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Basic Study on Surface Modification of GaN Substrate by Atmospheric Microplasma
大気圧マイクロプラズマによるGaN基板表面改質の基礎検討

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GaN is widely studied and developing its growth material for new application such as power device or emitting various color of light by adjusting its band gap by mixing it with Indium or Aluminium. GaN is usually formed by nitriding GaAs and grown on the sapphire substrate with a high dislocation density. For this dislocation, microchannel epitaxy (MCE) or regrowth of GaN is required to reduce dislocations. Recently, plasma treatment is used for interface treatment, regrowing of GaN crystal and nitridation process of GaAs. In this article we present the investigation result of GaN surface modification by microplasma under atmospheric pressure.

1. Introduction

GaN is well known material for blue LED and semiconductor lasers. GaN is usually formed by nitriding GaAs and grown on the sapphire substrate with a high dislocation density [1]. For this dislocation, microchannel epitaxy (MCE) or regrowth of GaN is required to reduce dislocations [2]. Recently, plasma treatment is expected for interface treatment, regrowth of GaN and nitridation process of GaAs [3].

Effect on surface treatment of GaN substrate by microplasma under atmospheric pressure was carried out [4].

2. Experimental Method

Figure 1 shows the schematic image of microplasma electrodes for GaN surface treatment. Microplasma was generated with a pair of electrodes covered with dielectric layer and faced each other at a small discharge gap under 100 µm. Due to a small discharge gaps 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 voltages only about 1 kV. Streamers were generated between electrodes could generate various radicals and ions. These active species could affect a target surface.

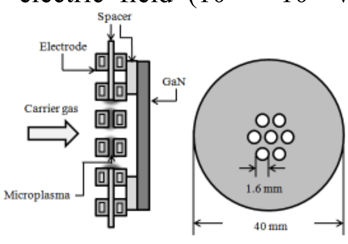
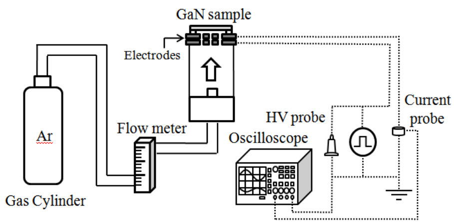


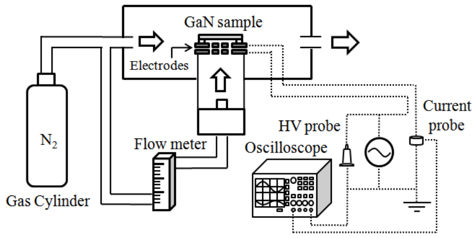
Fig. 1. Schematic image of microplasma electrodes.

Figure 2 shows the experimental setup for surface treatment of GaN substrate. In the experimental setup (a), surface treatment of GaN substrate was performed in atmosphere with Ar carrier gas. A marx generater, a negative pulse power supply, was used for microplasma generation. Discharge voltage of -1.3 kV, rise time of 50 ns, pulse width of 3 µs and frequency of 24 kHz, energized the electrodes. Flow rate of Ar carrier gas was set at 5 L/min. In the setup (b), experiment was performed in a nitrogen atmosphere with N_2 carrier gas. A neon transformer, a AC high voltage, was used as a power supply. Discharge voltage of 1.5 kV and frequency of 27 kHz was energized the electrodes. Flow rate of N_2 carrier gas was set at 5 L/min.

Contact angle on the GaN surface and an analysis by X-ray Photoelectron Spectroscopy (XPS) was measured before and after microplasma surface treatment of GaN substrate.



(a) Ar plasma treatment in atmosphere.

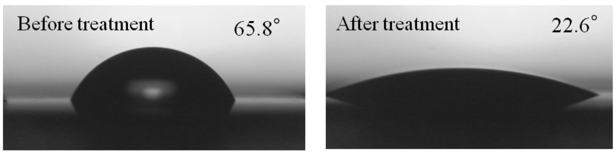


(b) N_2 plasma treatment in a nitrogen atmosphere.
Fig. 2. Experimental setups.

