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STRUCTURAL AND TEM ANALYSIS OF $Zn_{1-X}Mn_XTe$ CRYSTALS

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Abstract: Single crystals of $Zn_{1-x}Mn_xTe$ have been grown using vertical Bridgman growth technique. XRD analysis supports the zincblende structure of $Zn_{1-x}Mn_xTe$. As the concentration of Mn increases ($x > 2.5$), the single crystalline nature deteriorates (i.e grain size decreases) and polycrystalline nature with zincblende and hexagonal phases have been observed from x-ray diffractograms. This is supported by Transmission Electron Microscopic study of the samples. Surface morphology is studied from optical microscopic studies.

Keywords: $Zn_{1-x}Mn_xTe$ (ZMT)Crystals, Transmission electron microscopy (TEM), Bridgman growth technique, Optical microscopy.
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Introduction

Substitution of magnetic ions like Mn, Fe, Co etc in II-VI, III-V and IV-VI host lattice leads to a new class of materials known as semi magnetic semi conductors or diluted magnetic semi conductor (DMS). In recent years II-VI doped with Mn alloys are attracted the scientific community because of their unique properties like giant faraday rotation [1-3], tunnability of lattice parameter and energy gap with respect to the concentration of Mn [4]. Single crystals with controlled addition of

Mn^{2+} magnetic ion in ZnTe host lattice (i.e., $Zn_{1-x}Mn_xTe$) has potential applications. $Zn_{1-x}Mn_xSe$ and $Zn_{1-x}Mn_xS$ crystals exhibits electro luminescence, which is an advanced stage in fabrication of flat panel display [5]. Nano structures of DMS have revolutionary applications in non-linear optics, fast optical switching and memory devices [6]. MnTe solubility in ZnTe is maximum ($x<0.86$) when compared to other DMS [7] but MnTe is highly unstable, decomposes immediately and crystallizes in zincblende form. Zincblende structured $Zn_{1-x}Mn_xTe$ crystals have been grown conventionally by melt growth technique [8]. Various methods of preparation of $Zn_{1-x}Mn_xTe$ in vertical and horizontal Bridgman methods have been reported [9]. Growth, structural (TEM & XRD) analysis, were carried out for microscopic structure of the crystals[10].

EXPERIMENTAL

ZMT crystals with different concentrations of Mn (x=0.1, 0.25,0.45,0.5,0.6 etc) have been prepared by Vertical Bridgman technique(VBT). The starting materials, ZnTe and freshly synthesized MnTe are taken in a quartz tube of 0.8 mm x15cm dimensions evacuated to $2x10^{-6}$Torr pressure, with one end conically shaped capillary. This was pulled with 0.6mm/hour through a furnace of temperature gradient 10^oC/cm. X-ray diffraction patterns of the crystals are recorded in the scanning range 20^o-100^o using Philips PW3020 X-ray diffractometer with Cu K_α (wavelength λ=1.542 A) target as X-ray source. Transmission Electron Microscopy [10] is used for characterization of the microstructure of the samples.

RESULTS AND DISCUSSION

(i) Structural Studies

X-ray diffraction spectra for ZMT crystals with different concentrations of Mn are shown in figure 1. For lower concentrations ($x < 0.2.5$) of Mn, XRD peaks and their corresponding (h k l) indexing support the zincblende structure of ZMT and the grain sizes are calculated from Debye-Scherrer's relation [11]. For higher concentrations of Mn ($x>0.25$), the single crystallinity is deteriorated and polycrystalline nature of peaks is observed. As the concentration of Mn increases the grain size is decreased as shown in table.1. The chemical compositions obtained from EDAX

analysis are in agreement with the starting compositions (x) with ± 0.05%. This variation may be due to the contamination of oxygen, with the starting materials during the growth process at high temperature (i.e.1300 C ^{0}).

