CHAPTER: 1

INTRODUCTION

An intense research going on the primitive elemental semiconductors Ge and Si, at present much more attention is made to compound semiconductor, viz., binary, ternary and quaternary ones. Among the binary compounds, the group II-IV, IV-VI, III-V and V_2-VI_3, semiconducting compounds have been receiving considerable attention due to their important photo conducting, photovoltaic, electro optic and their general electronic properties. Their pseudo binary and ternary compounds have also found their due significance. For the study of basic semiconducting properties, it is of primary importance that these properties be measured on bulk single crystal. The single crystals themselves are most frequently required directly or indirectly for device fabrication. The performance of the device principally depends on the bulk crystalline characteristics. Of crucial importance among the characteristic are purity, perfection and homogeneity. Because of this, the field of crystal growth carries no less significance than the crystals themselves. In most of the applications the semiconductors are used in the form of single crystal or thin film or both at a time.

Over the last two decades, thin film physics has become an independent subject in science. The area of research in this field is rapidly expanding owing to a wide use of thin films in technology and fundamental studies in physics, chemistry and electronics.

Much attention is paid to the studies of films of the Solids: Metals, semiconductor and dielectric. The term "films "usually means a three dimensional structure with on dimension (thickness) much smaller than the other two. Films in the thickness interval of 0.01 to1 μm generally called thin films and those with1 to 100 m are commonly referred to as thick films [1].

However, a physically significant measure of the "thickness" is the length of operation of various characteristic parameters, e.g., Debye screening length, dislocation spacing, mean free path of charge carriers, etc. The thinner the film, the more its properties are determined by its surface. Therefore, with a variation of thickness within the limits comparable with typical parameters, the film properties change and the observation of size effects indicates the influence of thickness on the properties.

The thin film physics and technology are relatively newer than crystals and crystal growth. The studies on thin films began only around the start of this century. While reduction in the device size has been a matter of major concern for thin film studies, the thin film characteristics themselves frequently exhibit all together quite curious properties depending on film thickness – the quantum size effect is a striking example. Numerous research papers have been published on attempts to understand various properties of semiconductors (both bulk and thin film) such as optical, magnetic, thermoelectric, photoconductivity and photovoltaic effect, etc. The thin film research has made extraordinary and rapid advancement in recent years to an extent that exotic structure like diamond films and nano-crystals have started coming to the forefront of research.

The compound semiconductors may be categorized in terms of the band gap: Wide and narrow band gap semiconductors. Again the band gap can be direct or indirect. Typically, of wide band gap compounds are GaP, InP, AlSb, GaAs, etc. whose band gaps are greater than 0.5 eV and less than 3eV (Those with band gaps greater than 3 eV have insulating or near insulating characteristics). Whereas compounds like InSb, PbSe, SnTe, PbTe, etc. have narrow band gap down to 0.18 eV (InSb). The group III-V compounds, to which the materials in the present study belong, have narrow band gaps. Whereas the wide gap semiconductors find most of the applications in electronic circuit devices, electro optical and optoelectronic devices, etc., the narrow gap semiconductors have but restricted range of applications which nevertheless are very important.

Around the world largest number of researchers are working on group III-V semiconductors. Especially on low band gap semiconductors. Low band gap semiconductors have so many applications such as pollution monitoring, gas leak detection, gas sensing and spectroscopy. Covering the near infrared (IR) region becomes important for the military as well as for industrial control, medical diagnostics, and other civilian needs [2-5].

Most objects emit radiation in the thermal band (MWIR/LWIR wavelength range). Infrared detectors working in the 8-12μm wavelength range, where air absorption is minimal, have recently attracted a lot of attention. The atmosphere has clear transmission windows in the MWIR and LWIR bands, making it very attractive for terrestrial applications. In many applications such as pollution monitoring, gas leak detection, gas sensing and spectroscopy, require the observation and identification of chemical species [6]. Covering the near infrared

(IR) region becomes important for the military as well as for industrial control, medical diagnostics, and other civilian needs [7-9].

