CONTROL OF BACKGROUND CARRIER CONCENTRATION IN H-MBE GROWN GaInNAs THIN FILMS FOR 4-JUNCTION SOLAR CELLS

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Dilute nitride III-V semiconductor alloy, GaInNAs, is a promising material for lattice-matched 4-junction solar cell because of its 1.0 eV band gap and lattice constant matching to GaAs [1]. In prior research, i-GaInNAsSb was used to fabricate a p-i-n junction in order to increase the collection efficiency of photocarriers by electric filed-assisted drift process [2]. The result suggested that the control of the background carrier concentration (BGCC) in i-layer is important. However, the origins of BGCC is still unclear. The formation of N-H complex formed by nitrogen and hydrogen has been reported in the GaNAs fabricated by chemical beam epitaxy (CBE), which may respond to BGCC [3]. This research will assess the BGCC in i-GaInNAs layer grown by atomic hydrogen assisted-molecule beam epitaxy (H-MBE).

Lattice-matched undoped GaIn₀.₃₅N₀.₆₅As thin films were fabricated on n-GaAs substrates by H-MBE, where atomic hydrogen was supplied during the growth of the GaInNAs layer. Inset of Fig.1 shows the concentration of hydrogen in separated grown GaInNAsSb control samples. As shown in the inset, the concentration of hydrogen increases when the growth temperature (Tg) decreases. Therefore, GaInNAs samples were grown with Tg = 500°C, 440°C and 380°C to investigate the dependence of carrier concentration on the concentration of hydrogen by hall measurement and C-V measurement.

Figure 1 shows the carrier concentration versus growth temperature of GaInNAs (300 K) analyzed by hall measurement. At Tg = 440°C, the concentration of electron is 4.1x10¹⁵ cm⁻³. At Tg = 500°C and 380°C, the BGCCs are below detection limit, which suggests the carrier concentrations are below ~10¹⁴ cm⁻³. The increase of electron concentration when the temperature decreases from 500°C to 440°C, is supposed to be related to the increase of hydrogen concentration and formation of donors originated from N-H complex. At Tg = 380°C, free carrier decreases because the increase of lattice defects caused by low temperature growth. Figure 2 shows the carrier concentration versus depletion width of GaInNAs with Tg = 440°C and 380°C analyzed by C-V measurement. The BGCC is 1.1x10¹⁶ cm⁻³ for Tg = 440°C and 4.9x10¹⁵ cm⁻³ for Tg = 380°C. The result indicates the possibility of lattice defects caused by low temperature growth as 380°C. Based on the results above, the control of hydrogen concentration and N-H complex is suggested to be significant to control BGCC. The effect of hydrogen concentration on solar cell characteristics will also be presented at the conference.

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Figure 1: Carrier concentration versus growth temperature of GaInNAs. (Hall measurement, 300 K) (Inset: Hydrogen concentration versus growth temperature of GaInNAsSb)

Figure 2: Carrier concentration versus depletion width of GaInNAs with growth temperature of 440°C and 380°C. (C-V measurement, 300 K)