Growth Techniques and Some Physical Properties of InSb Single Crystal

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Abstract:

Near intrinsic single crystal of InSb compound has been grown from the pure melting by annealing of two-zone furnuse technique and its some physical properties are characterized at room temperature. X-ray diffraction (XRD) observations show that the crystallographic direction is well oriented within (220) plane, while it is indicated that there is a poly crystalline structure for InSb thin films. The absorbance spectra at the fundamental absorption edge has been measured .The values of optical energy gap of single crystal specimens and deposited InSb films were calculated of 0.16 eV and 0.17 eV respectively at room temperature.

The aim in this paper is to study and compare the growth of single crystal and thin film to InSb.

Key words: Growth Techniques, InSb Single Crystal, and Physical Properties.

Introduction:

InSb material is a binaries (V-III) semiconductor which crystallize in the zince-bland (Zb) structure [1]. Previous studies of InSb semiconductors, showed that the optical band gap (o.18 eV) at 20 °C is closed to the optical band of atmosphere window at (3-5 μm) region[2]. The InSb devices as thermal cameras are important mostly in thermal detection of hot bodies at temperature range of (400-700)°C. It is the best material available for magnetic-field sensing devices such as Hall sensors and magneto resistors[3], speed-sensitive sensors[4], millimeter wave devices[5], and magnetic sensors[6].

This paper will present the resulting reported of growth techniques and experimental measurement made on representative InSb crystal specimens and thin film samples prepared at room temperature.

Material and Methods:

A- Bulk Material

Single crystal was grown in a manner similar to that described by Hulme and Mullin[7], King and Berhett[8], and others[9]. The sample was prepared by combining indium and antimonid in stoichiometric proportions. A quartz ampole was filled with the desired material. It was then evacuated to less than (10^{-5} mbar) by a conventional vacuum system. This consisted of a liquid nitrogen trap, a three-stage oil diffusion pump, and a mechanical rotary pump.

The resulting single crystal of InSb is grown from pure melt by vertical growth of two-zone furnuse as the following procedure. A quartz capsule is located in furnuse with central axis for heating quality. The capsule head was connected to nicrom wire for slowly pooling and position changing with temperature range in furnuse

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zone. The modified furnuse from Linberg company has digital temperature reader and electronic controller was computerized as shown in figure (1)[10].

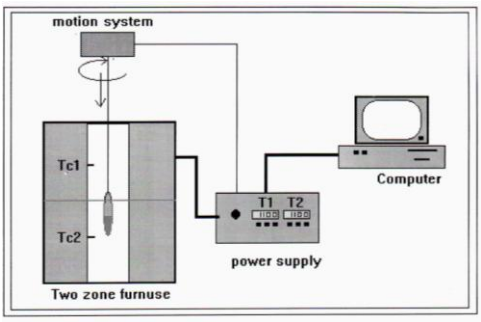

Fig.(1) crystal growth system (vertical)[10]

The melting temperature point (120 °C for In) was maintained for three hours to insure a completed melting. The furnuse temperature was raised to 600°C at rate (20 °C/hr) and maintained for three hours to insure a completed reaction. Upon cooling to temperature (60°C) at (5°C/hr), then reduction to room temperature. Figure (2) shows the sketch of timing diagram with temperature variation. The capsule was removed from the furnuse and broked. The usual ingot dimension was formed as quartz capsule (l = 20mm, ϕ=10mm). The sample was next prepared for (XRD) and optical measurements by either cleaning the specimens or sawing and polishing to appropriate dimensions in a manner similar to that described by Kurnick and Zitter[6].

