Atmospheric Pressure Microplasma Treatment of GaN Surface

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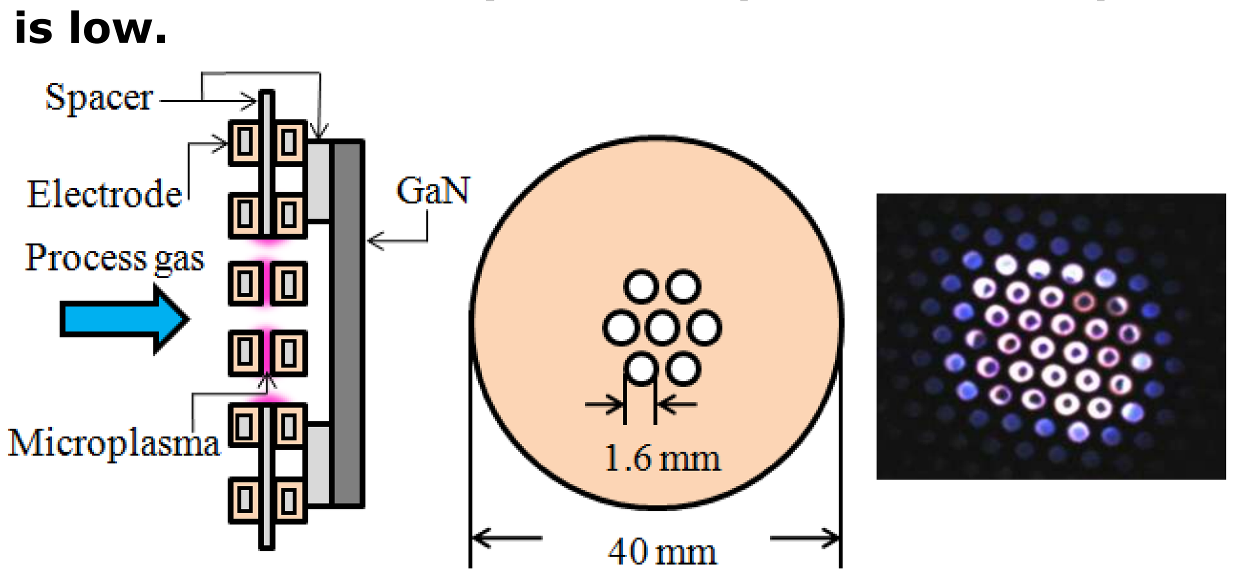
INTRODUCTION

In this article, we present the investigation result of GaN surface modification by microplasma under atmospheric pressure.
GaN is usually formed by nitriding GaAs and grown on the sapphire substrate with a high dislocation density. The large lattice mismatch between GaN crystal and sapphire substrate leads to the possibility of high threading dislocations densities in the nitride layers. Dislocations which occur in the GaN crystal degenerate its quality and electric characteristic.
Plasma process for interface treatment, nitriding process of GaAs and regrowth of GaN crystal was investigated as the convenient way to reduce dislocations of GaN crystal.
The use and possibility of atmospheric pressure microplasma for reducing dislocations or crystal growth of GaN was confirmed by using X-ray Photoelectron Spectroscopy (XPS) and Atomic Force Microscope AFM) to check the chemical and physical change of GaN surface after microplasma treatment.

METHODS

(1) Microplasma Electrodes

Microplasma was generated with a pair of electrodes which covered with dielectric layer and faced each other at small discharge gap under 100 μm with a spacer. Due to small discharge gaps (0~100μm) and to the assumed specific dielectric constant of $\varepsilon_r = 10^4$, a high intensity electric field (10^7 ~ 10^8 V/m) could be obtained with relatively low discharge voltage of only about 1 kV. Therefore only a small size reactor is necessary and the power consumption is low.

