

Growth and Characterization of ZnTe Crystal

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Abstract— High quality ZnTe crystals have been synthesized by vapor Transport method. The grown crystals were p-type. The concentration and mobility were $2.5 \times 10^{16} \text{ cm}^{-3}$ and $23 \text{ cm}^2/\text{Vs}$ at 300K, according to Hall effect measurements. Surface morphology of the crystal was investigated by scanning electron microscope (SEM). Crystal orientation and lattice parameters of the crystals were also analysed by XRD. From X-ray diffraction studies the structure of the grown crystals were found to be zinc-blende. The crystal emitted light in the visible range at room temperature.

Keywords— High quality crystals, p-type, zinc-blende, SEM, XRD

I. INTRODUCTION

Crystalline Zinc Telluride having a direct wide band-gap has attracted many researchers due to its important luminescence properties [1]. Since wide-gap II-VI compounds have higher ionicity, higher melting points and higher vapor pressure at the melting point than those of III-V and element semiconductor. It is difficult to grow their bulk crystal from the melt, compared III-V compound. The method of chemical transport reaction was one of the methods in vapor-phase growth techniques and usually used to grow single-crystals of binary and ternary chalcogenides such as ZnS, ZnTe, ZnSe, CdSe, CdS, HgI₂ and their ternary compounds. The term chemical transport reaction was first introduced by Schafer. Reynolds and Czyzak. Reynolds and Greene, Samelson and Nitsche used to grow single-crystals by chemical transport reaction with following transporting agents: I₂, Br₂, Cl₂, NH₄Cl, HCl and H₂S[2].

Crystallization from the vapor phase has an advantage over a melt growth, particularly for II-VI compounds as they have high melting temperature which can make the melt growth process difficult to be handled. Physical vapor transport acts a purification process because of difference in vapor pressure of native elements and impurities. Though to increase the transport rate and to reduce the growth temperature, the transporting agent (I₂) can be employed in case of Chemical Vapor Transport technique [3] but the disadvantage is the high level of unintentional doping of transporting agent (I₂) [4, 5].

The wide band gap II-VI compounds (Zinc Chalcogenides: ZnSe, ZnS, ZnTe) are promising materials for their use in many optoelectronic applications. ZnTe having a direct band gap of 2.26 eV at room temperature is one of the most important among them. Due to its wide band gap, it can effectively emit light of 540 nm, which is the spectral region

having maximum sensitivity for the human eyes. Thus this is the promising material for its application in pure Light Emitting Diode and Laser Diode [6, 7]. It also has a potential application as IR optics, crystal pieces for vacuum deposition and window material for CdTe based solar cells [8]. Because of its large electro-optic coefficient among most of the compound semiconductors it can be used as a terahertz detector [9]. Another reason for continued interest in II-VI compound semiconductor research is the search for the blue emitting materials. To increase the life time and to improve the performance of the electro optical devices based on ZnTe compound it is necessary to improve the basic properties of the grown compound.

II. EXPERIMENTAL PROCEDURE

A. Crystal Growth Process

High purity (99.99%) of Zn and Te powder (atomic ratio 48:52) were filled in a dried ampoule of 25 mm of diameter and 200 mm of length. Before filling of the materials the ampoule was properly washed and rinsed with distilled water. The ampoule was sealed at pressure 10^{-5} Torr. This sealed ampoule was placed in a dual zone furnace to obtain a charge of ZnTe at constant reaction temperature. Ampoule was maintained at constant temperature of 800°C for 30 hours and then cooled down to room temperature. The charge thus prepared was rigorously shaken to ensure the proper mixing of the constituents.

The synthesis of ZnTe is usually carried out directly from the elements. It is a highly exothermic reaction, sometimes leading to explosions.[10]. The synthesized compound was transferred into another quartz ampoule and was sealed at pressure of 10^{-5} Torr. This sealed ampoule was now loaded into two zone furnace for crystal growth. The source zone was kept at higher temperature compared to that of the growth zone for a finite period of time. In order to avoid any influence of mechanical vibration to the crystal quality, ampoule was kept motionless during the growth process. After definite time of period, it was slowly cooled down at the rate of 20 °C per hours to the room temperature. The temperature gradient was set to 50 °C that the resulted in the formation of small crystals.

