

Photoabsorption and energy band gap of amorphous Se alloy films

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Abstract. Amorphous selenium alloy films have been found to exhibit excellent photosensitive properties from 300 to 700 nm. These films constitute the essential part of xerographic photoreceptors. Optical absorption, energy band gap and X-ray structural analysis of $\text{Se}_{85}\text{Te}_{15}$ and $\text{Se}_{85}\text{As}_{15}$ films are reported. The effect of annealing on these parameters has also been indicated.

Keywords. Photoabsorption; energy band gap; amorphous Se alloy films.

1. Introduction

Photosensitive devices mostly comprise of amorphous thin films, elemental or compound semiconductors like Si, CdS and Se or their alloys in various planar or MOS structure (Misra and Aggarwal 1971; Zallen 1983; Misra 1985; Mehendru and Misra 1986; Sharma *et al* 1989). The lattice ordering in Se thin films plays a dominant role in determining the characteristics and performance of the photosensitive device. The performance of the device depends on preparation conditions, the impurity content, the film thickness and the post-deposition heat-treatment etc. of the film (Lanyon 1964; Watanabe and Kao 1979; Vermaak and Petruzello 1982; Onozuka and Oda 1988). The optical transmission, absorption and electrical conductivity of the amorphous films are determined by the short-range atomic ordering of the lattice (Zallen *et al* 1971; Tauc 1974). In thin films, the local order and defect concentration control the conductivity and photoresponse; hence the photosensitive properties are affected by addition of impurities to the host material (Juhasz and Kasap 1985) as it causes perturbation in the local charge balance (Street and Mott 1975; Anderson 1977; Mott 1985; Mahadevan *et al* 1988). In the present paper we report the preparation, optical properties and structural analysis of amorphous films of Se with Te and As.

2. Experimental

Uniform composition Se-Te films can be prepared by vacuum evaporation of alloy materials (Chiba and Funakoshi 1988). The starting material was prepared by mixing Se and Te in proper composition by weight. The mixture was sealed in an evacuated quartz tube and heated at 500°C for 1 h along with the rotation of the quartz tube. The quartz ampoule was quenched in ice cold water to obtain the Se-Te and Se-As alloy base materials. This quenched alloy was evaporated on to glass substrates held at room temperature in a vacuum of the order of 5×10^{-6} mm Hg. The films thus grown had a thickness of the order of 5000 Å (as determined by mass

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estimation of starting material and the deposited mass). The transmission and absorption spectra of the films in the range 300–2600 nm were obtained by using Hitachi U-3400 computerised spectrophotometer. The energy band gap E_g was calculated using the relation

$$\alpha = (h\nu - E_g)^{1/2},$$

where α is the absorption coefficient and ν the frequency of the incident radiation.

The X-ray diffraction data for the films were obtained and then chemical composition analysed by spectrochemical analysis and these agreed with that of the starting alloy to within 0.1%. The films were annealed in vacuum (10^{-5} mm Hg) at 70°C for 1 h.

3. Results and discussions

The data for $\text{Se}_{85}\text{As}_{15}$ and $\text{Se}_{85}\text{Te}_{15}$ films are reported in this paper. Figure 1 shows the absorption spectra for unannealed and annealed films of $\text{Se}_{85}\text{As}_{15}$ and $\text{Se}_{85}\text{Te}_{15}$ in the 300 to 2600 nm wavelength region. Also included are the data for amorphous Se films (Misra 1985). Se films have a large absorption below 600 nm (curve 5, figure 1). Compared to that of Se, which has a sharp cut-off, the absorption of unannealed $\text{Se}_{85}\text{As}_{15}$ films (curve 1, figure 1) shows a high

