Crystal Growth of High – Purity Bi_2Se_3 and Study of Crystal Structure

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Abstract

The Bi2Se3 compound was synthesis by fusing initial compounds consisting of extra pure elements in stoichiometric ratio from elements compound, charged inside quartz ampoule. The crystal growth of Bi_2Se_3 carried out using Brighaman technique process from melting f (Bi+Se) at temperature of 810 ºC for about 48 hrs. Single crystal of Bi_2Se_3 has been grown in direction (211) after slow cooling on account of heat gradient to zone furnaces at cooling rate (1-3) C/hr. The structure study of the compound was determined by x-ray diffraction technique, which it has bismuthinite structure and orthorhombic unit cell with lattice parameters of a=10.2678 Å, b=11.2392 Å and c=5.1737 Å

أنماء بلورة Bi_2Se_3 عالية النقاوة ودراسة خصائصها

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الخلاصة

حضر المركب Bi_2Se_3 بواسطة صهر عناصره الاولية عالية النقاوة بنسب وزنية مكافئة لتكوين المركب ، داخل امبولة من الكوارتز. نميت بلورة مفردة من المركب بتقنية برجمان من صهر العناصر(Se+Bi) بدرجة حرارة ٨١٠ºC لمدة ٤٨hr .درس التركيب البلوري لبلورة المركب Bi_2Se_3B المفردة بأستخدام تقنية حيود الاشعة السينية ظهر نمو بلوري عالي الشدة(٢١١) باتجاه كما درس التركيب البلوري لمسحوق المركب بتقنية حيود الاشعة السينية ووجد انه يمتلك تركيب بلوري البزموثينايت ذات وحدة خلية معيني قائم ذات ابعاد a= 10.2678 Å, b=11.2392 Å, c= 5.1737 Å

Introduction

Recently a considerably increasing interest has been observed in using binary semiconducting chalcogenides with the formula group V_2-VI_3 compound as photoconductors materials [1,2] .Many V_2-VI_3 compounds super lattice and multilayer with different structure have studied experimentally [3,4]) ,and some characteristics of these compounds . In these system, the energy band barriers for med by wide gap materials are As_2S_3 , As_2Se_3, Sb_2S_3 until Bi_2Se_3 [5], also have narrow – band gap material which forms Sb_2Se_3 , Sb_2Te_3 and Bi_2Te_3. These compounds have orpiment structure contain the arsenic element as stoichiometric ratio such as As_2S_3 that has monoclinic unit cell [6] either stibnite which contains antimony element at stoichiometric in crystal structure as Sb_2S_3 or bismuthinite structure which contains bismuth element in stoichiometric ratio as Bi_2S_3 and Bi_2Se_3 , also it has orthorhombic unit cell and have space group (pnma – D_{2h}^{16})[7,8]. Several workers study the compounds V_2-VI_3 group and found that the dimension of lattice parameters are a=4.134 Å and c=28.611 Å Bi_2Se_3[9].These

compounds have some unique properties that are different from other compounds , these are direct wide energy gap , structure variation with force filed , that leads to the variation of carriers concentration and mobility. These properties made these compounds f great interest in electronic application that contests the other groups of semiconductors.

Experimental Procedure

The Bi_2Se_3 compounds was synthesis by fusing initial compounds consisting of extra pure elements (Bi:99.999%) from Balzers com.) and (Se : 99.999% from Aldrech com.) in stoichiomertric from elements compound placed inside quratz ampoule after sealed on side to work tip. The quartz ampoule was evacuated to 10^{-6} torr , the ampoule with its charge was placed in a single zone **,** tube furnace type Lindbergh. The was heated above the melting point of the compound to 810 ºC at range 1.5 ºC /min.. The ampoule was kept for 48 hr. in the zone furnace at that temperature. The melt was shaken during heating several times then cooled slowly at range of (1-3) ºC/hr. on gradient heat inside zone furnace and along the solidification direction to axis furnace in Fig.(1). After solidification process for melt at low temperature we obtain single crystal from Bi_2Se_3 take container shape which consisted as show in Fig.(2) .

X-ray diffraction analysis contain that Bi_2Se_3 in single crystal , powder and thin films. After evaporation compound in vacuum 10^{-5} torr on clean glass microscopy substrate at room temperature by thermal evaporation method. The thickness of the deposited films was 0.664 μm.

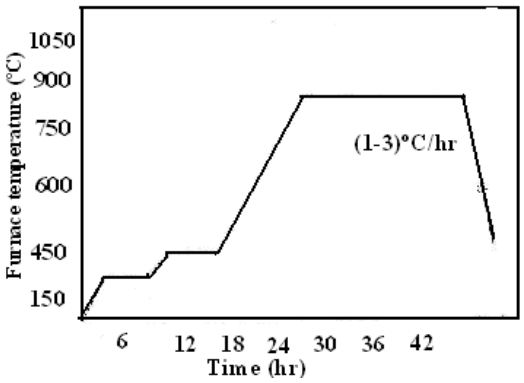

Fig.(1) Thermal diagram of various furnace temperature and heating time.