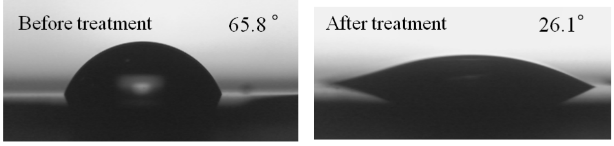
3. Experimental Result

3.1. Contact angle measurement

The contact angle of GaN surface was evaluated by contact angle meter with a drop of distilled water on the GaN surface. The contact angle was calculated by the θ/2 method. Figure 3 shows images of contact angle of GaN surface.



(a) Treated for10 s with Ar plasma.



(b) Treated for 30 s with N_2 plasma.
Fig. 3. Image of contact angle measurement.

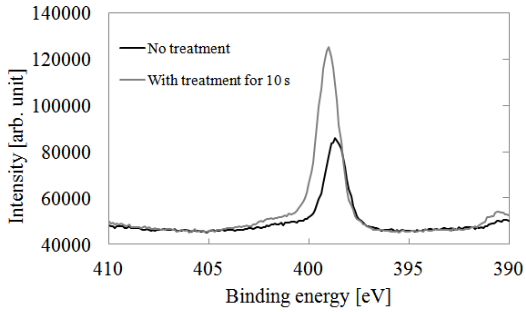
Initial contact angle of GaN surface was 65.8°. A decrease of contact angle was observed after microplasma treatment at both of experimental conditions. The contact angle decreased at 22.6° after Ar microplasma treatment applied for 10 s and at 26.1° after N_2 microplasma treatment applied for 30 s. It could be considered that increase of the hydrophilic groups concerning with nitrogen.

3.2. XPS analysis

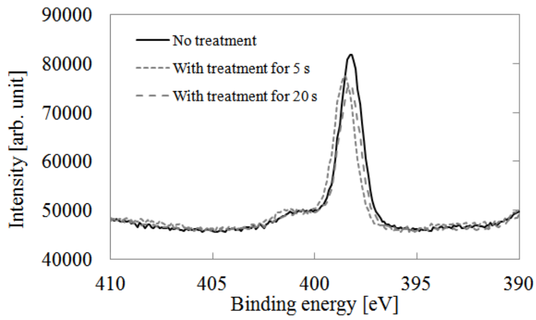
Chemical bonds on the GaN surface were analyzed by XPS. Figure 4 shows N 1s peaks of the GaN substrate surface.

On the Ar microplasma treatment in atmosphere, a increase of the N-Ga bond which formed GaN was observed. It could be considered that Ar plasma which has a high potential about 11.5 eV affected to GaN substrate surface.

In contrast, a decrease of the N-Ga bond was observed with experimental condition of N_2 microplasma treatment in a nitrogen atmosphere. This could be considered that the nitrogen atoms on the GaN substrate surface were decreased by N_2 plasma treatment.



(a) N 1s peaks treated with Ar microplasma.



(b) N 1s peaks treated with N_2 microplasma.
Fig. 4. N 1s peaks by XPS.

4. Conclusions

In this study, the following conclusions were obtained.

1. The possibility of the GaN surface modification by atmospheric microplasma had confirmed.
2. A decrease of a contact angle was observed at both of experimental conditions. It could be considered that increase of the hydrophilic groups concerning with nitrogen at both of experimental conditions.
3. A increase of the N-Ga bond was observed by Ar microplasma treatment in atmosphere. It could be considered that Ar plasma which has high potential affected to GaN substrate surface.
   A decrease of the N-Ga bond was observed by N_2 microplasma treatment in a nitrogen atmosphere. It could be considered that the nitrogen atoms on the GaN substrate surface were decreased by N_2 plasma treatment.

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