

Preparation and Study the Impact of Annealing Temperature on the Structural Properties of InSb_{0.96} Bi_{0.04} Alloy and Films

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ABSTRACT: The InSb_{0.96} Bi_{0.04} alloy was prepared successfully according to the compounds atomic ratio of the constituents of elements. The InSb_{0.96} Bi_{0.04} films were prepared by flash evaporation technique on clean glass. The prepared film was annealed at different annealing temperatures (RT, 423, 473, 523 and 573)K under vacuum. The structural properties of prepared un annealed and annealed films were investigated using x-ray diffraction (XRD). X-ray analysis showed that InSb_{0.96} Bi_{0.04} alloy and films are polycrystalline zinc blende structure at all different annealing temperatures.

KEYWORDS: InSbBi alloy and films, Flash evaporation method, Structural properties, Annealing temperature.

I. INTRODUCTION

Semiconductor, thin films have been produced and study in polycrystalline form for many decades. Indeed, most of the new semiconductor materials have been produced in polycrystalline form before technique development for producing single crystals as in the form of postaxial growth [1].

Since the discovery of the semiconductor properties of InSb in 1950, work on III-V compounds gave us much information about the physical processes, which cannot be obtained by germanium and silicon. The particular features that attracted interest were the low effective mass, which revealed itself by very high electron mobility, and the ionic component in the crystal binding [2].

Incorporation of Bi element to the InSb makes the energy band changing from that of semiconductor (InSb) to semi-metal (InBi), therefore, the extension of cut off wavelength from (3-5 μ m) to longer than (8-12 μ m) for this material system is still possible. However, the InSbBi system seems to have difficulties mainly due to the limitation of the Bi solubility in the InSb [3].

The InSb_{1-x}Bi_x system that is extended solid solution would require both compositional and structural metastability, the complete solid solubility of most pseudo binary III-V alloys indicates that the free-energy difference between metastable InSb_{1-x}Bi_x and the equilibrium state should be small. The slow self-diffusion in III-V compounds indicates that metastable III-V alloys should exhibit reasonable thermal stability [4].

The long-wavelength infrared detectors have found many civilian applications such as night vision reconnaissance, communication systems, industrial thermograph, medical imaging and meteorological research [5, 6].

Accordingly there has been extensive research for the development of infrared materials and detectors operating in the long-wavelength infrared region (8-12 μ m) since this range is the most important atmospheric window in detecting room temperature objects [6].

The development of studying this semiconductor compound material start by Jaukoff and Jean-Louis in 1972. They reported the growth of bulk InSb_{1-x}Bi_x single crystals using the Czochralski technique and found a solid solubility limit of 2.6 mole % InBi. They studied the annealing and quenching effect on the solubility of prepared alloy [7].

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In 1980 Zilko and Greene [4] demonstrate the growth of $\text{InSb}_{1-x}\text{Bi}_x$ on (110) GaAs substrates using multi-target RF sputtering (MTS) with $x \leq 12$ mol % at growth temperature of 438K. The films were metastable in two directions on the In-Sb-Bi ternary phase diagram the solid solubility of tetragonal InBi in zinc blend structure InSb was increased by more than a factor of 4. Noreika et al. 1982 [8] prepared InSbBi by molecular beam epitaxy (MBE) using in situ reflection electron diffraction, conditions for epitaxial growth of stoichiometric layers were established on (001) and (110) surfaces of both InSb and GaAs wafers. Bi incorporation into InSb during growth (MBE) is strongly dependent on Bi surface concentration and influenced by substrate temperature and surface nonstoichiometry.

Mohan et al. 2000 [9] demonstrated the growth of bulk $\text{InSb}_{1-x}\text{Bi}_x$ single crystals with x varying from 0 to 0.06 employed vertical Bridgman technique. The solubility of InBi in InSb was determined using differential thermal analysis.

This survey showed clearly very sophisticated techniques [10] have been used for preparing $\text{InSb}_{1-x}\text{Bi}_x$ alloys.

The present investigation comprise the growth $\text{InSb}_{1-x}\text{Bi}_x$ as an alloy. The flash evaporation technique was used to prepare $\text{InSb}_{1-x}\text{Bi}_x$ film at $x=0.04$ and study the impact of annealing temperature on structural properties of prepared $\text{InSb}_{0.96}\text{Bi}_{0.04}$ alloy and films.