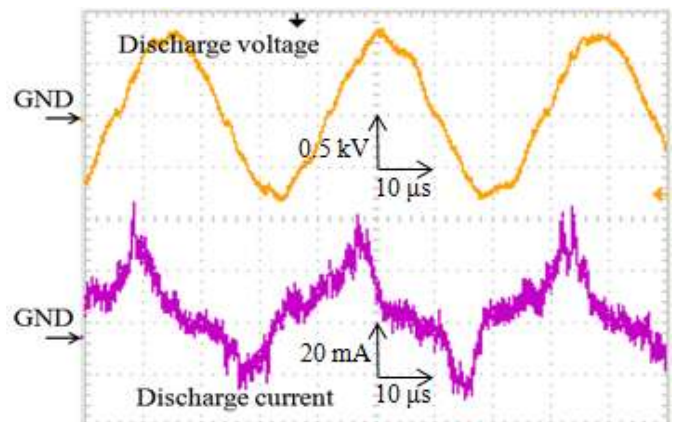


Structure of microplasma electrodes

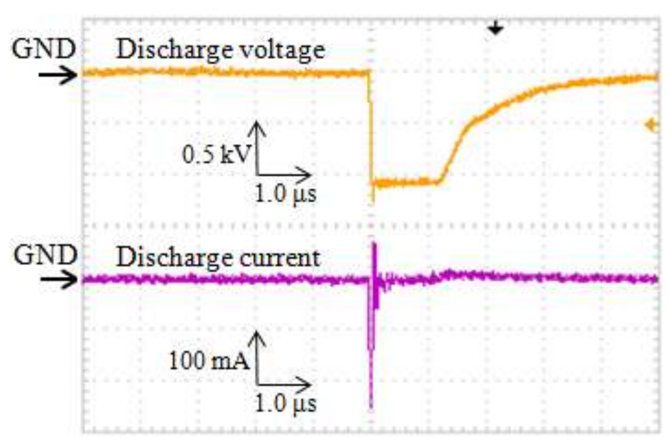
Hole size: 1.6 mm
Total area of holes: 14 mm²
Discharge gap: 100 μm
Distance between GaN surface and electrode: 1 mm

Fig. 1 Microplasma electrodes.

Figure 2 shows a current-voltage waveform during generating microplasma. Spick current occurred at rise and decay time of discharge voltage. This is a typical waveform of dielectric barrier discharge.



(a) AC-powered microplasma.



(b) Pulse-powered microplasma.

Fig. 2 Image of microplasma generation.

(2) Experimental setup

Fig. 3 shows the experimental setup for surface treatment of GaN substrate. In this study, a neon transformer was used as a power supply to generate microplasma. Streamers were generated between electrodes could generate various radicals and ions. These active species could affect a target surface [1].

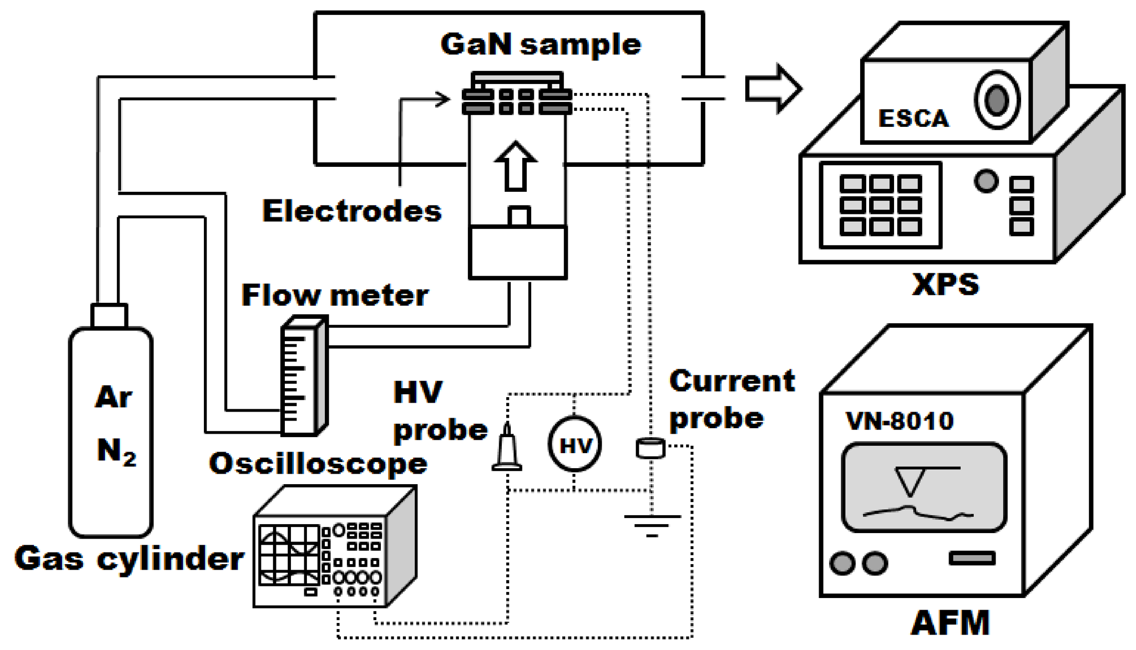


Fig. 3 Experimental setup for surface treatment of GaN substrate.

