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Influence of Low Frequency Mechanical Vibrations on Crystal Growth of GaInSb Ternary Alloy: Growth by VDS Technique

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Abstract *—Crystal growth of bulk GaInSb ternary alloy using vertical directional solidification (VDS) technique with controlled low frequency coupled mechanical vibrations has been investigated. Growth rate of 1.5 mm per hour, mechanical vibrations with ramp of frequency ranging from 25 Hz to 200 Hz and amplitude varying from 0.25 mm to 0.05 mm has shown the significant improvement in compositional homogeneity along axial direction. The phase formation has investigated using X-ray analysis and compositional variation investigated using EDAX. The micro cracks, lamellar crystal growth defects and ampoule cracking remains presents in vibration assisted GaInSb ternary alloy crystal grown using VDS technique.*

Keywords— *GaInSb, crystal growth, VDS.*

I. Introduction

GaInSb is a well known III-V ternary semiconductor material useful for thermo photovoltaic (TPV) device, infrared laser and sensors in infrared region, since the wavelength can be varied from wide range (1.7 µm to 6.8 µm) by varying Indium content [1]. However, the growth of GaInSb bulk single crystal using conventional solidification techniques such as Bridgman-Stockbarger or Czochralski, Gradient freeze, is more difficult due to large separation of liquids and solidus lines in phase diagram [2]. This large separation in liquids and solidus lines in phase diagram leads to segregation and constitutional super cooling, which results in multi phasing and micro cracks in crystals [3, 4]. To eliminate these difficulties, various modifications to these techniques like accelerated crucible rotation technique (ACRT), solute feed technique, Rotary Bridgman and baffle mixing, solute feeding Czochralski, Submerged heater, magnetic field assisted growth, etc are employed for past few decade [5,6,7,8]. However, due to inherent problems in growing GaInSb from melt and poor yield of substrate grown from melt, bulk single crystal substrates of GaInSb are still not availed for commercial applications.

In this work, we presented the effect of low frequency coupled mechanical vibrations on crystal growth of $Ga_{0.5}In_{0.5}Sb$ ternary bulk crystal using vertical directional solidification (VDS) technique [9].

II. Experimental

The granules of 4N grade (Manufacturer: Alpha Aesar , US) Gallium (Ga) Indium(In) and Antimony (Sb) were taken in stoichiometric proportion and sealed in a quartz ampoule, with inner diameter of 14 mm and cone angle 35^o, under Argon atmosphere at pressure of 150 Torr. To avoid the oxidation due to ampoule breaking during growth, double walled ampoule was used while growth. To achieve homogenous mixing, sealed ampoule was kept at 800 ^{0}C for 15 hours with continuous stirring mode. The coupled mechanical vibrations with ramp of frequency ranging from 25 Hz to 200 Hz and amplitude varying from 0.25 mm to 0.05 mm were vertically applied during the growth. The ampoule lowering rate was kept constant at 1.5 mm/hour. The schematic of VDS growth system and temperature profile are shown in fig. 1 and fig. 2 respectively.

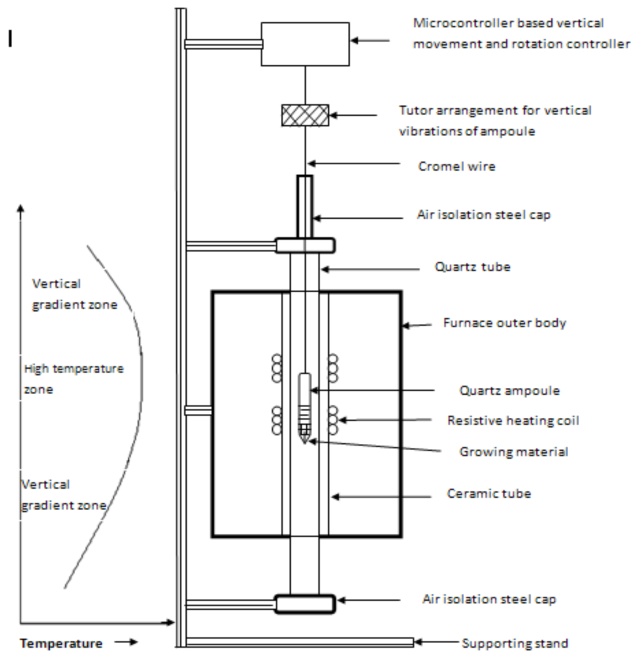

Fig. 1. Schematic of VDS crystal grower.

