Properties of InGaSb crystals grown under μG at International Space Station and 1G conditions

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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]. However it is difficult to grow high quality crystals due to large separation between liquidus and solidus lines that influence segregation phenomena during growth. Moreover in 1G, the high temperature solution growth process is affected by solute convection. Hence it is important to understand the growth process due to solute and heat transport at high temperature under μG, where convection is suppressed [2]. For this study InGaSb growth was conducted on earth and in space to analyse the growth properties of InGaSb alloy semiconductor. The μG space experiment was conducted in Japanese experimental module "KIBO" at the International Space Station (ISS).

Experimental method

InGaSb crystals were grown under 1G and μG conditions by vertical gradient freezing method using sandwiched structure (GaSb(111)A/Te-doped InSb/GaSb(111)A) of ampoule. 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 Laue to cut along (110) plane, vertical to growth direction. The cut crystals were etched in 1:3:1 ratio of HF:$KMnO_4$(sat.):CH_3COOH solution under optimized conditions to measure the composition and growth rate.

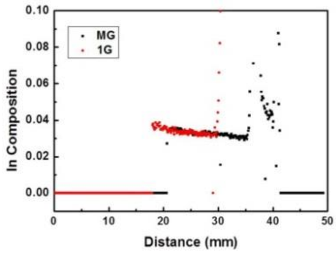

Fig. 1: In composition measured by EPMA

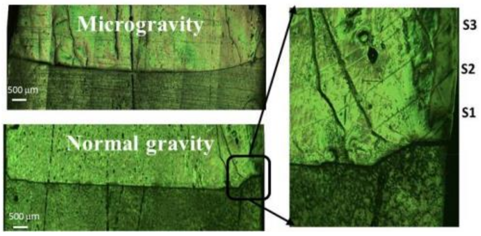

Fig. 2: Facet formation under 1G

Results and discussion

Indium composition of the InGaSb grown crystals under μG and 1G conditions are shown in Fig. 1, that revealed gradual decrease along growth direction owing to shift of growth interface towards high temperature feed region. Dissolution of seed crystal was more under 1G whereas feed dissolution was more under μG owing to dominant convective and diffusive solute transport. The maximum growth rate of μG sample (0.15 mm/h) was found to be higher than that of 1G sample (0.1 mm/h). Moreover, facets were formed on the periphery of 1G sample (Fig. 2) and first two striations were appeared only at the periphery region. It shows the initial growth started from periphery. The suppressed convection under μG resulted in growth of crystal from all over seed interface. Dominant convective and diffusive solute transport under respective 1G and μG conditions affected the growth of InGaSb.

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