of electric current carriers may be expected for materials with homopolar bonds and, possibily , those with high mass of the atoms which make up the crystal lattice. Beginning with these considerations, electrical properties of intermetallic compounds HgSe, HgTe and their solid solutions have been investigated in (1-25).

Mercury telluride has physico-chemical properties which are analogous of those of mercury selenide: the crystal lattice in each of these compounds is of an identical structure (sphalerite), the predominant type of bond is homopolar, and the current carrier mobilities are great. However, as indicated by Tsidil ' Kovskii(9) , there are considerable difference in the electrical properties of

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LITERATURE REVIEW

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1.1) Optical Absorption Theory:

In recent years, the theory of optical absorption in semiconductors has been developed rapidly. In particular, the theory for the tetrahedrally bonded elements and compounds (diamond and zincblende structure) is in good quantitative agreement with the experimental measurements. From the position and detailed shape of the absorption edge, it is possible to obtain information about the electronic states at the band edges. Additional information concerning higher and lower lying bands may in principle be obtained by measuring absorption at energies beyond the edge, although this techique is limited by rapidly increasing opacity in this region.

In this section, the theory of direct and indirect transitions will be briefly reviewed. The results will then be extended to include modifications appropriate to the region of very small energy gaps.

1.1.a) Direct Transitions

The standard formula for the taransition rate for transitions between bands has the form (12)

$$w_{cv}(\hbar w) = (2\pi/\hbar)|M_{cv}|^{2} \rho_{cv}(k), \qquad (1)$$

where $|M_{cv}|$ is the matrix emelent between bands c and v for the interaction between the incoming radiation of energy $\hbar w$ and electrons, and $\rho_{cv}(k)$ is the density-of-states function for the electron transitions of wave vector k assumed to be unchanged in the transition. If only a pair of standard parabolic valence and conduction bands characterized by effective mass m_v and m_c contribute to absorption, the absoption coefficient for direct allowed transitions takes the form(12)

$$K(\hbar w) = \left(\frac{n}{cN}\right)\left(\frac{2\pi}{\hbar}\right)|M_{cv}|^2 (2\pi)^{-1} \times (2m^*/\hbar^2)^{3/2}(\hbar w - E_g)^{1/2}, \qquad (2)$$

where $m^* = m_c m_v/(m_c+m_v)$, and E_g is the energy gap. The absorption coefficient is thus given by the number of transitions per unit time per unit volume divided by the flux density of quanta cN/n (N is taken to be the density of quanta of energy $\hbar w$) in the material of refractive index n.

Implicit in the derivation of Eq. (2) is the assumption that the excited electron is free to move throughout the crystal unaffected by the other electrons. It has been found necessary to take account of the mutual attraction of the electron-hole pair formed in the absorption process in order to satisfactorily explain the features of the experimental measurements. This survey midifies the expected form of the absorption coefficient near the edge. In this region, the absorption does not rise from zero as indicated by Eq. (2) but from a finite value K (E_g). For this value, Elliot (27,28) obtains

$$K(E_g) = \left(\frac{n}{cN}\right)\left(\frac{2\pi}{\hbar}\right) |M_{cv}|^2 (2m^*/\hbar^2)^{3/2} E_{ex}{}^{1/2}(0), \qquad (3)$$

where $E_{ex}(0)$ is the binding energy of the ground state of an exciton of zero-wave vector. For photon energies greater than E_g by more than 100 $E_{ex}(0)$, the absorption coefficient approaches that givenby Eq. (2).

For quantitative comparisons with experiment, it is necessary to take into account the actual band structrure and evaluate the optical-interband matrix element. Kane has evaluated this matrix element for InSb,(29) and the result may be adapted to other compounds of related band structure.(30,31) The effective mass m* in eqs. (2) and (3). must be summed over the heavy-and light-hole bands which contribute to the absorption at the edge. Assuming that m_s now represents this sum, and taking a value for the optical matrix element characteristic of the 3-5 compounds (32,33) Eq. (3) becomes :