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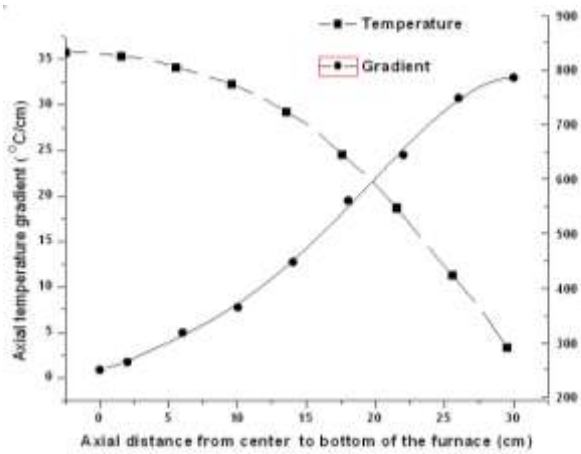

Fig. 2. Temperature profile.

III. Results and Analysis

1. Microstructure analysis:

For the microstructure analysis, as grown ingot (Fig. 3) sliced by using low speed diamond coated crystal cutter. It was observed that after 70% growth, cracking of ampoule occur in both growth with vibration and growth without vibration. This might be due to solidification of trapped indium in the gap between growing crystal and ampoule wall. The polished wafers were etched by selective CP_4 chemical etchant and the developed patterns were analyzed by metallurgical microscope (Model: Metzer-model-MEZ-780) with CCTV attachment.

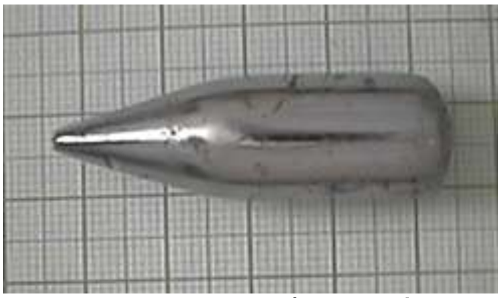

Fig. 3. As grown Ingot of $Ga_{0.5}$ $In_{0.5}Sb$.

The vibration assisted growth showed large grain areas (fig. 4) with micro cracks and twins-lamellar growth along axis of ingot (fig. 5).

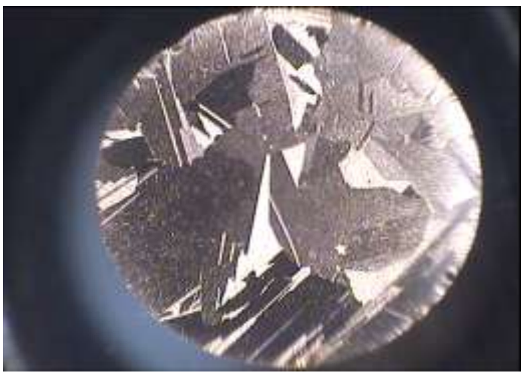

Fig. 4. Large grain wafer of $Ga_{0.5}$ $In_{0.5}$ Sb.

Fig. 5. Lamellar growth along axis of ingot.

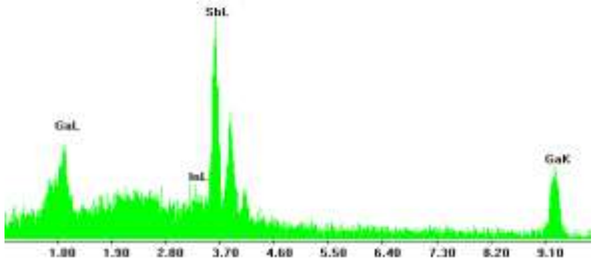

Fig. 6. EDAX spectra of $Ga_{0.5}$ $In_{0.5}Sb$.

2. Compositional Analysis:

The axial compositional Analysis was done by EDAX (Model: FEI Quanta 200 ESEM system) (Fig. 6). The composition comparison of the crystal grown with and without vibration (fig. 7, fig. 8) shown that mechanical vibration reduces the indium segregation. The accumulated Indium at the melt-solid interface diffuses to the melt by thinning the diffusion boundary layer which leads to reduce the Indium segregation in concentrated GaInSb ternary alloy crystal growth. The vibrations of ampoule helps in avoiding random nucleation in the growth melt as well as constitutional super cooling at the growth interface and decrease cracks in the crystal that originate from interface breakdown due to accumulated Indium. The periodic fluctuations in composition (fig. 8) of Gallium and Indium might be due to formation of dead vibration zones at solid-liquid interface.