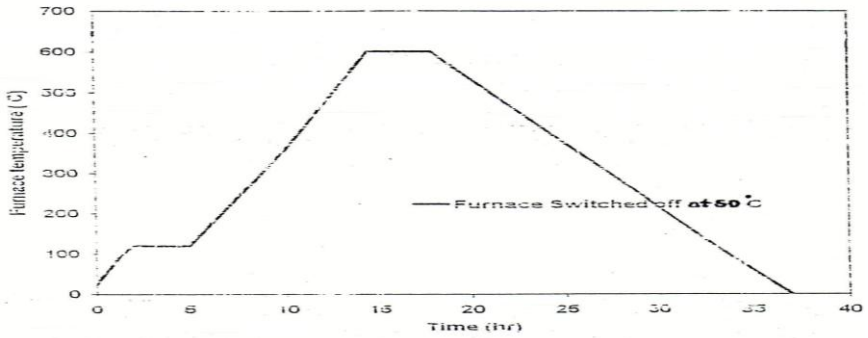

Fig.(2) diagram of the variation at turns temperature with annealing time for mixture of InSb compound

The preparation of thin specimens (0.5-1 mm) may be carried out by sowing and polishing by micro cloth-diamond paste (0.25, 1.5 and 3µm). The fine polishing is required for removing the surface defects and the affect of chemical reaching on crystal specimens are being qualified. This process is done by using a mixture of HNO_3 (16% + 5mL), HF (40% + 3mL), and CH_3COOH (27% + 3mL) acid. A HNO_3 acid being used to chemical removing, HF acid is being used to prevent the surface oxidation, while a CH_3COOH acid is being used as reaction assistance. The specimens are mixed in the acids mixture for two second and this procedure stops, when specimens have (100µm) thickness. As surface conductance and recombination can be important, the etching process must be carefully controlled.

B- Thin Films:

Depending on the nature of the original material the film from which it is formed may be influenced by the rate of evaporation, the kind and temperature of the substrate and the vacuum conditions during evaporation. It was therefore, essential to control as

many variable as possible to a certain the effect of each on the optical characteristics of the thin films. Modified Balzer coating unit (BAE O8O) was used to permit evaporation the InSb powder and deposited on substrates of ZnSe single crystal which has transmittance spectra as shown in figure (3). The substrates temperature was maintained at 200°C with annealing treatment (200°C/hr).

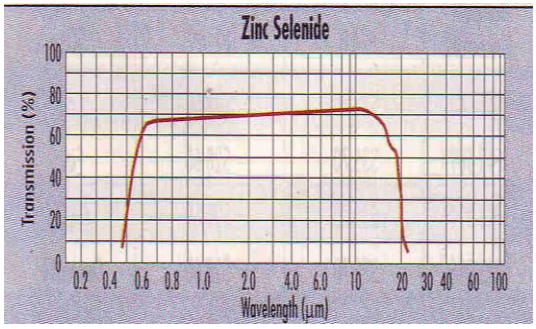

Fig.(3) :The transmittance spectrum of ZnSe substrate

Philips X-ray diffractometer was used to determine the crystalline structure of InSb ingot samples. FTIR spectrophotometer from Parkin Elemer was used to carryout the optical absorption spectrum in the (1-9)µm range of wavelength for the prepared crystal specimens and thin films. The absorption coefficients were calculated using the following equations [7]:

$$\alpha = 2.3\frac{A}{t} \ldots\ldots \qquad (1)$$

Where **A** is the absorbance percentage and **t** refers to the specimen thickness, and used the equation (2) to find the energy gap.

$$\alpha h\upsilon = A\,(h\upsilon - E_g)^n \quad \ldots (2)$$

Where **h** is Blanck constant, **υ** the frequency and $\mathbf{E}_g$ the energy gap.

Results and Disscuyions:

The X-ray analysis of prepared single crystal specimens indicates that the one growthing direction closed to (220) plane and the intensity of this plane reflection increases for near stoichiometric compound. This is illustrated in figure (4) which has a single peak position. Our results are a good agreement with A.S.T.M. card data of standard InSb compound properties, and JCPDS-ICDD No. 6-208 (Int. diff. data 1990).

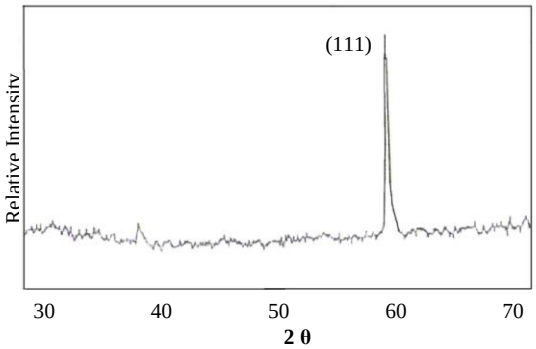

Fig.(4) the X-Ray Diffraction patterns of InSb crystal prepared

The previous studies observed that, when grown from an essentially pure melt, Si, Ge, GaAs, InSb, and many other materials have as their most slowly growing planes the [111] family[11,12,13]. Figure (5) is concluded that the polycrystalline InSb film can be grown highly oriented along the (220),(200) and ,(111) direction by vacuum evaporation technique. The results are in comparable with films prepared by other techniques [14].