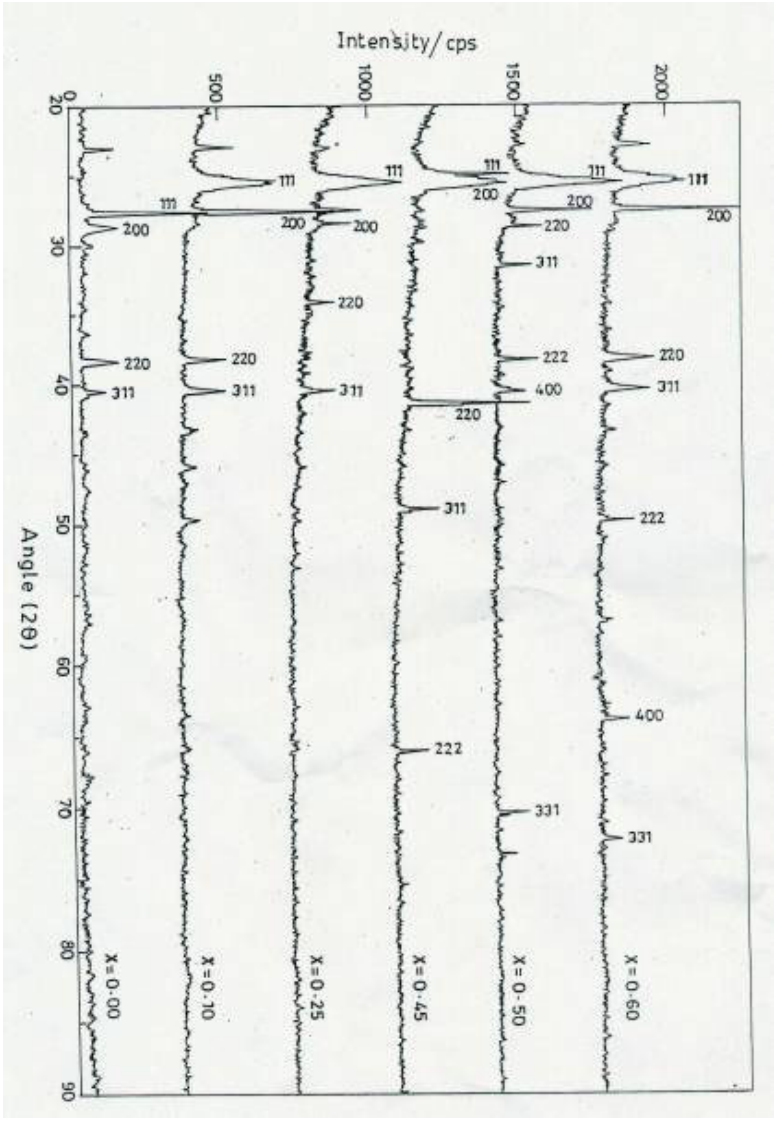

Figure 1. X-ray diffractograms for different concentrations of ZnMnTe for x=0.0, 0.1, 0.25, 0.45, 0.50, 0.60.

Compound	Concentration (x)	Grain Size (microns)
$Zn_{1-x}Mn_xTe$	0.10	0.02266
	0.25	0.01416
	0.45	0.01251
	0.50	0.01175
	0.60	0.00952

Table 1. Concentration of Mn as a function of the grain size

(ii) Optical and TEM Analysis

From optical photographs figures 2 and 3, it is observed that the surface of the crystal is not uniform (at 500 ^{X} magnification), the crystallites with different facets shows that at the interface of the growing crystal and the surface of the quartz tube, nucleation process is not uniform. Figure 4

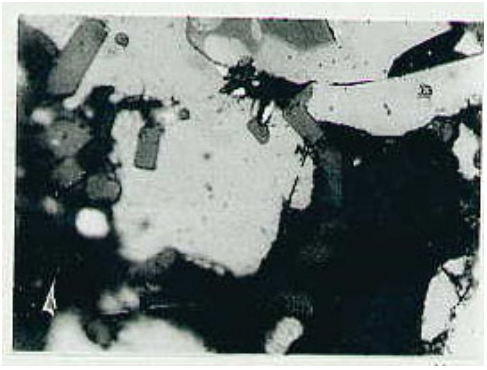

Figure 2. Optical micrographs showing the surface of the crystal with different facets (500X resolution).

Figure 3. Surface morphology of the crystal with increase in crystallite size (500X resolution).

Figure 4. TEM bright field micrograph showing the (100nm) size of particles with uniform texture (defect free surface with nucleation sites for x = 0.25).

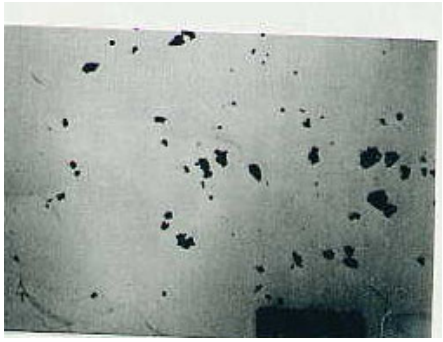

Figure 5. TEM bright field image for a crystal of high concentration with enhanced magnification.

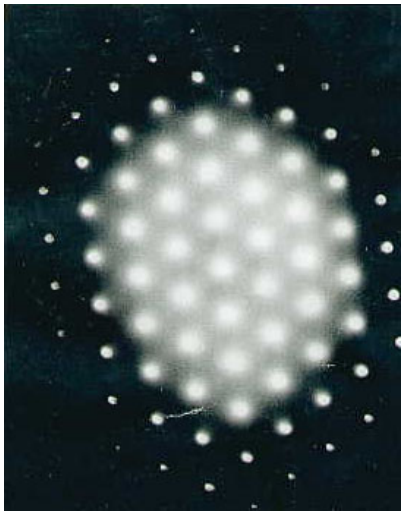

Figure 6. Crystallite at a selected area diffraction showing hexagonal phase for x = 0.5.

shows bright field image of the particle i.e. the defect free crystals at lower concentrations of Mn ($x<0.25$) at 100nm resolution, while figure 5 shows the bright field image of the particles at higher concentration at 100 nm resolution. These regions do not show any detailed structure but indicates randomly oriented small crystallites and precipitations of tellurium [12]. Figure 6 represents the hexagonal phase of MnTe at higher concentration for $x=0.5$ from the selected area diffraction of TEM analysis. At higher concentration of Mn, more brittle and poor quality of crystals is formed with multi phases (zincblende and hexagonal) and least amount of contamination of oxygen was observed. Tellurium rich phases are also observed for higher concentration of Mn. From the grain size calculation and micrographs obtained from TEM analysis confirm the grain sizes in nano scale range and hence a nano phase existence is observed [13].

Conclusions

ZMT crystals have been grown for different concentrations of Mn using conventional Bridgman technique successfully. XRD analysis confirms the zincblende structure of the substance at lower concentrations of Mn while at higher concentrations zincblende and hexagonal mixed phases are observed. This was supported by TEM analysis of the samples. Least amount of contamination of oxygen was observed.

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