Effect of carrier gas on the properties of MOVPE-grown GaN and GaN/AlGaN MQWs: a comparison of H_2 to N_2 as a carrier gas

S. Yamaguchi[1], M. Kariya[2], M. Kosaki[2], S. Nitta[2], Y. Yukawa[2], H. Amano[1,3] and I. Akasaki[1,3]

High-Tech Research Center[1], Meijo University,

Department of Electrical and Electronic Engineering[2], Meijo University,

Department of Materials Science and Engineering[3], Meijo University,

1-501 Shiogamaguchi, Tempaku-ku, Nagoya, 468-8502, Japan

E-mail:syamagu@meijo-u.ac.jp

Recently, several research groups have reported that isoelectronic In-doping improves the crystalline and optical properties of GaN[1-3]. More recently, we have found that with increasing incorporated In in GaN the strain in GaN decreases (the crystalline mosaicity decreases), and such phenomenon was observed regardless of the carrier gas species (H_2 or N_2) for the growth of GaN[4,5]. Through that experiment, it was found that GaN grown with N_2 (H_2) carrier gas (denoted below by N_2- (H_2-)GaN,) is under tensile (compressive) stress at room temperature. We report the controllability of the properties of GaN/$Al_{0.17}Ga_{0.83}N$ MQWs grown on GaN by MOVPE with H_2 or N_2 carrier gas.

Atmospheric pressure MOVPE method was used for the growth. Trimethylgallium (TMG), trimethylaluminum (TMA) and ammonia (NH_3) were used as Ga, Al and N source gases, respectively. In order to confirm the tensile stress in N_2-GaN and to avoid the nucleation annealing effect, which may cause that tensile stress, the following structure was prepared. N_2-GaN was grown on H_2-GaN, and the total thickness was fixed to 1.5 μm. The ratio of the thickness of N_2-GaN to that of H_2-GaN is x ($0<x<1$). Both N2- and H2-GaN were grown at 950℃. GaN/$Al_{0.17}Ga_{0.83}N$ MQWs were grown on a GaN layer with 2 μm in thickness. The GaN layer was grown at 1050℃ on a sapphire (0001) substrate with LT-AlN. The growth temperature of the QWs was set to be 950℃. The carrier gas used during the growth of QWs was either H_2 or N_2, while that for GaN growth and LT-AlN deposition was H_2. The well width and the barrier width of the QWs were 5 nm and 7 nm, respectively, and the number of layer periods was 10. The thickness of the QWs and AlN molar fraction of AlGaN were determined by XRD measurements. In order to characterize the structural properties of the films, we performed XRD analysis. $2\theta-\omega$ scan and ω-scan from the (0002) and $(10\bar{1}0)$ diffraction plane were measured. In addition, photoluminescence (PL) was measured at RT. The 325 nm line of a He-Cd laser was used as the excitation source.

Figure 1 shows the in-plain strain in N_2-GaN as a function of x. It is evident that with increasing x the tensile stress component increases, indicating that the tensile stress in N_2-GaN is not due to the condition of LT-AlN layer. In some region of x, photoluminescence intensity became higher compared to H_2-GaN (x=0). In general, the thermal diffusivity and the deposition rate of a reactant in a carrier gas differs from those in other kinds of carrier gases. This may lead to the generation of some point defects which are due to the expansion of GaN.

Figure 2 shows the $2\theta-\omega$ scan of XRD profiles from the (0002) plane for GaN/$Al_{0.17}Ga_{0.83}N$ MQWs grown in H_2 or N_2 carrier gas. It is distinctly observed that the satellite peaks for MQWs grown in N_2 carrier gas (N_2-MQWs) are sharper and stronger in intensity than those of MQWs grown in H_2 carrier gas (H_2-MQWs). For N_2-MQWs, the –2 to +1 order satellite peaks are clearly observed, while for H_2-MQWs, very broad –1 and +1 order satellite peaks are observed at both sides of the 0 order satellite peak. PL intensity from N_2-MQWs was much higher than that from H_2-MQWs (not shown here). One possible explanation for the reason why the features of the two types of MQWs differ is related to the condition of strain in the GaN well layer.