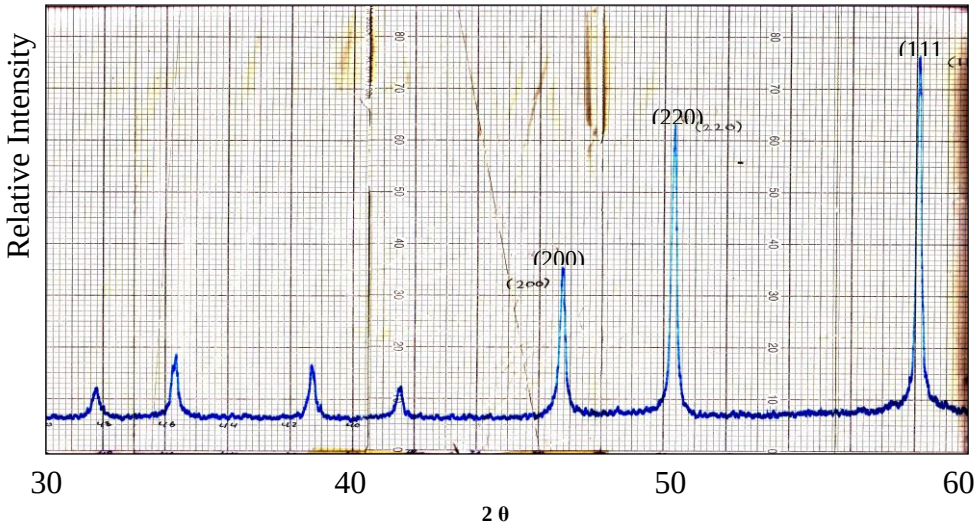

Fig.(5) :the XRD patterns of deposited InSb thin films.

The absorbance and transmittance spectra of crystal specimens as shown in figure (6,7) and its deposited films was carried out in the spectral range (1-9)μm as shown in figure (8,9). It is clear that the spectral characterizations are effected by the stoichiometric composition and the degree of crystalline of single crystal specimens, corresponding to the thin film samples. In order to increase the homogeneity of prepared thin films to the stoichiometric composition, several attempts must be employed to optimize deposition rate and substrates temperature.

