Structural and Optical Properties of Electron-beam-evaporated ZnSe$_{1-x}$Te$_x$ Ternary Compounds with Various Te Contents

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ZnSe$_{1-x}$Te$_x$ films with different tellurium (Te) contents were deposited by using an electron beam (EB) evaporation technique onto glass substrates for applications to optoelectronic devices. The structural and the optical properties of the ZnSe$_{1-x}$Te$_x$ films were studied in the present work. The host material ZnSe$_{1-x}$Te$_x$, were prepared by using the physical vapor deposition method of the electron beam evaporation technique (PVD: EBE) under a pressure of 1 × 10$^{-5}$ mbar. The X-ray diffractogram indicated that these alloy films had cubic structure with a strong preferential orientation of the crystallites along the (1 1 1) direction. The optical properties showed that the band gap ($E_g$) values varied from 2.73 to 2.41 eV as the tellurium content varied from 0.2 to 0.8. Thus the material properties can be altered and excellently controlled by controlling the system composition x.

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I. INTRODUCTION

Zinc Selenide(ZnSe) with its wide direct bandgap of 2.67 eV at 300K is the most promising material for blue optoelectronic devices [1–4]. ZnSe has been used as a window material for thin film CdTe solar cells [5]. Intense green and red luminescence has been achieved in doped ZnSe [6]. Zinc telluride (ZnTe) has been intensively investigated during the last years as a contact material for p-type CdTe in large-area low-cost solar cells [7–9]. ZnTe always exhibits p-type conductivity due to a high degree of self-compensation of incorporated donors by native defects and can be readily doped with arsenic to resistivities as low as 1 Ω cm [9,10]. Ternary alloys, such as ZnSe$_{1-x}$Te$_x$, are technologically useful because the bandgap can be tuned between the end-member values as the composition “x” is varied. This makes the proper characterization of these materials the subject of many investigations [11–14]. ZnSe$_{1-x}$Te$_x$ is an example of an II-VI semiconductor pseudo-binary alloy that can be made over the entire range of compositions [15]. II-VI alloys are becoming increasingly important because they are often used as the basis for magnetic semiconductors with the additional alloying of small amounts of Mn on the metal sub-lattice [16, 17]. The recent suggestion that high-speed logical circuits can be made out of devices by using spin diffusion instead of electron diffusion called “spintronics” is adding extra impetus to research on these materials [18]. Hence, it is important to characterize the structural and the optoelectronic properties of these alloys in detail.

The study of alloys is complicated by the fact that considerable local atomic strain is present due to the disordering effect of the alloying. This means that local bond-lengths can differ from those inferred from the average (crystallographic) structure by as much as 0.1
II. EXPERIMENT AND DISCUSSION

Thin films of ZnSe$_{1-x}$Te$_x$ with different “x” compositions were deposited from ZnSe and ZnTe powders (Aldrich, 99.99%) by using electron beam evaporation technique in a HINDHIVAC vacuum coating unit (model: 12A4D) fitted with an electron beam power supply (model: EBG-PS-3K). Finely-powdered samples of ~ 10g of ZnSe$_{1-x}$Te$_x$ were made with x = 0.2, 0.4, 0.6 and 0.8. The starting reagents (zinc selenide, metal basis, 99.9995%; zinc telluride, metal basis, 99.999%) were finely ground, mixed in the correct stoichiometry, and sealed in quartz tubes under vacuum. The samples were then heated at 900 $^\circ$C for 12 – 16 hours. This procedure of grinding, vacuum sealing, and heating was repeated two times to obtain high-quality, homogeneous materials. The colors of the solid solutions varied gradually from dark red (ZnTe) to brownish yellow (ZnSe) as the x-value was decreased, reflecting the bandgap of the alloy samples smoothly changing in the optical frequency range. By taking into consideration the different melting points and vapor pressures of elemental Zn, Te and Se, we deposited the ZnSe$_{1-x}$Te$_x$ films on glass substrates. The different preparation parameters, such as the source-to-substrate distance (12 cm) and the partial pressure (10$^{-5}$ mbar), were varied and optimized for depositing uniform, well-adherent and transparent films. The films were found to be uniform and pore-free, and adhered well to the glass substrates.

The normal spectral transmittance (T) was measured by using an UV-vis-nir spectrophotometer over the wavelength range 300 – 2500 nm. The calculation of the absorption coefficient $\alpha$ gave a higher value of 10$^4$ cm$^{-1}$ near the absorption edge, and in the visible region, $\alpha$ depended on the radiation energy and on the composition of the films. The absorption data were analyzed using the relation for the near-edge absorption of direct-bandgap semiconductor films:

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

The structural properties of the films were studied by using a JEOL JDX X-ray diffractometer (XRD) with Cu Kα radiation ($\lambda = 1.541$ Å) and a Ni filter. The optical spectra were recorded in the wavelength range 300 – 2500 nm by using an UV-Vis-NIR spectrophotometer (Hitachi V-3400). The surface morphology of the films was studied by AFM. XRD spectra of the EB-evaporated ZnSe$_{1-x}$Te$_x$ with different Te contents x = 0.2, 0.4, 0.6 and 0.8 were analyzed to study the film’s nature, phases and structure. This provides information about the lattice of the ZnSe base binary material, which has been modified by the introduction of different ZnTe contents. This is attributed to the fact that the atomic radius of Te is 1.405 Å which is larger than that of Se atom, 1.255 Å [21]. The actual amounts of the elements in ZnSe$_{(1-x)}$Te$_x$ films for different “Te” composi-