Topic number 8

Effect of discharge tube temperature on the density of N(^{4}S^o) in a remote nitrogen plasma source

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We investigated the characteristics of surface nitriding of 4H-SiC using a remote nitrogen plasma to improve the carrier mobility of a SiC-based power transistor. Our previous report suggests the possibility of an efficient, low-damage nitriding process using the remote nitrogen plasma which has a high flux ratio of $N_2(A^3\Sigma_u^+)$/N(^{4}S^o). In this paper, we tried to control the densities of reactive nitrogen species by heating the discharge tube. Quartz and p-BN tubes were employed for the discharge tube. We observed the increase in the N(^{4}S^o) density with the discharge tube temperature between 20 and 600 ^{o}C. On the other hand, the N(^{4}S^o) density was roughly independent of the discharge tube temperature when we employed a quartz tube.

1. Introduction

The control of the flux ratio of reactive species supplied from a reactive plasma is of importance in various plasma processing technologies to optimize their performances. We are investigating the characteristics of surface nitriding of 4H-SiC using a remote nitrogen plasma to improve the carrier mobility of a SiC-based power transistor. In a previous report, we pointed out a possibility of an efficient, low-damage nitriding process using the remote nitrogen plasma which have high flux ratio of $N_2(A^3\Sigma_u^+)$/N(^{4}S^o) [1]. To realize the control of the flux ratio of reactive nitrogen species, we investigated the effect of the material of the discharge tube and its temperature. In this paper, we report the effect of the discharge tube temperature on the N(^{4}S^o) density in the spatial afterglow region of the remote nitrogen plasma.

2. Experiment

The nitrogen plasma was produced by attaching a microwave resonator on the outside of a quartz or p-BN tube. The resonator was connected to a microwave power supply at 2.45 GHz. The microwave power was 100 W. The bottom side of the discharge tube was connected to a stainless-steel cylindrical chamber. The gas pressure was adjusted at 0.5 Torr by controlling the pumping speed. We attached a kanthal spiral wire on the outside of the discharge tube in the region between the microwave resonator and the stainless-steel chamber. The discharge tube was heated up to 600 ^{o}C by applying a heating power to the kanthal wire. The N(^{4}S^o) density was measured in the spatial afterglow region by vacuum ultraviolet absorption spectroscopy. The distance between the microwave resonator and the measurement position was 12 and 13 cm when employing the quartz and p-BN tubes, respectively.

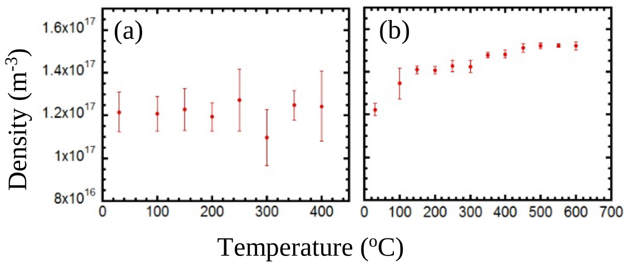

Fig.1. Relationship between density of N(^{4}S^o) and temperature of (a) quartz and (b) p-BN tubes in the spatial afterglow region.

3. Results and Discussion

Figures 1(a) and 1(b) show the relationships between the N(^{4}S^o) density and the discharge tube temperature when we employed a quartz and p-BN tubes, respectively. As shown in the Fig. 1(b), we observed the increase in the N(^{4}S^o) density with the discharge tube temperature when we employed the p-BN tube. On the other hand, the N(^{4}S^o) density was roughly independent of the temperature when we employed the quartz tube. Since the N(^{4}S^o) density decreased with the distance from the microwave resonator, the result shown in Fig. 1(b) may be caused by the decrease in the surface loss probability of N(^{4}S^o) on the surface of the p-BN tube at a high temperature. Another possibility is the production of N(^{4}S^o) in the region between the microwave resonator and the measurement position due to collisions among vibrationally excited molecular nitrogen (the V-V pumping-up mechanism).

4. References

[1] M. Shimabayashi, K. Kurihara, and K. Sasaki, Jpn. J. Appl. Phys. **55** (2016) 036503.