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Investigation of Plasma-Induced Damages in GaN with Different Processing

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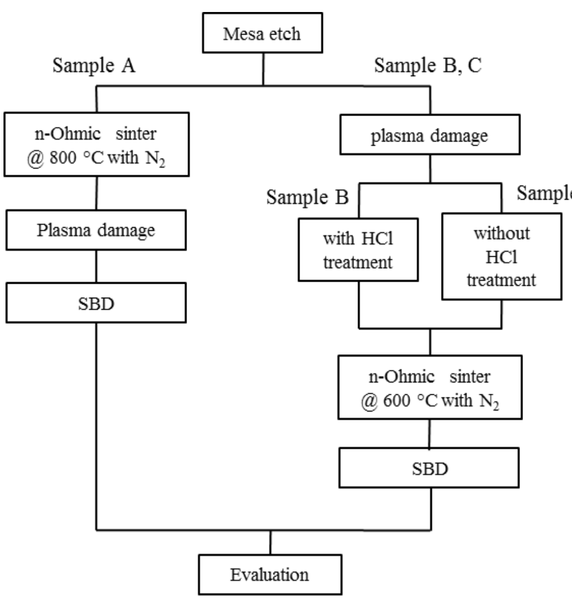
1. Introduction

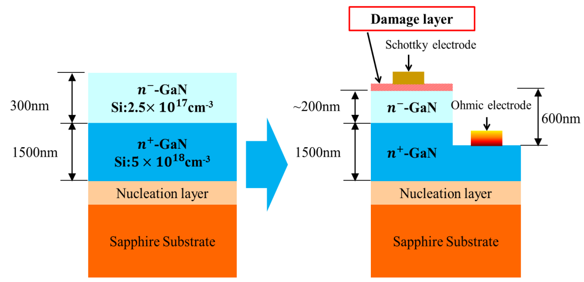
Gallium nitride has been largely investigated in the past decade as a result of its high bond strength and wide band gap. The high bond strength has also made GaN relatively difficult to process for device applications. Device fabrication processes for GaN-based materials usually rely on dry etching methods which use a variety of plasma and ion conditions, known to lead to surface damage [1-3]. Also, it is well known that plasma-induced damage may cause the degradation of electrical and optical device properties [4-7]. Moreover, the dry etching process reveals ion-induced lattice defects, discharge-gas-related residues and non-stoichiometric surfaces, which lead to the degradation of device characteristics. In this study, the effects of dry etching on Au/n-GaN Schottky diodes (SBDs) were investigated by changing various processes.

2. Device Structure and Fabrication Process

The complete process and schematic image of the fabricated Au/n-GaN Schottky diode is shown in Fig. 1.



(a) Complete process



(b) Au/n-GaN Schottky diode

Fig. 1 (a) Complete process and (b) schematic diagram of the

The n^--GaN/n^+-GaN epi-wafer was used for the fabrication of SBDs. After mesa-etching for n^+-GaN Ohmic contact by ICP-RIE using Cl_2/Ar plasma, n^--GaN (100 nm) layer was etched by ICP-RIE with various Cl_2/Ar ratio and bias power (P_B) to estimate plasma induced damage on Schottky area (Sample group A, B, C). In order to overcome the plasma damage, the surface was treated by HCl at 108°C for 30 min before fabricating Ohmic electrode (with treatment group B and without treatment group C). Ti/Al/Ti/Au (30/30/20/200 nm) of Ohmic electrode was formed on n^+-GaN layer. The Schottky electrode of 200 nm Au was formed on plasma exposed surface. The Electrical properties were estimated by I-V and C-V measurements.

3. Result and Discussion

It is observed from Fig. 2 (a) and (b) that the reverse bias leakage current density is increasing with increasing bias power. As the bias power for ICP-RIE was increased, leakage current density increased. The leakage current density was also dependent on the gas composition during ICP-RIE process, i.e., the leakage current density was minimum at 25% of Ar ratio as shown in Fig 2. (b). The ionized donor concentration (N_d) estimated from C-V measurement is illustrated in Fig. 2 (c), in which Cl_2/Ar ratio was varied under the constant total amount of Cl_2+Ar. When the RIE was carried out without Ar, N_d seems to increase within 70 nm from the surface. N_d decrease by increasing the Ar concentration in RIE gas. If the RIE process was carried out in Ar concentration of 75%, N_d decreased region was as deep as 120 nm from the surface. The decrease of N_d would be due to the deep trap generation induced by Ar ion. On the other hand the Cl_2 plasma would induce shallow donor-liked defects.