It is possible with II-VI HgCdTe detectors, but they exhibit major drawbacks. They have poor compositional uniformity due to: high Hg vapor pressure, week Hg bonds, change of material parameters with time, thermal instability.

HgCdTe has been the traditional material for long wavelength infrared photo detectors operating in the wavelength range from 8-12 μm [10]. Due to the difficulties in growth and processing steps in this group II-VI alloy, a number of III-V semiconductor structure are investigated as alternative for LWIR photo detectors [11]. The highly developed III-V materials are usually favoured over group II-VI narrow band gap semiconductors, and they play an important role in detector technology development. This is because group III-V (III= Ga, In; V= Sb, Bi) semiconductors have a variety of physical features that are both useful and feasible. Researchers have spent a lot of time studying Sb-based semiconductors. [12-13].

II. InSb: Bi

Atomic number of Indium is 49 having electronic configuration [Kr] $4d^{10}$ $5s^2$ $5p^1$. Indium is very soft metal. The melting point of Indium is 156.6 °C. Atomic number of Antimony is 51. Its electronic configuration is [Kr] $4d^{10}$ $5s^2$ $5p^3$. The melting point of Sb is 630.6 °C. Bismuth has atomic number 83 with electronic configuration [X_e] $4f^{14}$ $5d^{10}$ $6s^2$ $6p^3$. The melting point of Bismuth is 271.4°C.

1. InSb:

To overcome this limitations of HgCdTe, various new materials are introduced one of them is InSb. The compound InSb has received significant attention. It's a binary (III-V) semiconductor having low optical band gap ≈ 0.18 eV, which makes this material very important for detector technology [14]. The low band gap of 0.18 eV at room temperature allows to operate it in long wavelength limit.

Study interest in InSb carried out not only because of the low band gap but also very good quality InSb single crystals can be grown using melt growth. Phase diagram of InSb is shown in figure-1. Phase diagram describe the equilibrium of solid phase with liquid phase of InSb. Phase diagram shows the melting point at527.7 °C [15]. This melting point help to

grow InSb crystals from the melt by the conventional methods. Now day's 2 to 3 inch crystals of InSb are available commercially. As shown in figure-2 InSb crystallizes in to the zinc-blende structure [16].

InSb has high charge carrier mobility. The advancement of this compound alloy is to be successfully used in photo detectors operating in the spectral range 3-5 μm. InSb has a very small effective mass for electrons and thus has a large Bohr radius of ~ 65nm [17]. The InSb material based devices are mostly used in thermal detection of hot systems. InSb possess very good thermoelectric properties. It is the best material available for magnetic-field sensing device such as Hall sensors, magneto resistors, speed sensitive sensors etc. [18-20]. The cut off wavelength λ_c at low temperature for InSb is 5.4 μm. To extend λ_c in to the desired 8-10μm range requires a reduction of the band gap of the material. This can be achieved by incorporation a large group V atom such as Bi in to the lattice [21]. Those applications make this study so important to be done.