II. EXPERIMENTAL PROCEDURES

To prepare the $\text{InSb}_{1-x}\text{Bi}_x$ for $x=0.04$ we used highly pure Indium (In), Antimonite (Sb) and Bismuth (Bi) elements (99.999%) according to the relative atomic weight of elements.

The $\text{InSb}_{1-x}\text{Bi}_x$ alloy growth under vacuum pressure (10^{-5}) Torr. The components of the alloy were placed in a quartz tube which was attached to the evacuated system. The tube was sealed when the pressure reached 10^{-5} Torr, then it was placed in an electric furnace, set to a certain temperature for alloy at Bi content equal to 0.04. The tube was kept at this temperature for four days; through the heating period, the tube was rocked repeatedly several times to get well homogenous mixture. After that the ampoule was quenched rapidly in cold water. The composition analysis was done by atomic absorption spectroscopy method (AAS) for quantitative measurement of atomic percentage of the material (In, Sb and Bi) in the alloy, where HCl or HF were used as solvent for this material.

The $\text{InSb}_{0.96}\text{Bi}_{0.04}$ films were deposited on clean glass using flash evaporation technique from prepared alloy. The thickness of the films is an essential parameter in the property of its; thus we used two methods to measure it, firstly the weight method and secondly is optical interference fringes.

X-ray diffraction analysis was used to examine the structure properties of prepared alloy and films annealed at various annealing temperatures ($T_a = \text{RT}, 423, 473, 523$ and 573)K.

III. RESULTS AND DISCUSSION

Atomic absorption spectroscopy (AAS) has been used to examine the amount or concentration of the elements (In, Sb and Bi) in the alloy by depending on the atomic absorption of the standard elements of these elements. The results of this spectroscopy are of high accuracy in measuring the concentration of the elements as shown in Table 1 of these results.

Table 1 The composition of $\text{InSb}_{0.96}\text{Bi}_{0.04}$ alloy determined by AAS

Alloy	Theoretical of elements %			Experimental of elements %			Total %
	In	Sb	Bi	In	Sb	Bi	
$\text{InSb}_{0.96}\text{Bi}_{0.04}$	0.50	0.48	0.02	0.52	0.459	0.021	100

The X-ray diffraction (XRD) study of $\text{InSb}_{1-x}\text{Bi}_x$ alloy, and the structure of $\text{InSb}_{1-x}\text{Bi}_x$ films prepared at different annealing temperatures were carried out in order to get an idea about the structural changes produced by heat treatment at various annealing temperatures (T_a). The structure characterization of $\text{InSb}_{1-x}\text{Bi}_x$ alloy at $x=0.04$ and un annealed and

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annealed films at different annealing temperatures (RT, 423, 473, 523 and 573) K were examined by X-ray diffraction (XRD). Figure 1 illustrated the XRD pattern for $\text{InSb}_{0.96}\text{Bi}_{0.04}$ alloy and un annealed and annealed films at different annealing temperatures (RT, 423, 473, 523 and 573)K.

All the prepared alloy and un annealed and annealed films are polycrystalline zinc blend structure. These results are in a good agreement with Zilko and Greene [4] which confirm that the prepared alloys have a stoichiometric composition.

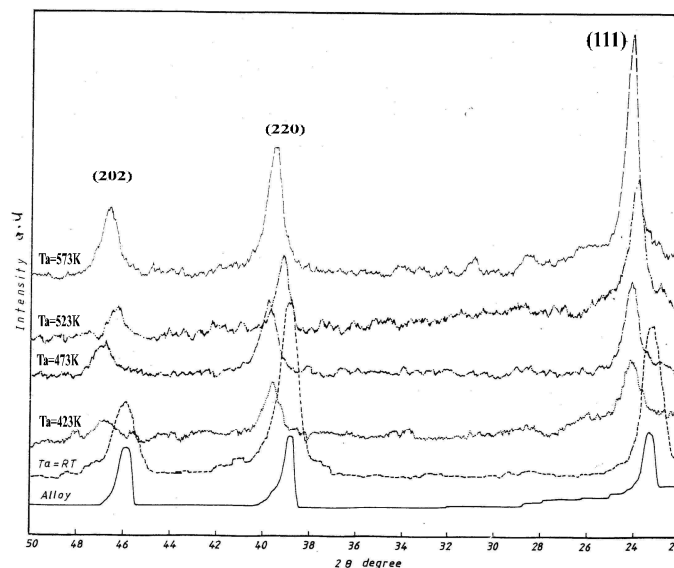


Fig. 1 XRD pattern of $\text{InSb}_{0.96}\text{Bi}_{0.04}$ alloy and films.

