Extended Abstracts of the 1999 International Conference on Solid State Devices and Materials, Tokyo, 1999, pp. 52-53

The Effect of Isoelectronic In-Doping on the Structural and Optical Properties of (Al)GaN Grown by Metal Organic Vapor Phase Epitaxy

Shigeo Yamaguchi[1], Michihiko Kariya[1], Shugo Nitta[1], Hiroshi Amano[1,2], and Isamu Akasaki [1,2]

Department of Electrical and Electronic Engineering[1], Meijo University

High-Tech Research Center[2], Meijo University

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

Phone: +81-52-832-1151 (ext. 5064) Fax: +81-52-832-1244 e-mail: syamagu@meijo-u.ac.jp

1. Introduction

Use of low temperature deposited buffer layer on the growth of GaN on sapphire enables us to grow high quality films without cracks [1], although there are high density threading dislocations [TDs] on the order of 10^8-$10^{11}cm^{-2}$. Very recently, reduction of TDs has been achieved by epitaxial lateral overgrowth (ELO) [2] or low temperature interlayer technique [3,4]. We have tried another approach to reduce defects, that is, isoelectronic In-doping [5]. With use of the technique, we may easily control the density of dislocations only by changing the supplied In source. Although the effect of In-doping on the luminescence properties of GaN has been reported by several research groups [6], at the moment, there is no report studying systematically the effect of In-doping on the structural and optical properties of the film and the mechanisms for such effect. Here, we show, for the first time, that In-doping does relieve strain and reduce mosaicity of GaN and AlGaN. We grew GaN and AlGaN at 900 C in a H2 or N2 carrier gas (denoted below by H2-(Al)GaN and N2-(Al)GaN, respectively).

2. Results

Figure 1 shows the tilting component of the mosaicity of H2- and N2-GaN of 1.8μm and 2.7μm measured by X-ray diffraction analysis as a function of trimethylindium (TMI) flow. The tilting decreases with increasing TMIn flow during growth. Moreover, the twisting component of the mosaicity of the samples also showed a similar tendency (not shown here). Figure 2 shows lattice constants c and a of H2- and N2-GaN of 1.8 μm and 2.7 μm in thickness. It is

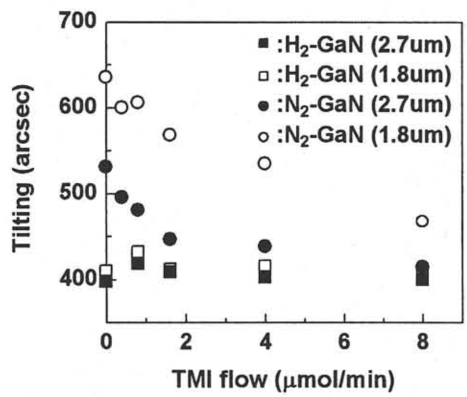

Fig. 1 Tilting component of the mosaicity of H_2- and N_2-GaN with 1.8 μm and 2.7 μm-thickness.

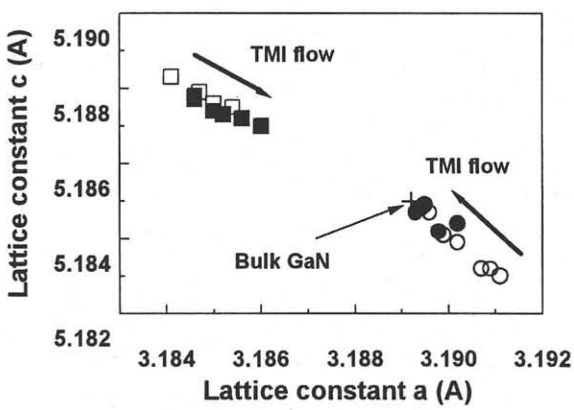

Fig. 2 Lattice constants c and a of H_2- and N_2-GaN with 1.8 μm and 2.7μm-thickness. The symbols are the same as in Fig.1.

observed that H2-GaN is under compressive stress and, strikingly, N2-GaN is under tensile stress at room temperature. These results are also confirmed by wafer curvature measurements. Wafer curvatures are +12.7m for H2-GaN and -38.2m for N2-GaN, respectively. With increasing TMIn during growth, lattice constants c and a of the both H2-GaN and N2-GaN get closer to the values of bulk GaN. The absolute value of the wafer curvature also increased with increasing TMIn flow. The reason why N2-GaN is tensile is under consideration. It was also found that the growth pits distinguished by using In doping for both H2- and N2-GaN.

Figure 3 shows the tilting component of the mosaicity of H2- $Al_{0.95}Ga_{0.05}N$ of 3.0 μm as a function of TMI flow. It is also found for AlGaN that the tilting decreases with increasing TMI flow.

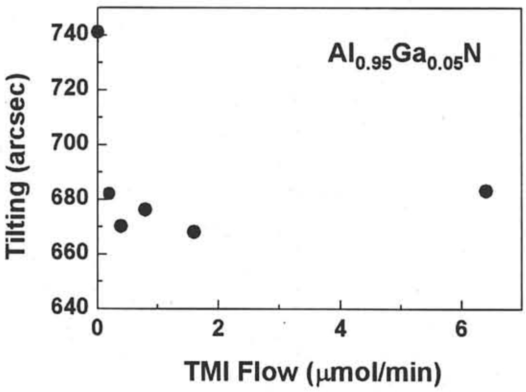

Fig. 3 Tilting component of the mosaicity of H2-$Al_{0.95}Ga_{0.05}N$ with 3.0μm-thickness.

In-doping is also effective on the improvement of the optical properties. The photoluminescence intensity of free exciton emission at room temperature increased with an increase in TMIn flow irrespective of the kind of carrier gas.

We would explain these results above mentioned by taking into account the solid solution hardening effect. We consider at this stage that such effect is caused by the incorporation of indium into the dislocation and it serves as a pinning of sliding of dislocations.

3. Conclusions

Isoelectronic In-doping was found to be effective on reduction in strain and crystal mosaicity and on improvement of optical properties of GaN and AlGaN grown by MOVPE.

Isoelectronic In-doping will be useful for achievement of higher performance of any optical devices.

Acknowledgements

This work was partly supported by Japan Society for the Promotion of Science (JSPS) Research for the Future Program in the Area of Atomic Scale Surface and Interface Dynamics under the project "Dynamic Process and Control of the Buffer Layer at the Interface in a Highly-Mismatched System", and the Ministry of Education, Science, Sports and Culture of Japan (contract nos. 09450133, 09875083).

References

[1] H.Amano, N.Sawaki, I.Akasaki, and Y.Toyoda, Appl.Phys.Lett., 48, 353 (1986)

[2] A.Usui, H.Sunakawa, A.Sakai, and A.A.Yamaguchi, Jpn.J.Appl.Phys. 36, L899 (1997)

[3] M.Iwaya, T.Takeuchi, S.Yamaguchi, C.Wetzel, H.Amano, and I. Akasaki, Jpn.J.Appl.Phys., 37, L316 (1998)

[4] H.Amano, M.Iwaya, T.Kashima, M.Katsuragawa, I.Akasaki, J.Han, S.Hearne, J.A.Floro, E.Cheson, and J.Figiel, Jpn.J.Appl.Phys., 37, L1540 (1988)

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

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