17p-A27-8

# RTA of MOVPE-grown Mg-doped $In_xGa_{1-x}N$ (x~0.3) for Mg activation

**Univ. of Fukui[1], JST-CREST[2], Osaka City Univ.[3]**
**°Md. Tanvir Hasan[1,2], A. Mihara[1,2], N. Shigekawa[3], A. Yamamoto[1,2], M. Kuzuhara[1]**
**E-mail: tan_vir_bd@yahoo.com**

**Introduction:** Achieving highly conductive p-type GaN and related alloys is a key issue in the nitride semiconductor device fabrication. Nakamura et al reported that the annealing temperature ($T_{act}$) should be higher than 700ºC for achieving low resistivity of Mg-doped GaN films [1]. For InGaN, there is a possibility that the annealing at high $T_{act}$ can bring about phase separation [2] of grown films. Recently, we have reported that the phase separation in $In_xGa_{1-x}N$ (x~0.3) is suppressed by reducing growth temperature to around 570°C [3]. In this paper, we report the rapid thermal annealing (RTA) of Mg-doped $In_xGa_{1-x}N$ (x~0.36) grown by MOVPE. P-type samples are successfully obtained by using RTA at around 850°C.

**Experiments:** The growth of InGaN alloys was conducted using a MOVPE system. TEG, TMI, and $NH_3$ were used for Ga, In, and N sources, respectively. $Cp_2Mg$ was used for Mg source. Growth temperature and pressure were fixed at 570°C and 150 Torr, respectively. Two types of substrates, AlN/Si and $\alpha$-$Al_2O_3$, were employed. The growth rate of InGaN was about 0.5 μm/h with In content of 0.36. Finally, samples were annealed in $N_2$ using RTA. For comparison, the furnace annealing was also employed.

**Results and discussion:** Figure 1 shows the cross-sectional SEM images for as-grown and furnace-annealed (at 650ºC for 20 min) samples. The annealed sample has a porous region in the film, showing the decomposition (phase separation) of the InGaN film [3]. Figure 2 shows the cross-sectional SEM images for as-grown and RTA (at 850ºC for 10 sec) samples. One can see that no porous region exists in the annealed sample. Thus, it is confirmed

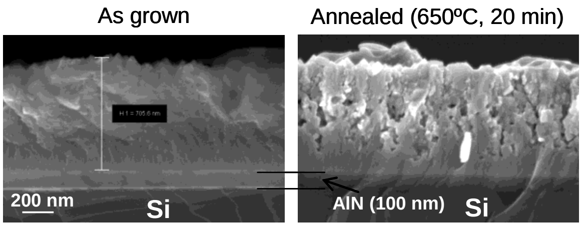


Fig.1. Cross-sectional SEM images for as-grown and furnace-annealed (at 650ºC for 20 min) samples.

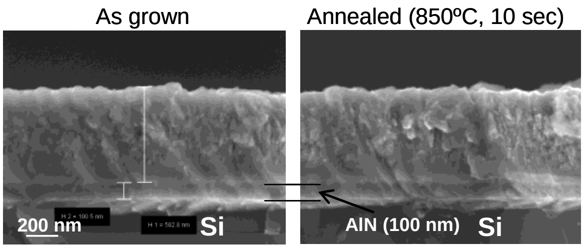


Fig.2. Cross-sectional SEM images for as-grown and RTA (at 850ºC for 10 sec) samples.

that the decomposition of InGaN can be suppressed by reducing annealing time, even if $T_{act}$ is much higher than growth temperature.

Figure 3 shows the $T_{act}$ dependence of carrier concentration and Hall mobility for RTA $In_xGa_{1-x}N$ (x~0.36) grown at 570°C. As shown in this figure, the carrier concentration is increased and Hall mobility is decreased with increasing $T_{act}$. The p-type conduction was confirmed by Hall and thermo-voltaic measurements for samples annealed at 850ºC. For samples annealed at 700-800ºC, p-type conduction was confirmed only by thermo-voltaic measurements. For the rest of samples, conduction type could not be identified. These results indicate that Mg-acceptor activation annealing should be done above 700ºC.

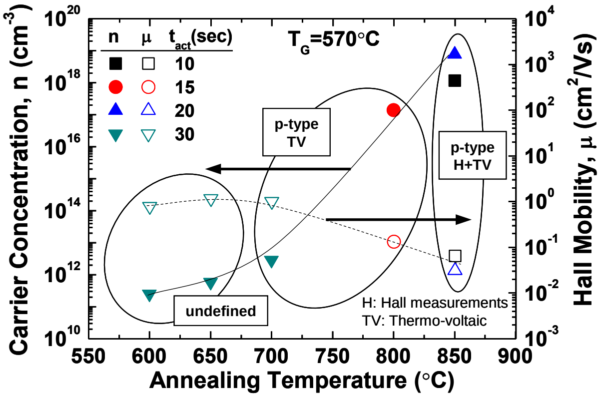


Fig.3. Carrier concentration and mobility of RTA InGaN samples grown at 570 ºC.

**Conclusion:** This paper reports the rapid thermal annealing (RTA) of Mg-doped $In_xGa_{1-x}N$ (x~0.36) grown by MOVPE. P-type samples are successfully obtained by using RTA at around 850°C.

This work was supported in part by “Creative research for clean energy generation using solar energy” project in CREST programs of JST, Japan.

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