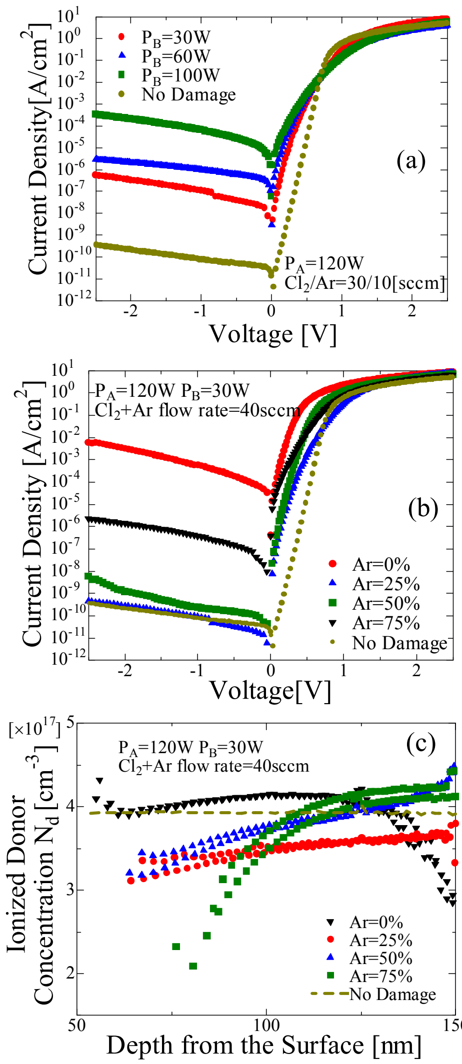


Fig. 2 I-V characteristics of (a) bias power (b) Cl_2/Ar gas ratios varied and (c) calculated value of ionized donor concentration versus depth from the surface by C-V measurement.

In order to improve the performance of the device, HCl treatment on the device was applied. Figure 3 (a) and (b) shows I-V and I-T characteristics of before and after HCl treatment. With HCl treatment, the leakage current density was found to decrease more than one order, shown in Fig. 3 (a). This suggests that Cl_2 plasma induced shallow donor-liked defects were etched by HCl and deep traps anneal out by sinter process, as a result, the Schottky barrier height increased and the leak current density was decreased. However, the result of I-T measurement revealed that discharge transient current due to emission of captured electron at deep traps was still observed, even though the improvement by HCl treatment and sintering was achieved. Further work is in progress and will be presented at the conference.

4. Conclusions

The effects of ICP-RIE plasma damage on Au/n-GaN Schottky diodes characteristics have been studied. Plasma induces ion damage to the surface, which leads to the degradation of Schottky characteristics. The electrical properties of the Au/n-GaN SBD were strongly influenced by plasma bias power, Cl_2/Ar gas ratios. The leakage current density was found to decrease more than one order due to HCl treatment and sintering.

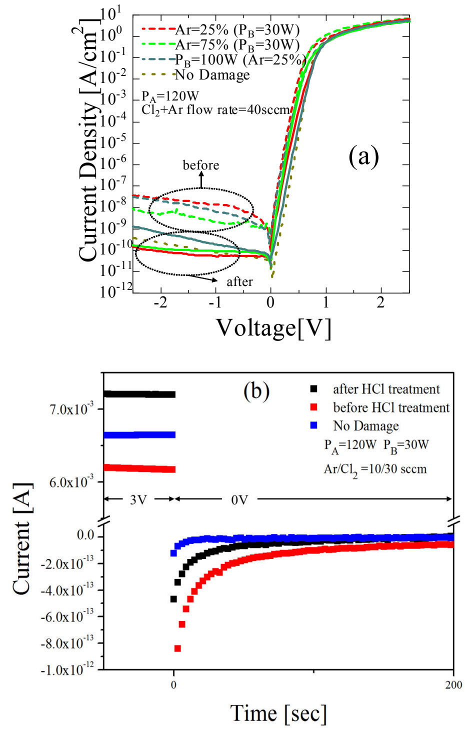


Fig. 3 (a) I-V characteristics of before (dot line) and after (solid line) HCl treatment, (b) I-T characteristics of before and after HCl treatment, measured at 0 V bias after 3V for 3min charging.

Acknowledgements

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