It can be inferred from Tables 2 and 3 that the comparison between the values of diffraction angles (2θ), interplaner distance (d) and miller indices (hkl) of the peaks related to $\text{InSb}_{1-x}\text{Bi}_x$ and InBi of alloy and films for $\text{InSb}_{0.96}\text{Bi}_{0.04}$, at various annealing temperatures, which are deduced by using Bragg's law ($n\lambda = 2d \sin \theta$). From the pattern of XRD, we can observe from Fig. 1 and Tables 2 and 3, that the values of d and 2θ for $\text{InSb}_{0.96}\text{Bi}_{0.04}$ alloy are nearly similar to values of standard alloy which are deduced from Zilko and Greene[4] because we do not found the ASTM cards for this ternary alloy. They found that the prepared films were metastable in two directions on the In-Sb-Bi ternary phase diagram the solid solubility of tetragonal InBi in zinc blende structure InSb was increased by more than a factor of 4.

The peaks of $\text{InSb}_{0.96}\text{Bi}_{0.04}$ alloy are located at 2θ (23.3, 38.7 and 45.9) which are shifted to lower 2θ nearly about one degree than that for standard alloy which is reported by Zilko and Greene [4] and in our alloy the peak of Bi and the other peak of InBi were disappeared.

Table 2 Structural parameter for $\text{InSb}_{0.96}\text{Bi}_{0.04}$ alloy

Phase	$\text{InSb}_{0.96}\text{Bi}_{0.04}$ alloy			Standard[4]		
	$2\theta(\text{deg.})$	$d(\text{\AA})$	hkl	$2\theta(\text{deg.})$	$d(\text{\AA})$	hkl
InSbBi	23.3	3.814	111	24.0	3.704	111
InSbBi	38.7	2.324	220	39.5	2.279	220
InBi	45.9	1.977	202	47.1	1.927	202
InBi				61.7	1.50	311
Bi				28.0	3.18	102

While the X-ray analysis of $\text{InSb}_{1-x}\text{Bi}_x$ films which are annealed at various T_a under vacuum showed that annealing has shifted the position of peaks to longer 2θ . Another noticeable remarked is that the values of 2θ , d , and hkl for $\text{InSb}_{1-x}\text{Bi}_x$ films annealed at 423K for $x=0.04$ are similar to the standard values which have been pointed out by other researchers.

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Table 3 Structural parameter for $\text{InSb}_{0.96}\text{Bi}_{0.04}$ film at different annealing temperatures

Phase	InSb _{0.94} Bi _{0.04} films										hkl
	T _a =RT		T _a =423K		T _a =473K		T _a =523K		T _a =573K		
	2θ (deg.)	d (Å°)	2θ (deg.)	d(Å°)	2θ (deg.)	d(Å°)	2θ (deg.)	d(Å°)	2θ (deg.)	d(Å°)	
InSbBi	23.4	3.798	24.2	3.674	24.3	3.659	23.9	3.72	24.1	3.689	111
InSbBi	38.8	2.318	39.6	2.273	39.7	2.268	39.4	2.285	39.7	2.268	220
InBi	45.9	1.977	46.8	1.941	46.8	1.941	46.5	1.953	46.8	1.941	202

IV. CONCLUSION

The $\text{InSb}_{0.96}\text{Bi}_{0.04}$ alloy was prepared successfully according to the compounds atomic ratio of the constituents of elements. The structural study for prepared $\text{InSb}_{0.96}\text{Bi}_{0.04}$ alloy and their prepared un annealed and annealed at various annealing temperatures film by flash evaporation technique had investigated . The obtained results of the present work, it can be concluded that The $\text{InSb}_{1-x}\text{Bi}_x$ alloy and all un annealed and annealed films prepared at various annealing temperature were polycrystalline zinc blende structure. In general the peaks of annealed films shifted to lower two theta .

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