III. RESULTS AND DISCUSSION

A. Experimental Result of ZnTe Crystal Growth

Complete details of the growth parameters for growth cycles of about 72 hours are shown in Table 1. The grown crystals were single crystals and they are in the forms of knife-edge and platelet. These knife-edge single crystals are grown on a cluster of polycrystalline mass. The grown crystals are shown in Fig.1. The color of the crystals is deep red.

TABLE I
GROWTH CONDITIONS FOR VARIOUS CYCLES FOR ZnTe CRYSTAL

Run No.	Temperature Distribution			Result
	Hot Zone	Cold Zone	Diff.	
1.	800 °C	700°C	100 °C	Ingots
2.	800 °C	750 °C	50 °C	Needle-like
3.	900 °C	800 °C	100 °C	Ingots
4.	900 °C	850 °C	50°C	Crystals

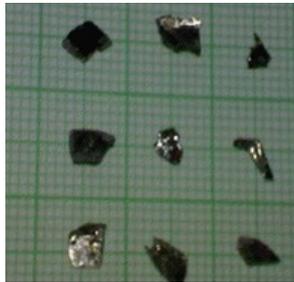


Fig. 1 As grown crystals of ZnTe

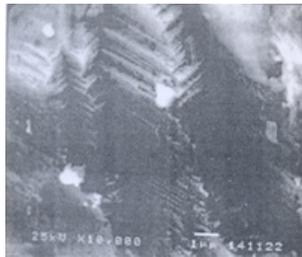


Fig. 2 SEM micrograph of ZnTe crystal

B. Scanning Electron Microscopy of ZnTe Crystal

The as-grown crystal surface features are examined by utilizing a scanning electron microscopy. Then the crystal surface was analysed by the scanning electron microscope with the accelerating voltage of 25kV and magnification is 10^4 . Fig. 2 shows SEM micrograph of ZnTe crystal. The triangular patterns are spreading along the crystal surface. These as-grown layers are developed step by step with few striations. Most of these steps are not of the same size and the step heights are different from one another. The triangular

pattern size is $2.5 \mu\text{m} \times 1.5 \mu\text{m}$. The length of one side of the triangular at the base is $4 \mu\text{m}$ long.

C. X-ray Diffraction Study of ZnTe Crystal

X-ray diffraction analyses are used to study phase formation and transformation, lattice parameters, the preferred orientation of ZnTe crystal. The crystal structures of the ZnTe crystal are characterized by X-ray diffraction, (Rigaku model RINT 2000 diffractor) using $\text{CuK}\alpha$ radiation ($\lambda = 1.54056 \text{ \AA}$) with 40kV/30 mA), sampling width of 0.02° , and scan speed of $4^\circ/\text{min}$, in the 2θ range of 20° - 60° . More than five prominent diffraction peaks from 20° - 60° are corrected in order to calculate lattice constants.

The X-ray diffractogram of ZnTe shows a well-defined sharp diffraction peaks as shown in Fig. 3. Since the peaks (111), (201), (211), (300), (311) and (321) for corresponding angles 2θ s of 25° , 32° , 37° , 42° , 50° and 56° are observed, it is confirmed that the prepare ZnTe sample is formed as a crystal. The sharpness of the peaks indicates good crystallinity of the specimens. There is no peaks either Zn or Te except zinc blende ZnTe. In the X-ray data, the position and intensities of X-ray diffraction peaks of ZnTe correspond to zinc blende structure and lattice constant is 6.078 \AA .

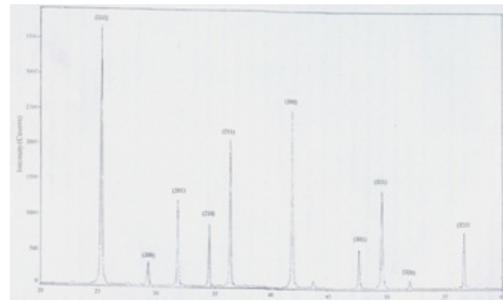


Fig. 3 XRD patterns of ZnTe Crystal

D. Electrical Characteristic of ZnTe Crystal

Fig.4 illustrates the I-V characteristic of ZnTe crystal. It is exhibited the poor diode characteristic and also studied the emission of light from the surface of the samples at room temperature. The characteristic curve consists of five regions:

1) *Region I (Ohm's law region)*: At low values of the applied voltage, the current was proportional to the voltage as shown in I-V characteristic. Using the relation for a semi-ideal function; $I = A \exp(qV/nKT)$ in Fig. 4. It is found that n was equal to $1.67 \sim 2$.