The combination of N_2 and H_2 carrier gases is expected to be very useful in order to realize higher performance of nitride-based optical devices.

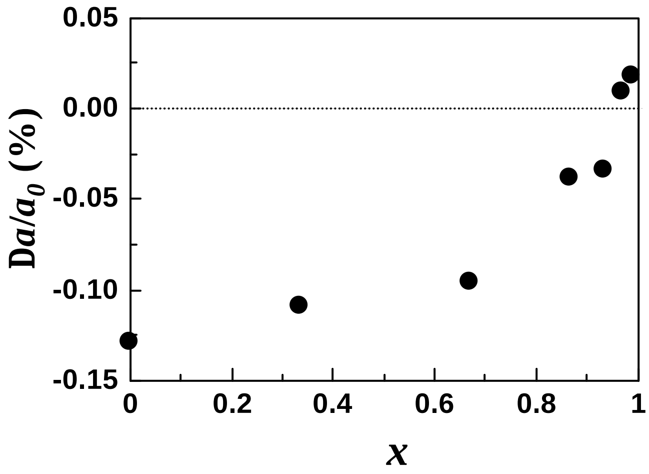

Figure 1. In-plain strain in GaN as a function of *x*. (about the definition of *x*, see the text.)

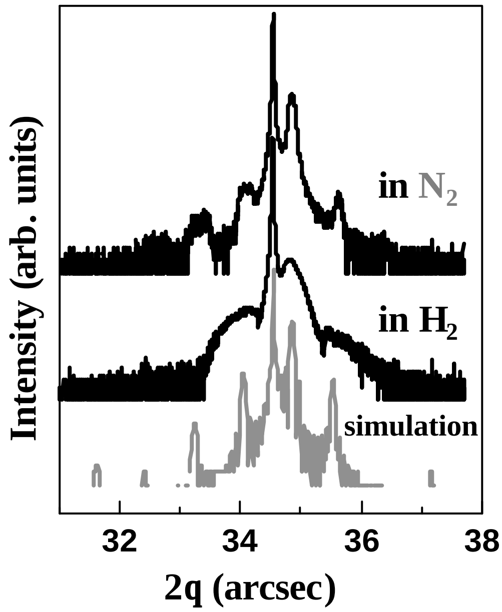

Figure 2. XRD 2θ/ω scan of GaN/AlGaN MQWs with H_2 or N_2 carrier gas.

Acknowledgements

This work was partly supported by the Japan Society for the Promotion of Science "Research for the Future Program in the Area of Atomic Scale Surface and Interface Dynamics" under the project of "Dynamic Process and Control of the Buffer Layer at the Interface in a Highly-Mismatched System (JSPS96P00204)", and the Ministry of Education, Science, Sports and Culture of Japan (contract no. 11450131, 12450017 and 12875006).

References

[1]C. K. Shu, J. Ou, H. C. Lin, W. K. Chen and M. C. Lee: Appl. Phys. Lett. 73, 641(1998).

[2]F. Widemann, B. Daudin, G. Feuillet, N. Pelekanos and J. L. Rouviere: Appl. Phys. Lett. 73, 2642 (1998) .

[3]X. Q. Shen, P. Ramvall, P. Riblet, and Y. Aoyagi: Jpn. J. Appl. Phys. 38, L411(1999).

[4] S.Yamaguchi, M.Kariya, S. Nitta, H. Amano, and I. Akasaki: Appl. Phys. Lett. 73, 4106(1999).

[5]M. Kariya, S. Nitta, M. Kosaki, Y. Yukawa, S. Yamaguchi, H. Amano, and I. Akasaki: Jpn. J. Appl. Phys. 39, L143 (2000).