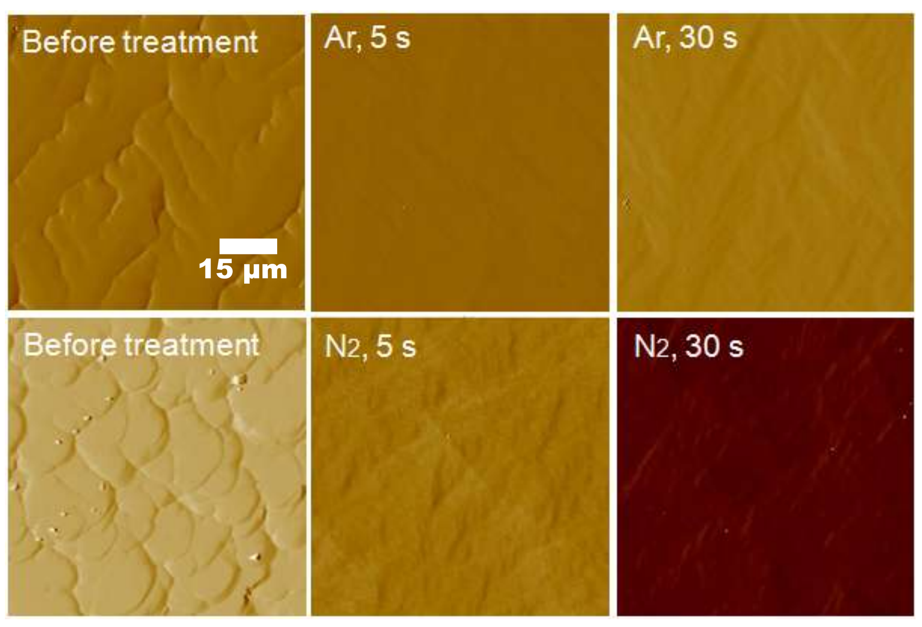
Table 1 Experimental conditions.

Atmosphere gas	Ar	N_2
Carrier gas		
Carrier gas Flow rate [m/s]	5	
Discharge voltage [kV]	0.9	1.7
Discharge gap [μm]	100	
From GaN surface to electrode [mm]	1	

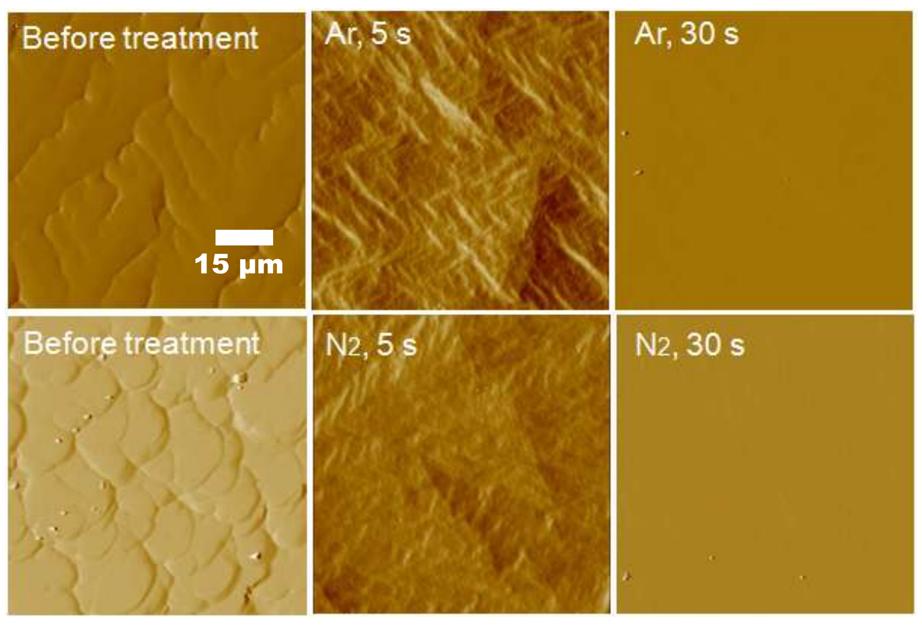
RESULT

AFM analysis

A significant physical modification of GaN surface was observed in both Ar and N2 microplasma treatment. In Ar microplasma treatment, a high amount of radicals and excited species derived from Ar attributed to physical change of GaN surface. This could be considered that the etching effect of Ar. In N2 microplasma treatment, excited N2 or N radicals generated by microplasma could have affected the dangling bonds of GaN surface due to the chemical reaction.