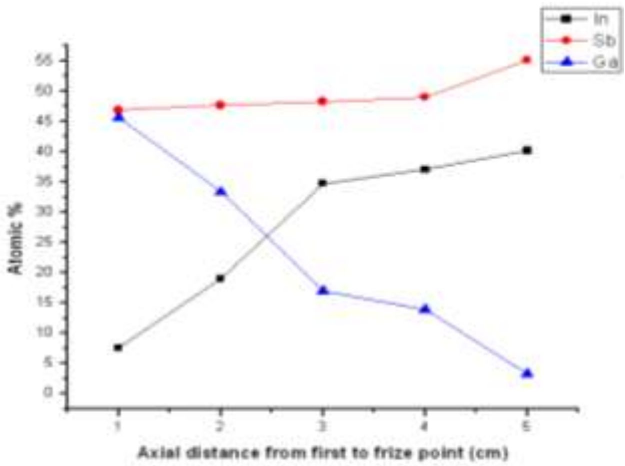

Fig. 7. Compositional variation along axis of ingot without vibration.

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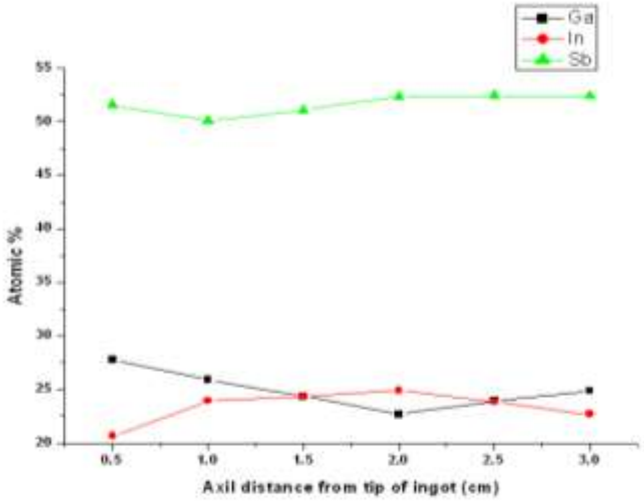

Fig. 8. Compositional variation along axis of ingot with vibration.

3. *FTIR and X-ray Analysis:*

The powder X-ray (Model: JEOL JD-X, 8030) analysis showed the phase formation of $Ga_{0.5}$ $In_{0.5}Sb$ with zinc blende crystal structure (fig. 9) with lattice constant $6.283A^0$. The X –ray diffraction for single crystal analysis shown the oriented growth along (331) crystallographic plane.

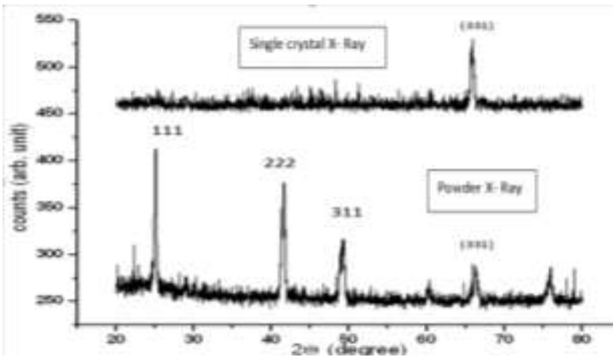

Fig. 9. X-Ray diffraction of $Ga_{0.5}In_{0.5}$ Sb.

IV. CONCLUSIONS

We have demonstrate that the controlled mechanical vibrations having ramp from 50 Hz to 200 Hz and amplitude varying from 0.25 mm to 0.05 mm could be an alternative tool for transporting accumulated Indium at the melt-solid interface to the melt during crystal growth of GaInSb using VDS method. This leads to reduce the Indium segregation in concentrated GaInSb ternary alloy crystal growth. However, micro cracks, microstructure defects and ampoule breaking remains presents in vibration assisted GaInSb ternary alloy crystal growth suing VDS technique.

REFERENCES

[1] N Murakami, K. Arafune, Y Hayakawa, J. Crystal Growth 275 (2005) 433.
[2] G B Stringfellow, J.Phys.Chem.Solids, 33 (1972)665.
[3] J.P. Garandet, T. Duffar, J.J. Favier, J. Crystal Growth 106 (1990) 426
[4] C Marin, P S Datta, E Dieguez, P Dusserre, T Duffar, J. Crystal Growth 173(1997) 271-276.
[5] S Plaskett and J F Wood, J.Crystal Growth 11 (1971)341.
[6] S Sen, PhD thesis, University of South California, 1976.
[7] R.T. Gray, PhD thesis, Clarkson University, New York, 1991.
[8] P S Datta, A G Ostrogorsky, J. Crystal Growth 194 (1998) 1-7.
[9] D.B. Gadkari, K.B. Lal, and B.M. Arora,A process for the preparation and orientation growth of single self seeded crystal of antimonide alloys and / or elementary binary or ternary semiconductors materials; Indian Patent: 139/BOM/1999 (1999) 26-2-1999 and The Gazette of India No 8 February 21, 2004Page- 551, Patent No. 192132 (2004).

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