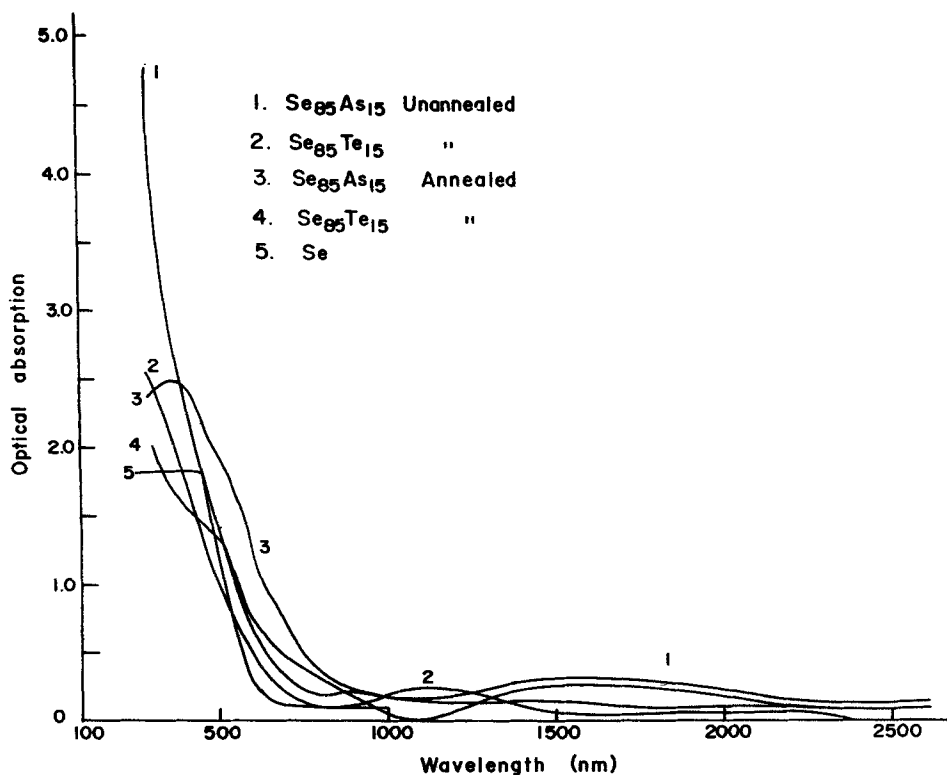


Figure 1. Optical absorption of $\text{Se}_{85}\text{As}_{15}$, and $\text{Se}_{85}\text{Te}_{15}$ alloy films in the wavelength range 300–2600 nm before and after annealing and also of Se amorphous films.

absorption below 500 nm. On annealing (for 60 min at 70°C) these films indicate a lower absorption in the 300 to 500 nm region (curve 3, figure 1).

The data for unannealed and annealed films of $\text{Se}_{85}\text{Te}_{15}$ are depicted in curves 2 and 4 of figure 1. They indicate a high absorption below 600 nm. A peak which appears in the absorption spectra of as-deposited $\text{Se}_{85}\text{Te}_{15}$ films probably shifts to lower wavelength values on annealing.

Figure 2 shows the square of absorption as a function of photon energy for (a) unannealed and (b) annealed $\text{Se}_{85}\text{As}_{15}$ films. On annealing, a peak appears at about 4 eV which is due to crystallization.

The X-ray diffractograms of unannealed and annealed $\text{Se}_{85}\text{As}_{15}$ films and of the annealed $\text{Se}_{85}\text{Te}_{15}$ films are shown in figure 3, traces (a), (b) and (c) respectively. These data were taken for films annealed for 10 min at 70°C. Peaks due to formation of microcrystallites in an amorphous matrix are seen for the annealed films. Similar results are reported during annealing of InSe films (Sharma *et al* 1990).

Figure 4 shows the band gap energy vs annealing time for these films. The annealing temperature is 70°C. The as-deposited films of Se, $\text{Se}_{85}\text{As}_{15}$ and $\text{Se}_{85}\text{Te}_{15}$ have band gap energies of 2.62, 2.56 and 2.30 eV respectively. The effect of annealing is dominant within the first ten min. For $\text{Se}_{85}\text{As}_{15}$ films, the band gap reduces from 2.56 eV to 2.47 eV after annealing for 10 min and reduces to 2.20 eV for larger annealing times. For the $\text{Se}_{85}\text{Te}_{15}$ films, on the other hand, the band gap increases from 2.39 to 2.47 eV in the first 10 min and increases to 2.65 eV on further annealing. In the case of Se, the band gap reduces from 2.62 eV to 1.70 eV on annealing. Thus, annealing of $\text{Se}_{85}\text{Te}_{15}$ films renders these films more insulating compared to those of $\text{Se}_{85}\text{As}_{15}$ films, which become more conducting on annealing. Similar results have been reported for As-Se halide and Ge-Se glasses (Napó *et al* 1988; Sanghera *et al* 1988).

4. Conclusion

Amorphous film of Se with Te and As can be prepared by vacuum evaporation of

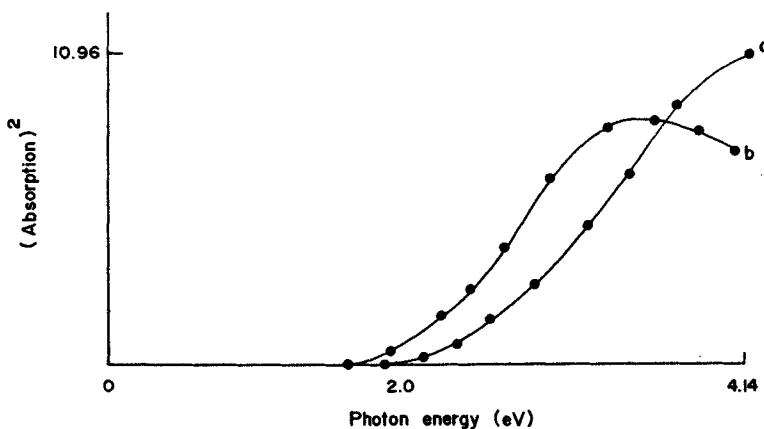


Figure 2. Variation of the square of optical absorption with photon energy for (a) unannealed and (b) annealed $\text{Se}_{85}\text{As}_{15}$ films.

