Extended Abstracts of the 2004 International Conference on Solid State Devices and Materials, Tokyo, 2004, pp. 548-549

P6-4

Characteristics of Pt/Schottky Diodes fabricated on the Cracked GaN Epitaxial Layer on (111) Silicon

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1. Introduction

Silicon is an attractive substrate for III-nitride epitaxy, because the extensive area is available at a significantly low cost. Since there are thermal mismatch as well as the lattice structure difference, it is not available to control the cracks on the whole wafer perfectly by the process parameters. In this sense, to achieve the electronic devices on the partially cracked nitride layers, it is essential to investigate the contact properties on the cracked GaN surfaces. We studied metal-semiconductor contact properties by fabricating a schottky diode on the cracked GaN layer grown on p-type (111) silicon substrate. And we compared it with the GaN schottky diode on sapphire substrate

2. Experiment and Results

We fabricated the planar type schottky diodes of circular diode pattern on GaN/Si and GaN/sapphire. Ti/Al/Ni/Au(350/2000/400/500Å) layers are deposited for an ohmic metal, and Pt(100Å) for a schottky metal. All of the metals were formed by the lift-off process. Si_3N_4 film was used for passivation between the two contacts.[1]

Fig. 1 shows the surface and cross sectional photomicrographs. There is significant crack density in the hexagonal GaN crystal directions on the top view. We can find the voids at the epitial interface of the crack on the cross section view.

Fig. 2 shows *ln*J-V characteristic of the fabricated Pt/schottky diodes of different diameters. They had effective barrier height of around 0.75eV and ideal factor of 2.4. Similar schottky diode on sapphire substrate had the barrier height of 0.85, which is significantly higher.

The forward *ln*J-V characteristics of schottky diodes do not exhibit uniform linearity. It is thought that, because of the cracks in GaN epi-layer on silicon, there can be non-ideal current flow mechanisms which are effectively parallel with the current conduction of the intrinsic GaN schottky diode as shown in Fig. 3. They might be parasitic Pt-silicon schottky diode and/or crack induced surface conduction. In the reverse I-V curve, it shows an acceptable increase of the reverse leakage current according to the reverse bias as a rectifier. And the reverse breakdown voltage is 5~10 V above which the leakage current increases markedly. And by further bias, it shows effectively ohmic behavior. Considering the previous reports[2], it is very promising to apply the cracked AlGaN/GaN layer to the fabrication HFET's.

Fig. 4 shows time dependent *ln*J-V curves to check the reliability of Pt schottky diode fabricated on GaN/silicon. The reverse electrical properties were very stable with time, which imply the acceptable reliability.

Fig. 5 shows the transmission line method(TLM) measurement plot for the ohmic contacts on the GaN layer on (111) silicon wafer. We used Ti/Al/Ni/Au multi-layers and annealed in N_2 ambient at 700 °C for 30 s for ohmic metal. Because of the random distribution of the cracks and random direction of them, the plot has non-linear data points. The contact resistivity was $5.51\times10^{-5}\,\Omega\,cm^2$. Inset of Fig. 5 is the I-V curve between two contact pads, which clearly shows ohmic properties of them.

Fig. 6 shows the spectral responsivity of the fabricated schottky diode. We got the cutoff wavelength of 360 nm, peak responsivity of 0.097 at 300nm, and UV/visible rejection ratio of about 10^4, which shows potential applicability to the opto-eletronic devices as well.

3. Summary

In conclusion, even though there is significant crack density in the GaN layer on silicon, we successfully achieved the schottky diode. The result gives a positive signal to apply the cracked GaN layer on silicon subatrate to the HFET's and integration of the electronic devices.