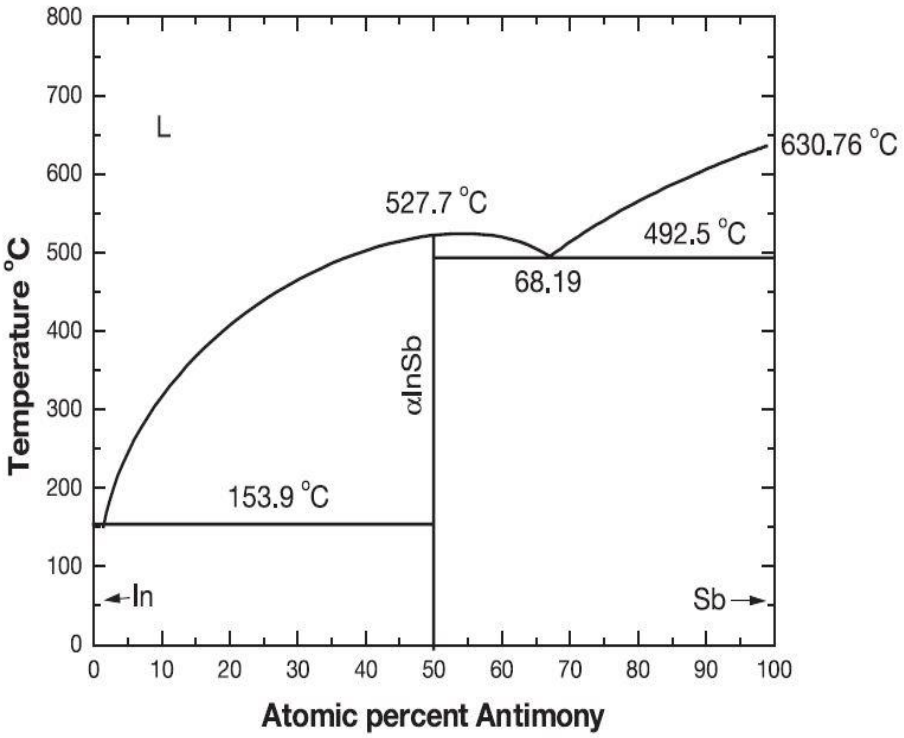

Figure 1 Phase Diagram of InSb

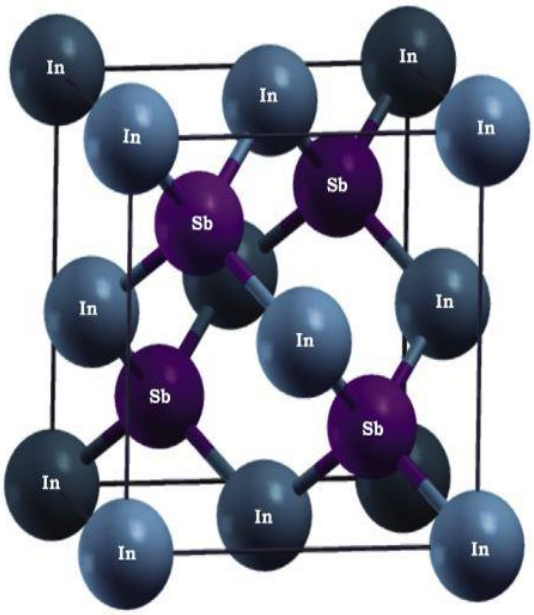

Figure-2 InSb crystal structure

Bi:

Semiconducting materials with improved properties are in need of the current era for the advanced device applications. Bismuth is the heaviest among the group V elements. Compounds containing these elements have been not explored much. These compounds have large potential in device applications. They can be used in electronics, optoelectronics, thermoelectric and also in understanding fundamental physics. Dilute bismuth provides large band gap reduction. This is because it shifts up the valence band edge.

Researchers are exploring the potential properties of Bismuth from last decade. It is the heaviest, innocuous with low electronegative element. Bismuth has a large atomic radius. Surfactant effect, large band gap lowering and strong spin orbit coupling for its incorporation in to normal III-V materials are some interesting properties of Bismuth [22]. In Group III-V compounds addition of small amount of Bi will reduce the band gap by measurable amount. This effect of lower band gap between conduction band and valance band can be achieved easily. This improved property allows the material use in extension of photo detectors and can reduce the temperature dependency of the device performance. Dilute bismuth alloys can be used in the transistors, LEDs and solar cells. Small wireless devices have high power consumption in output amplifiers. Dilute Bismuth with Group III-V materials can be used to reduce this power consumption of hetrojunction bipolar transistors [23].

By doping Bi in InSb the band gap can be reduced by fair margin [24]. This would make single crystal of $InSb_{1-x}Bi_x$ useful in various detectors. Hence the band gap of single crystal $InSb_{1-x}Bi_x$was taken up in this study.

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