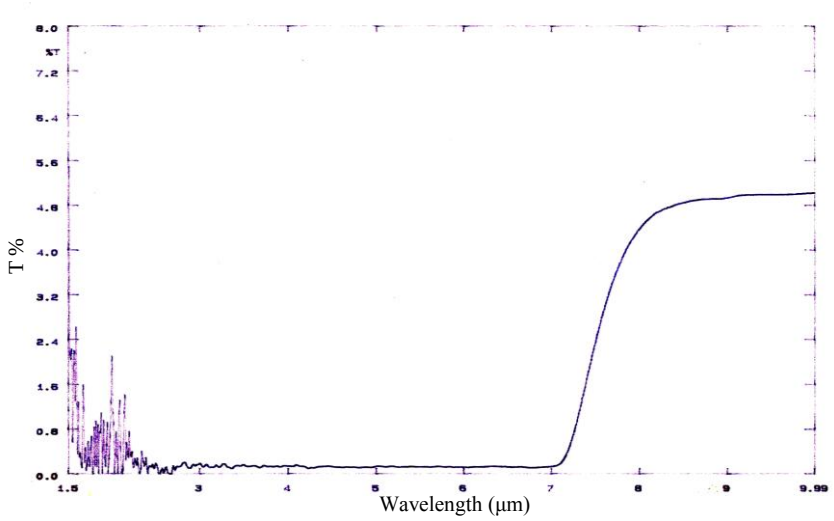

Fig.(6) Transmission as a function of wavelength for InSb crystal

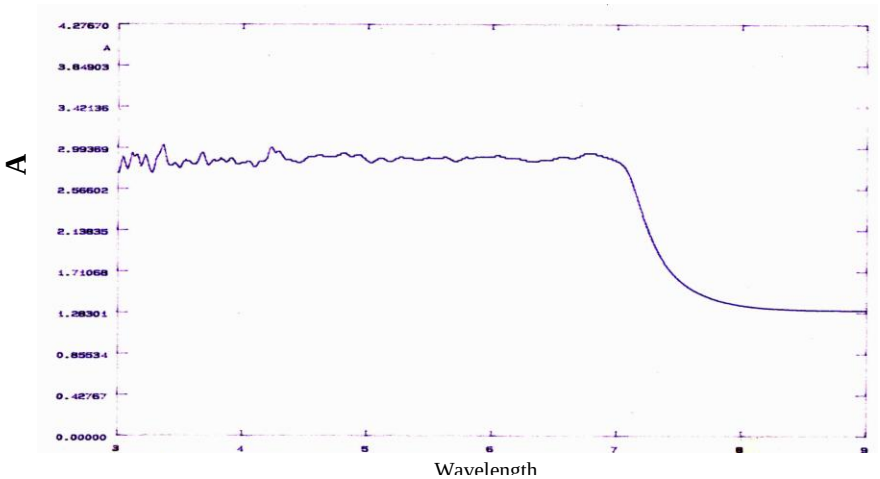

Fig.(7) Absorption as a function of wavelength for InSb crystal

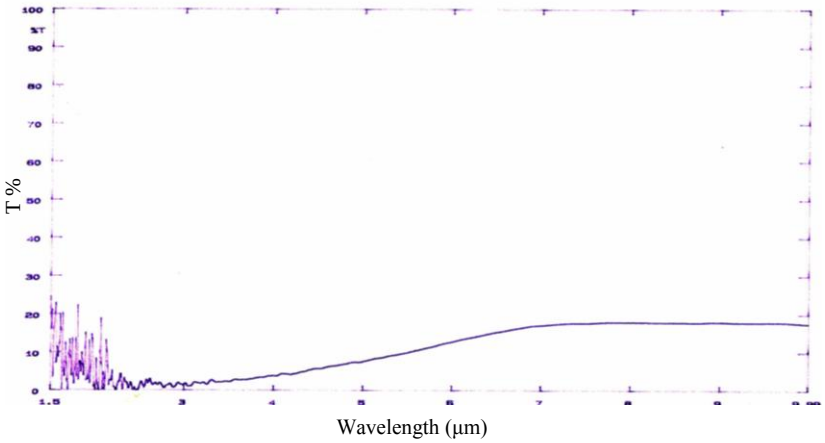

Fig.(8) Transmission as a function of wavelength for InSb thin film

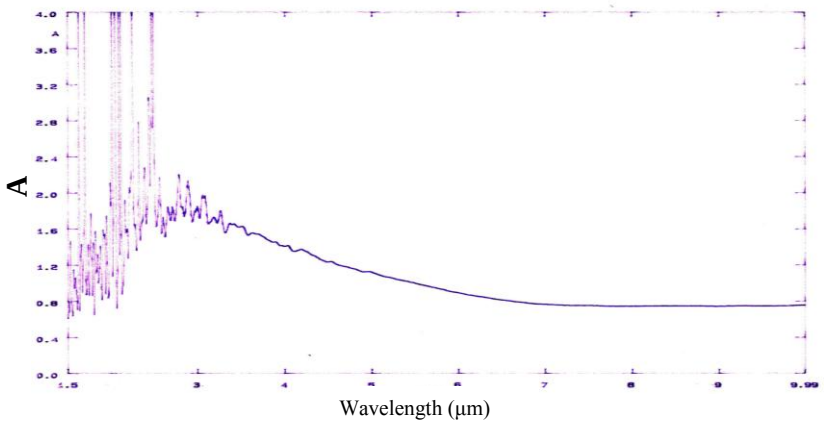

Fig.(9) Absorption as a function of wavelength for InSb thin film

The absorption coefficient values were measured at room temperature, and the plot of $(\alpha h\nu)^{1/2}$ against $(h\nu)$ was shown in figures (10, 11). Ordinary, the increments in absorption coefficient value are considered as a direct electronic transition. On other hand the increasing of optical transmittance percentage could be