(a) AC-powered microplasma treatment.

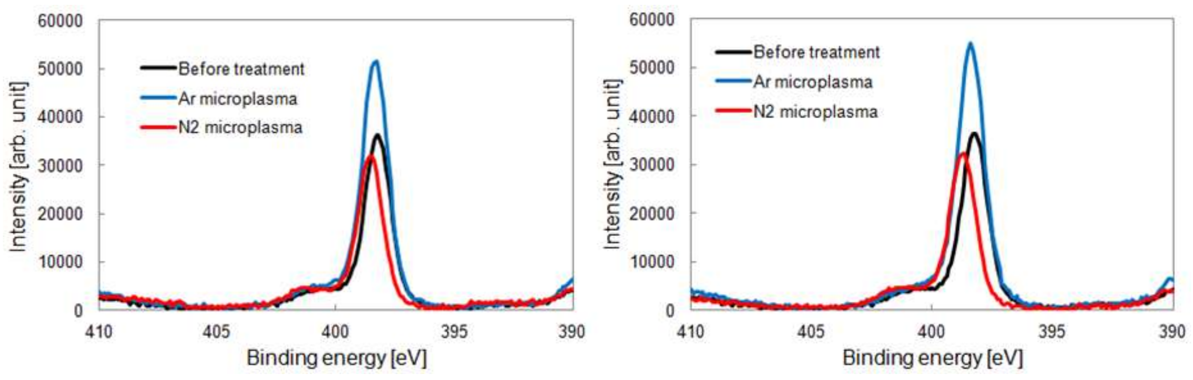


(b) Pulse-powered microplasma treatment.

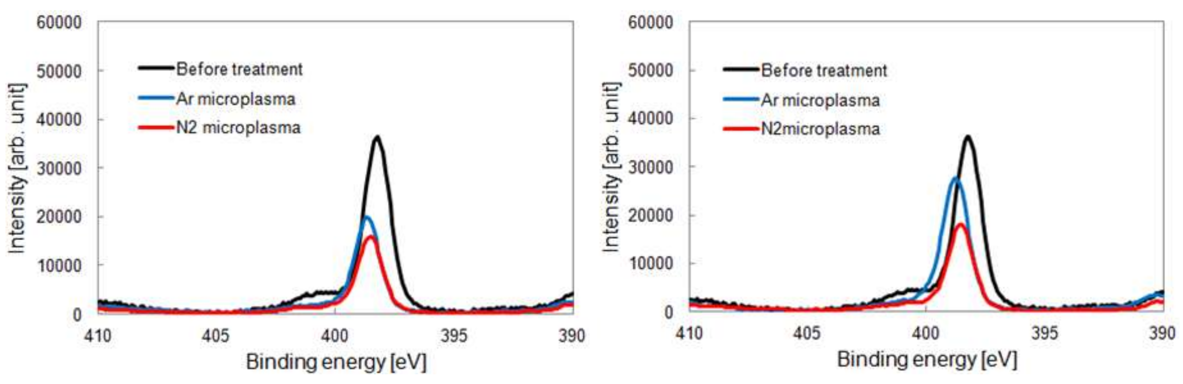
Fig. 4 AFM images of GaN surface.

XPS analysis

Chemical bonds on the GaN substrate surface were analyzed by XPS. Excited Ar species and metastable N_2 species were generated from microplasma, mainly contributed to surface modification of GaN substrate. These active species have relatively long life time, thus these active species could affect the GaN surface.
Increases of N-Ga bonds which formed GaN substrate was observed with Ar microplasma treatment in a argon atmosphere. In contrast, decreases of N-Ga bonds was observed with N_2 microplasma treatment in a nitrogen atmosphere. It is confirmed that carrier gas and atmosphere gas are important factors for surface modification of GaN substrate.

