Growth of InGaSb ternary alloys from Ga and Sb faces of GaSb(111) under prolonged microgravity at the International Space Station

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Introduction

InGaSb ternary alloy semiconductor with tuneable lattice parameter (6.096 ～ 6.479 Å) and wavelength (1.7 ～ 6.8 μm) is a potential material for thermo photovoltaic and IR detector applications [1]. The major growth issues of InGaSb are (1) effect of convection, (2) segregation and (3) orientation dependence of growth process. To understand these factors, it is necessary to understand the solute transport and growth phenomena under microgravity (μG) where the cause of complex solute transport process under normal gravity (1G) is suppressed [2]. In addition to our earlier report on the growth process of InGaSb from GaSb(111)A under 1G and μG [3], we explain now the directional solidification of InGaSb from Ga and Sb faces of GaSb(111) under microgravity at the international space station (ISS).

Experimental method

InGaSb crystals were grown from Ga and Sb faces of GaSb(111) under μG condition on board ISS by vertical gradient freezing method using the sandwiched structures (GaSb(111)A/InSb/GaSb(111)A and GaSb(111)B/InSb/GaSb(111)B) of ampoules. The growth was carried out under high vacuum at around 700 ˚C and heat pulses were introduced to measure the growth rate and interface shape. The grown crystals were taken X-ray Laue to cut along (110) plane, along the growth direction. The cut crystals were mirror polished and analysed by electron probe micro analysis (EPMA) and etching process to measure the composition and growth rate.

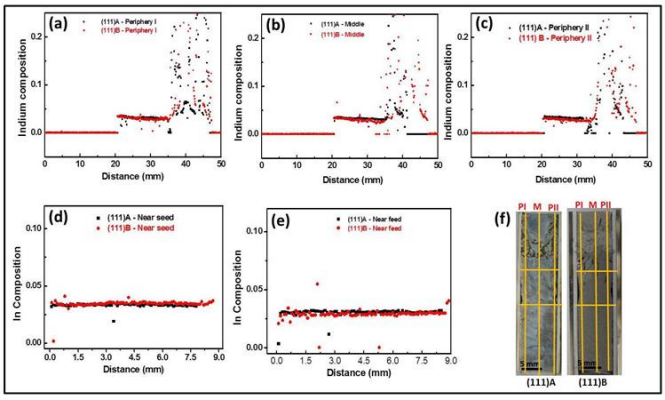

Fig.1 Indium composition measured by EPMA

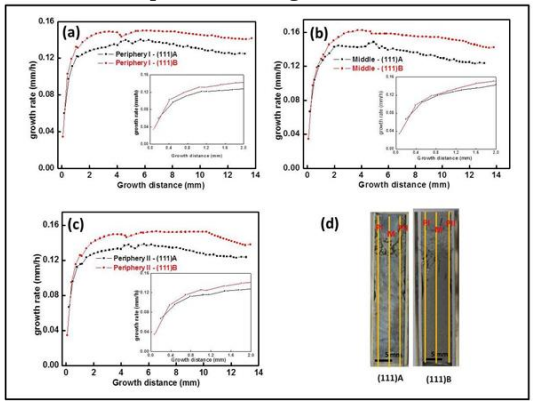

Fig. 2 Growth rate of InGaSb from GaSb(111)A and B

Results and discussion

The indium composition (Fig. 1) along the growth direction gradually decreased from the low-temperature seed interface to the high-temperature feed interface according to the InSb-GaSb phase diagram. The indium composition across growth was homogeneous, showing the uniform distribution of the temperature profile along the radial direction. The distance between growth striations was measured to calculate the growth rate (Fig. 2) and it was found that the difference between the growth rates at the initial stage was very small when compared with the later stages of growth. The experimental results indicate that the GaSb seed and feed crystals dissolved more along (111)B than (111)A because of the difference in the atomic arrangement of Ga and Sb atoms and their binding with the next atomic layer in their respective planes. In a diffusion-controlled growth process under microgravity, the dissolution of GaSb (111)B was higher than that of (111)A and the growth rate of InGaSb ternary alloy from GaSb (111)B was greater than that of GaSb (111)A.

Reference

1. P. S. Dutta, H. L. Bhat, and V. Kumar, Journal of Applied Physics **81** (1997) 5821
2. M. Arivanandan, Y. Hayakawa et al., Defect and Diffusion Forums, **323-325** (2012) 539
3. Y. Inatomi, V. Nirmal Kumar, Y. Okano, Y. Hayakawa et al. Nature partner journal npj-Microgravity, **1** (2015) 15011