attributed to the increasing of crystallite degree (grain size) of crystal specimens and thin films. For all samples the values of optical energy gap (Eg) have been determined from the straight line fitting of the figure (10, 11). The Eg values were found to be (0.16 eV) and (0.17 eV) for single crystal and thin film specimens respectively. The Eg reduction related to the limited localized states of impurities effect near absorption edg. This effect observation is in agreement with Morten et.al and Clerk's explanations [2,15].

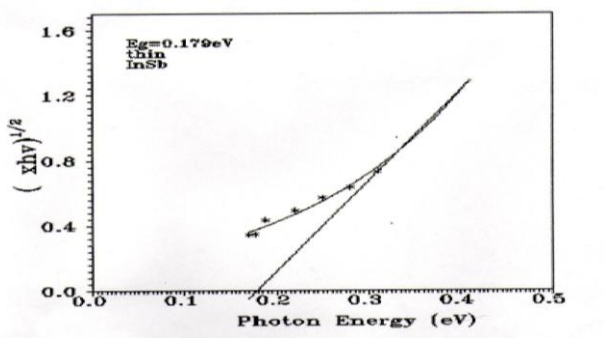

Fig. (10) the value of optical energy gap for InSb thin film specimen

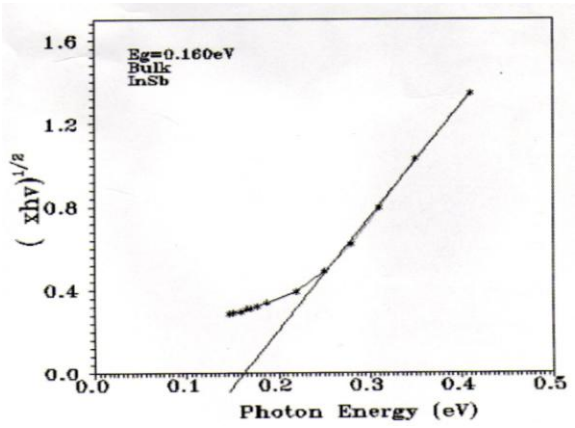

Fig.(11) the value of optical energy gap for InSb single crystal specimen

Finally, it has been shown that the pure melt techniques (two-zone furnuse), used extensively to prepare specimens of InSb single crystal. These our specimens have been similar properties to those, which are used for fabrication the photoconductive and photodiode detectors and the infrared devices of region (1-5)μm wavelength[4].

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المسلك التكنولوجي لإنماء البلورة المفردة (InSb) ودراسة بعض خصائصها الفيزيائية

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الخلاصة:

تم في هذا البحث إنماء بلورة مفردة من مركب InSb وبطريقة السحب من المنصهر النقي للمواد الأولية للمركب وباستخدام الفرن الحراري ذو النطاقين (two-zone furnes).درست بعض الخصاءص الفيزياوية للبلورة المنماة , حيث حدد التركيب البلوري للشرائح البلورية وكذلك الأغشية الرقيقة المرسبة بطريقة التبخير الحراري باستخدام مطياف الأشعة السينية (XRD) وأظهرت النتائج المستحصلة وجود شدة انعكاس عالية ومفردة تمثل اتجاه النمو البلوري للمستوي (220) لشرائح العينات البلورية بينما شدات انعكاس مختلفة لاتجاهات بلورية متعددة للأغشية الرقيقة تمثل التركيب البلوري المتعدد.

حددت الخصائص البصرية عند حافة الامتصاص الاساسية للعينات المحضرة بدرجة حرارة الغرفة وقيست فجوة الطاقة البصرية وكانت قيمتها (0.16 eV) للشرائح البلورية المفردة و (0.17 eV) للأغشية الرقيقة المرسبة.

ان الهدف من هذا البحث هو دراسة ومقارنة بعض الخواص الفيزيائية لبلورات منمات احادية البلورة واغشية رقيقة لمادة (InSb) .