2) *Region II (power-law region)*: The power-law dependence for the sample is $I \propto (V - V_0)^m$ and 'm' is 2.17. This region predominate also at room temperature, beginning from current of 50 mA.

3) *Region III (transition)*: With further increase of voltage beyond region II, the current rose sharply. This sharp rise is caused by the filling of the traps of density. At the voltage of

the end of the transition region, then one may obtain the current ratio of about 100 fold.

4) *Region IV (emission)*: After the rise in current was terminated at the end of the transition region. In this region it could be observed for light emission are perceived by naked eye and also the proportional increase in its intensity with increasing current. These experimental results will give the evidence for the presence of both free holes and free electrons from which electroluminescence is produced by the radiative recombination of them. The threshold voltage for light emission was about 5 V to 6 V for DC operation.

5) *Region V (break down region)*: The I-V characteristic of Fig.4 exhibited the current decrease when sufficiently large voltage are applied. Then it may be that the negative resistance results from thermal breakdown in the semi-insulation layer.

In the as grown state, ZnTe shows only p-type conductivity by hot probe measurement. The Hall effect in ZnTe crystal has been measured by a DC method. The four-probe method was used to determine the resistivity is 10.51 Ωcm at 300 K. The Hall effect measurements give the right value for the carrier concentration 'p', which according to the introduction is that of the crystal is given by the equation,

$$p = \left(\frac{B}{e}\right) \left(\frac{J}{E_H}\right) \quad \text{Equation (1)}$$

where, e is the magnitude of the charge on the carrier, J is the current density, B is the magnetic field and E_H is the electric field intensity. The calculation of the mobility in this work is based on the fact that the mobility of the perfect crystal can be determined by combining DC Hall measurements giving the carrier concentration. The mobility 'σ' is calculated from the equation,

$$\sigma = pe \mu \quad \text{Equation (2)}$$

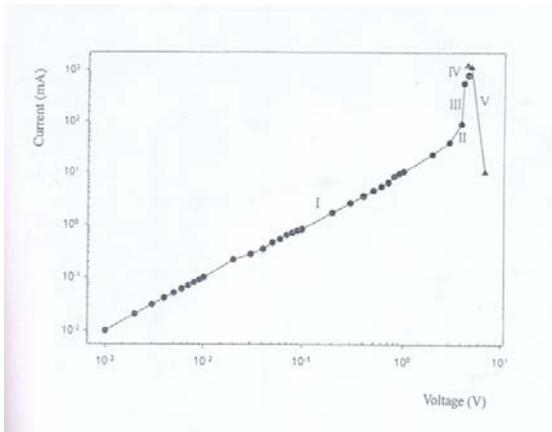


Fig. 4 I-V Characteristic of ZnTe Crystal on a Logarithmic Scale

IV. CONCLUSIONS

Vapor Transport Technique is suitable for the growth of ZnTe crystals. It is found that the temperature gradient of 50°C is appropriate for the growth of small shining crystal. The X-ray diffraction analysis confirms zinc-blende structure of grown crystals. The crystal is examined by XRD and SEM. In the as-grown state, ZnTe shows p-type conductivity, while n-type conductivity is difficult to achieve.

Electrical measurement were made using copper contacts to the top and bottom surfaces of ZnTe crystal. The I-V characteristic obtained for these crystal were reproducible on reversal of polarity, as depicted in Fig. 4. The threshold voltage for light emission was about 5 V to 6 V for DC operation. ZnTe semiconductors have excellent photoluminescence properties and they cannot be doped. One can notice that it is impossible to dope n-type. This limitation is also believed due to self-compensation by electrically active native defects.

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