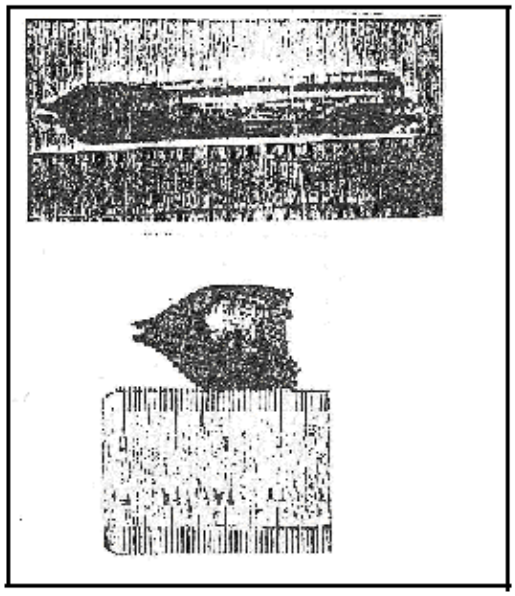

Fig. (2) Grown Bi_2Se_3 Single crystal by slow cooling method

Result and discussion

The result to crystallographic studies of Bi_2Se_3 powder at room temperature is shown Fig. (3). It is clear from the x-ray diffraction pattern that the compound has a bismuthinite structure of orthorhombic unit cell with lattice parameters a=10.2678 Å , b=11.2392 Å and c=5.1737 Å. From these results the direction (211) is preferable which have high intensity percent comparing with other peaks. Also the x-ray diffraction

pattern of single crystal of Bi_2Se_3 revealed that growth is (211) direction after perpendicular cutting of crystal axis [9, 10].

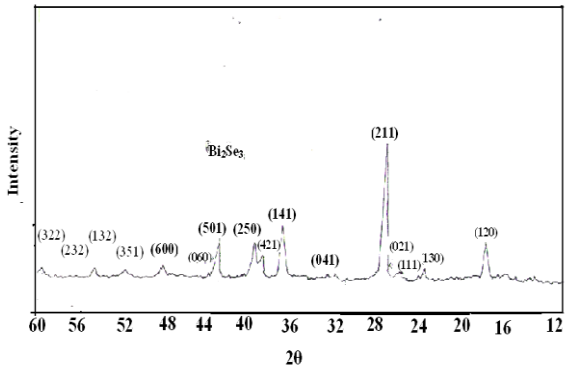

Fig. (3) XRD patterns for powder of Bi_2Se_3.

This direction shows preferred orientation as shown Fig. (4). But there are few surface defects result from cutting and polishing processes. To get ride of many processes were preformed such as long period of polishing, ultrasonic cutting, and crystal surface etching.

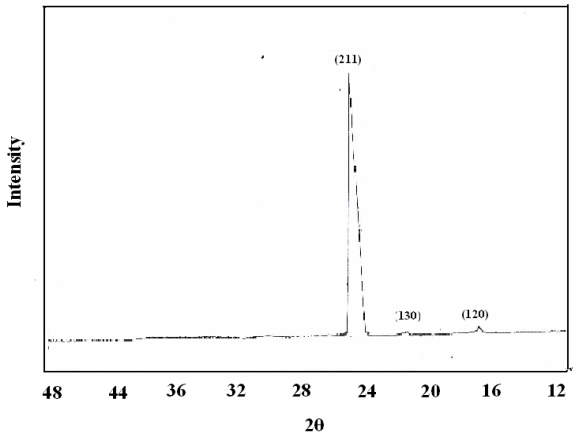

Fig.(4)XRD patterns recorded using Cukα radiation for single crystal.

Thin films to Bi_2Se_3 have amorphous structure but after heat treatment small peaks appear which an indication polycrystalline structure to the films at temperature 250 ºC for one hour and this polycrystalline structure is due to grain size growth [11] in Fig.(5). The fusion of grains with nearest neighbors from islands that have preferred orientation in (250) direction for the most thin films with annealing at temperature 250 ºC.

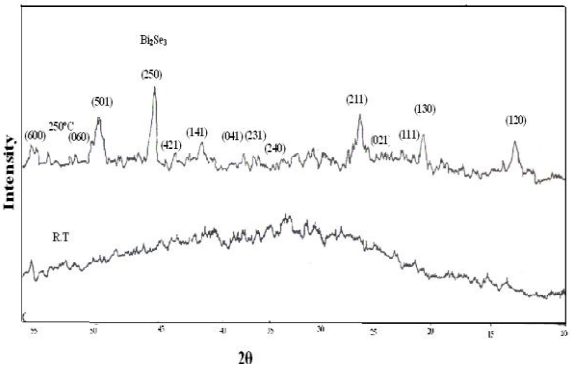

Fig. (3) XRD patterns for thin films at R.T and annealing at 250ºC for 1 hr. of Bi_2Se_3.

Conclusion

The compound Bi_2Se_3 prepared from high purity (99.999%) ordinary element with stoichometric ratio by reaction fusion inside evacuated ampoule. X-ray diffraction pattern study shows that the compound Bi_2Se_3 have polycrystalline bismuthinite structure. The single crystal growth by brighman technique of compound.

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