References

[1] S.H. Shin et.al, phys. stat. sol., (a) 188, No.1, p.341, 2001

[2] J. Kuzmik et.al, Proceedings of ISSDERC, p.319, 2003

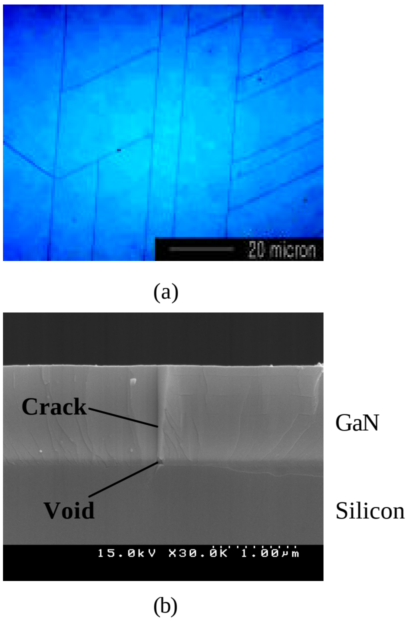

Fig. 1 Photomicrographs of the GaN layer on silicon; (a) top view, (b) cross sectional view

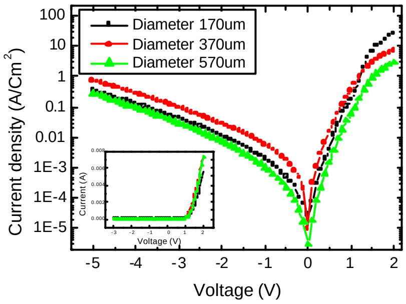

Fig. 2 *ln*J-V curve for Pt schottky diode fabricated on GaN/silicon
(Inset is the I-V curve)

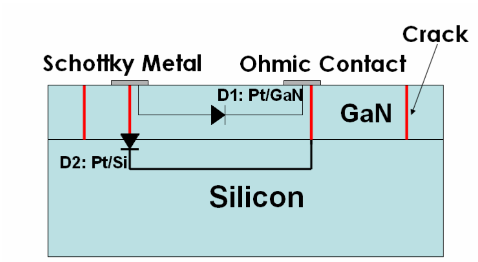

Fig. 3 Parallel conduction in the schottky diode on the cracked GaN Layer.

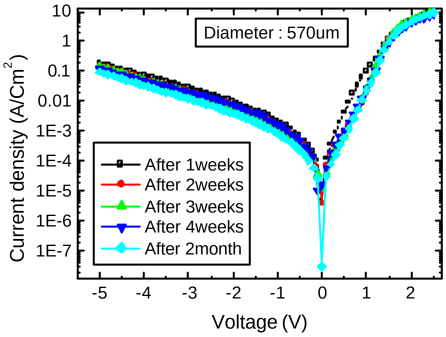

Fig 4. Aging characteristics of *ln*J-V for Pt schottky diode on GaN/silicon

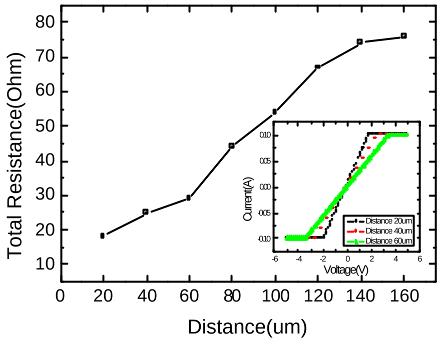

Fig. 5 Resistance versus distance plot by the TLM measurement of GaN/silicon
(Inset is the linear I-V curves)

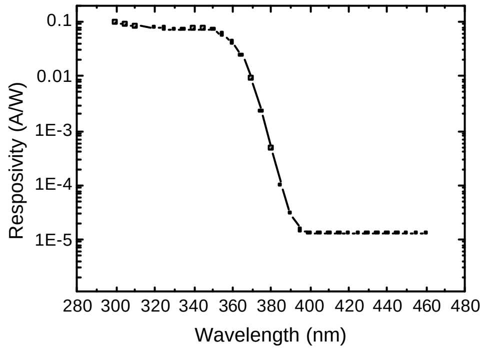

Fig. 4 Spectral photo-responsivity of the schottky diode on GaN/silicon