19aF-3

High Density Radical Source for GaN Epitaxial Growth
GaN結晶成長用高密度ラジカル源

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In a conventional Molecular Beam Epitaxy (MBE), a high crystallinity GaN can be obtained. However, the growth rate is lower than the Metalorganic Chemical Vapor Deposition (MOCVD), so that it is unsuitable for mass production. Therefore, we have developed a High Density Radical source (HDRS) for MBE. Conventional Radical Source (CRS) is composed of an inductively coupled plasma (ICP). By combining Capacitively Coupled Plasma (CCP) and ICP, nitrogen radicals with a density of higher than 10^{12} atoms/cm^3, which was more than 10 times higher than that for the CRS, were successfully generated in HDRS. In this study, the improvement of HDRS for practical use is discussed.

1. Introduction

The epitaxial growth of GaN layer is commonly carried out by MBE, [1] [2] and MOCVD [3]. MBE could realize low-temperature growth, which has a characteristic of suppression of the volatilization of Ⅲ-group material, particularly In. However, GaN by MBE has a characteristic of low growth rate (the typical growth rate is approximately 0.5 μm/h).

The high efficiency plasma source to supply sufficient atomic nitrogen radical (N) was considered as one of the most crucial issues for the high growth rate of nitride films.

To obtain the high density of radicals, we have obstacles as follows.

1) The measurement of N radical absolute density is important. Our VUVAS technology can only measure the absolute N radical density, particularly in the effused N radical source plasma region.
2) We evaluated the ICP plasma by the radical density measurement and made a new structure of HDRS with a complex plasma source, CCP with ICP and optimized the RF power feeding circuit.

With two methods as shown above, the N radical density over 10^{+12}cm/cm^{-3} was achieved [4][5].

In this study we tried to evaluate the density of ions in the flux, and to deflect ions by placing the Retard Electrode just close the downstream of the HDRS.

2. Experiment

Fig.1. shows the schematic illustration of HDRS. HDRS consisted of the 30mm-diameter tubular electrode as the ICP power supply. Pure nitrogen gas was introduced to the plasma discharge tube which acts as the CCP power supply. A part of confined radicals diffuse from the plasma discharge area to the main chamber through the aperture by the pressure difference between the two areas. The magnet unit was mounted around the cylinder electrode to trap electrons in order to increase the plasma density.

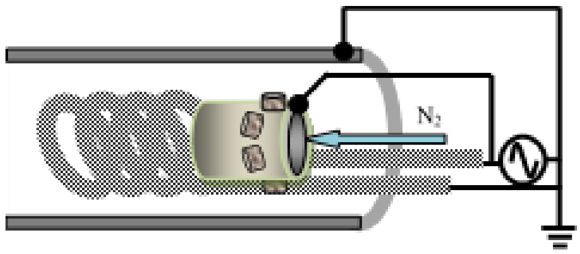

Fig.1. Schematic illustration of HDRS

The Retard Electrode, that was placed just close to the downstream of the tubular electrode, generated the electrostatic field vertical to the flux. While radicals were not affected by the electrostatic field, ions were deflected.

The radical density was measured by VUVAS which was described in the reference [6]. The density of ions was evaluated by a 5mm-daimeter Faraday Cup, placed 100mm in the downstream from the flux exit. An operating frequency of 13.56 MHz was used for the electric powers.

3. Result and discussion

Comparison of the density of the nitrogen radicals generated by CRS and HDRS are shown in Fig.2. The HRDS can generate nitrogen radicals in a wide pressure range. A maximum density of 2.3×10^{12} atoms/cm^3 was achieved. This is one order higher than the maximum value of CRS.

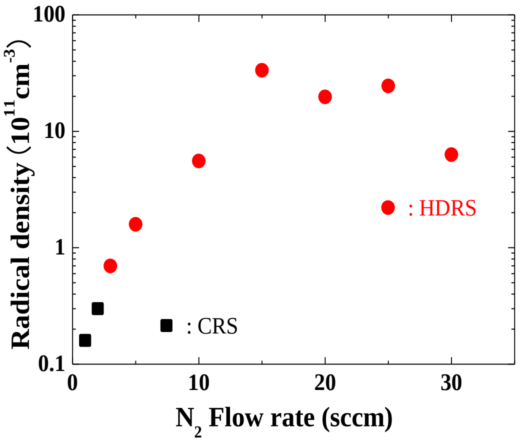

Fig.2. Absolute density of nitrogen radicals as a function of the flow rate.

Fig.3. shows the dependence of the ion current on the Retard voltage. The ion current is reduced as applied voltage is increased. The ion current at 150V was 1/20 of the ion current at 0V. This is because the electrostatic force in the direction perpendicular to the flow deflected ions. Ions of different velocities are contained in the flux. When the applied voltage becomes higher, only high speed ions can reach the Faraday Cup.

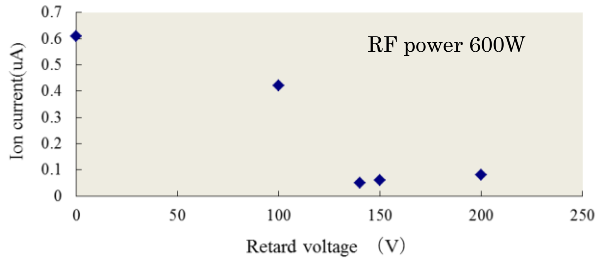

Fig.3. Retard ion current measurement. The N2 flow rate is 10 sccm. The measuring position is 100 mm in the downstream from the flux exit.

This does not mean low speed ions are removed. Low speed ions were deflected and the deflected ions have passed through the different position from Faraday Cup. Since the Faraday Cup was placed coaxially with the plasma discharge tube.

4. Conclusion

In this study, it has been found that the Retarding Electrode can deflect ions from the flux. We have developed the HDRS that can generate the high density N radicals and can control the ion density in the flux.

Acknowledgments

The authors would like to thank Dr. Koji Yamakawa (Katagiri Engineering Co., Ltd) for cooperation in the experiment and discussions.

References

[1] M. Mesrine, N. Grandjean, and J. Massies: Appl. Phys. Lett. 72 (1998) 350.
[2] Z. H. Wu et al.,: Appl. Phys. Lett. 98 (2011) 141905.
[3] H. Amano, N. Sawaki, I. Akasaki, and Y. Toyoda: Appl. Phys. Lett. 48 (1986) 353.
[4] Y. Kawai et al.,: Phys. Status Solidi C8, No.7-8, 2089-2091(2011)
[5] S.Chen et al.,: J. J. Applied Physics 52(2013)021001
[6] S.Takashima et al.,: J. Vac. Sci. Technol. A, 19, (2001) pp.599-602.