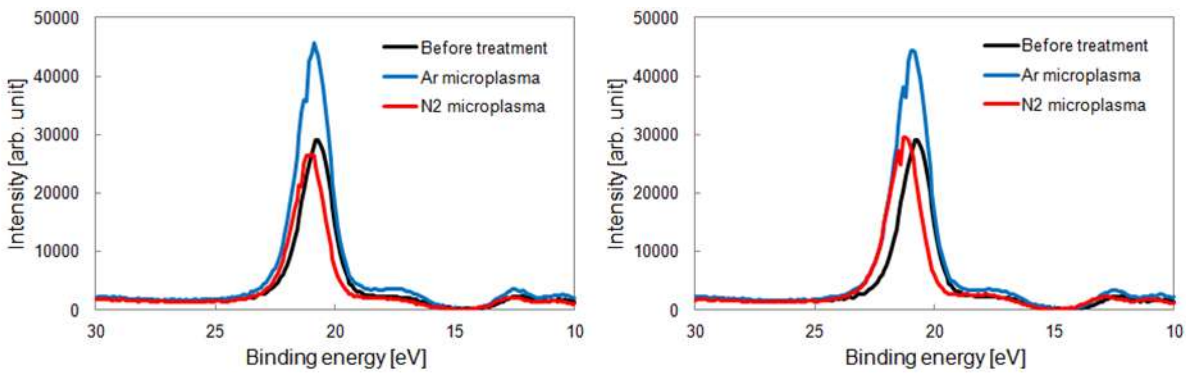


(a) AC-powered MP, 5 s. (b) AC-powered MP, 30 s.

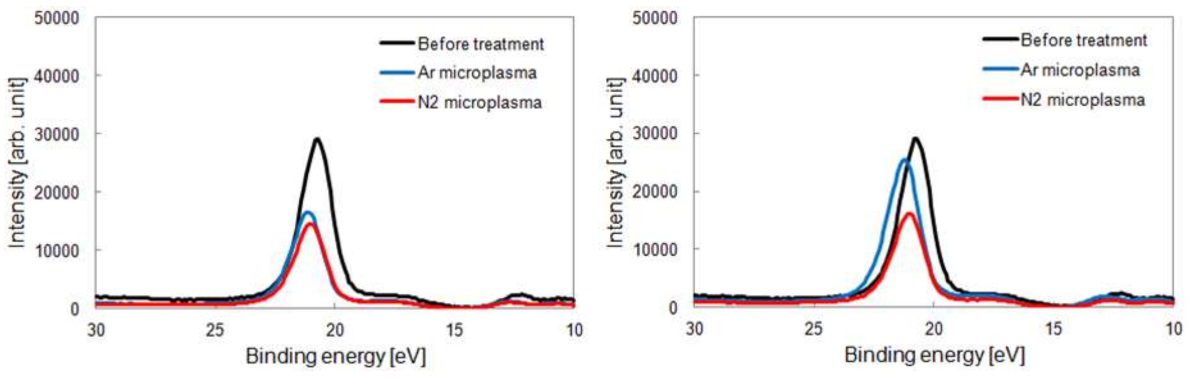


(c) Pulse-powered MP, 5 s. (d) Pulse-powered MP, 30 s.

Fig. 5 N 1s peaks of GaN surface by XPS.



(a) AC-powered MP, 5 s. (b) AC-powered MP, 30 s.



(c) Pulse-powered MP, 5 s. (d) Pulse-powered MP, 30 s.

Fig. 6 Ga 3d peaks of GaN surface by XPS.

CONCLUSIONS

In this study, the following conclusions were obtained.

1.The possibility of the GaN surface modification by atmospheric microplasma had confirmed.

2.Increases of the N-Ga bonds was observed by Ar microplasma treatment and decreases of the N-Ga bonds was observed by N_2 microplasma.

3.Physical change of GaN surface was observed in both Ar and N2 microplasma treatment. In Ar microplasma treatment, it could be considered that the etching effect of excited Ar species. In N2 microplasma treatment, excited N or N2 radicals affected to GaN surface due to the chemical reaction.

REFERENCE

[1] K. Shimizu, A. Umeda, S. Muramatsu, M. Blajan, *J. Appl. Phys.* 50, 08KA03-1 (2011).
[2] K. Shimizu, Y. Noma, M. Blajan and S. Naritsuka, *J. Appl. Phys.* 51, 08HB05-1 (2012).