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Phase separation of MOVPE-grown thick (~1 μm) $In_xGa_{1-x}N$(x~0.3) (II) ——— Suppression of the phase separation ———

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Introduction: In the previous work [1], we have demonstrated the decomposition of epitaxial $In_xGa_{1-x}N$ into metallic In-Ga and GaN-rich $In_zGa_{1-z}N$ as a result of phase separation. From the viewpoint of the application of InGaN, such phase separation is needed to be suppressed. Mostly, InGaN alloy films are prepared by MOVPE or MBE, where growth proceeds under conditions far from the thermal equilibrium. Therefore, such films show a tendency towards clustering and/or decomposition so that the system reaches an energetically stable state. The rate of the decomposition can be determined by the solid state diffusion mobility of atoms. In this work, we show that phase separation is almost suppressed by reducing growth temperature to 570ºC.

Experiments: The growth of $In_xGa_{1-x}N$ alloys (x~0.3) was conducted using a MOVPE system. Si(111) wafers with a layer of separately MOVPE-grown AlN(100 nm thick) were used as the starting substrates. During the growth process, the substrates were first annealed at 950ºC in NH_3 after which the temperature was ramped down to the growth temperature (550-700ºC). TEG, TMI, and NH_3 were used for Ga, In, and N sources, respectively. Growth pressure was fixed at 150 Torr. Growth rate of InGaN was about 0.7 μm/h.

Results and discussion: Fig. 1 shows the XRD 2θ/ω patterns for the epitaxial $In_xGa_{1-x}N$ grown at a different temperature. The decomposition reaction is clearly seen near 650ºC. The two peaks of metallic In and GaN-rich $In_zGa_{1-z}N$ are formed as a result of phase separation of the epitaxial $In_xGa_{1-x}N$. The metallic In was found to contain a small amount of Ga [1]. At 700ºC, the peak of metallic In is scarcely observed. This is due to the evaporation of In during growth. With decreasing growth temperature, phase separation was reduced, and almost suppressed at 570ºC. This is due to the lower diffusion mobility of atoms in InGaN at a low temperature. Fig. 2 shows the SEM images of cross-section for the epitaxial $In_xGa_{1-x}N$ grown at 570 and 650 ºC with a constant TMI/(TMI+TEG) molar ratio. A porous region as a result of phase separation is not found for the samples grown at 570 ºC.

Thus, the growth temperature, where two phases of metallic In-Ga and GaN-rich $In_zGa_{1-z}N$ are clearly observed, is limited to a relatively narrow range (<100ºC). Since phase separation at 650ºC is severer than that at 700ºC in spite of expected lower diffusion mobility of atoms at 650ºC, it is speculated that phase separation is enhanced by the presence of metallic In-Ga.

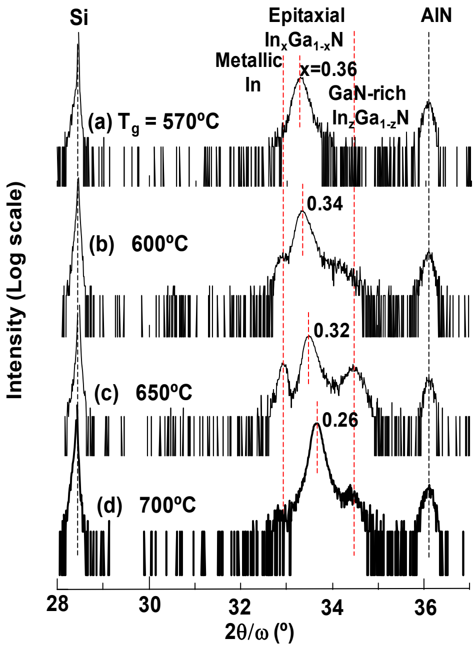

Fig.1. XRD 2θ/ω patterns for the epitaxial $In_xGa_{1-x}N$ grown at a different temperature with a constant TMI/(TMI+TEG) molar ratio. Growth time is 90 mins for all samples.

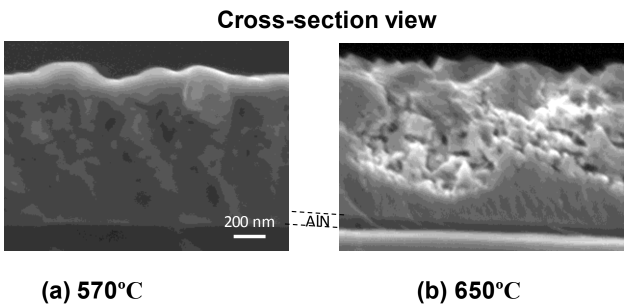

Fig.2. SEM images of cross-section for the epitaxial $In_xGa_{1-x}N$ grown at 570 and 650 ºC with a constant TMI/(TMI+TEG) molar ratio.

Conclusion: The decomposition reaction of InGaN is found to be suppressed by reducing growth temperature to around 570ºC

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