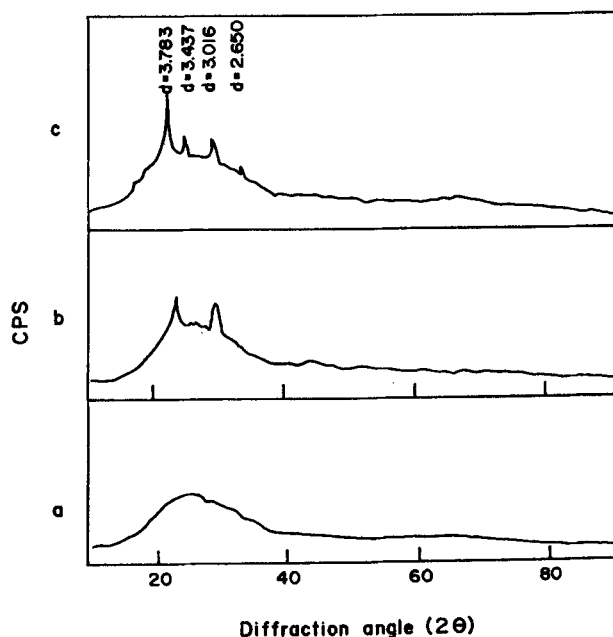


Figure 3. X-ray diffractogram of $\text{Se}_{85}\text{As}_{15}$ films. a. unannealed, b. annealed, (for 10 min at 70°C) and c. annealed $\text{Se}_{85}\text{Te}_{15}$ films (for 10 min at 70°C).

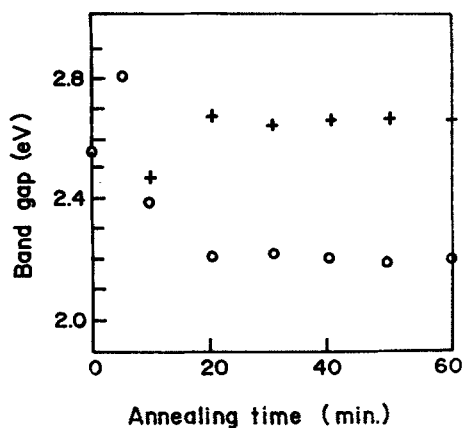


Figure 4. Variation of the energy band gap of the Se, $\text{Se}_{85}\text{As}_{15}$ and $\text{Se}_{85}\text{Te}_{15}$ alloy films, with duration of annealing.

the base materials. The alloy films of Se with Te and As have advantage over pure amorphous Se in their modified optical absorption, electrical conductivity and variable energy band gap, depending upon the composition of the alloy materials. The optical absorption of $\text{Se}_{85}\text{Te}_{15}$ and $\text{Se}_{85}\text{As}_{15}$ extends over a wide range of wavelengths yielding an improved photosensitivity. Annealing of the films modifies the optical absorption, energy band gap and electrical conductivity and induces crystallization of the alloy films. Efficient photoreceptors can be prepared by using the appropriate composition, annealing temperature time and film thickness.

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References

- Anderson P W 1977 *Phys. Rev.* **B16** 420
Chiba R and Funakoshi N 1988 *Thin Solid Films* **157** 307
Damodar Das V and Jansilaxmi P 1988 *J. Mater. Sci.* **23** 3869
Juhasz C and Kasap S O 1985 *J. Phys.* **D18** 721
Lanyon H P D 1964 *J. Appl. Phys.* **35** 1616
Mahadevan S, Giridhar A and Singh A K 1988 *J. Non-Cryst. Solids* **3** 155
Mehendru P C and Misra S C K 1986 *Indian J. Technol.* **24** 576
Misra S C K and Aggarwal Y K 1971 *Res. Ind.* **16** 260
Misra S C K 1985 *Indian J. Pure Appl. Phys.* **23** 78
Misra S C K, Sharma T P, Sharma S K, Kumar R and Jain G 1990 *Indian J. Technol.* **28** 205
Mott N F 1985 *Contemp. Phys.* **26** 203
Napo K, Bernede J C, Safoula G, Burgand P and Aneriziani A 1988 *Thin Solid Films* **157** 291
Onozuka A and Oda O 1988 *J. Non-cryst. Solids* **103** 289
Sanghera J S, Heo J and Mackenzie J D 1988 *J. Non-cryst. Solids* **103** 155
Sharma D C, Misra S C K, Kamalasanan M N and Chand S 1989 *Indian J. Pure Appl. Phys.* **23** 53
Sharma T P, Sharma S K, Kumar R, Jain G and Misra S C K 1990 *Indian J. Pure Appl. Phys.* **28** 486
Street R A and Mott N F 1975 *Phys. Rev. Lett.* **35** 1293
Tauc J 1974 in *Amorphous and liquid semiconductors* (London: Plenum)
Vermaak J S and Petruzello J 1982 *J. Appl. Phys.* **53** 6809
Watanabe H and Kao K C 1979 *Jap. J. Appl. Phys.* **18** 1849
Zallen R 1983 *Physics of amorphous solids* (New York: John Wiley)
Zallen R, Drews R E, Emerald R L and Slade M L 1971 *Phys. Rev. Lett.* **26** 1564