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α-Ga_2O_3 Schottky barrier diodes fabricated by Mist Epitaxy technique

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Abstract

We report the fabrication of α-Ga_2O_3 thin films by Mist Epitaxy technique toward device applications. The Schottky barrier diode (SBD) based on n-/n+ α-Ga_2O_3 layers successfully grown on a c-plane sapphire substrate exhibited reverse breakdown voltage as high as 500 V, corresponding to the breakdown field of over 5 MV/cm expected to α-Ga_2O_3 which is calculated by breakdown voltage and thin film thickness. The results encourage the promising potential of Mist Epitaxy as a technology to supply a variety of devices at low cost.

1. Introduction

Gallium oxide (Ga_2O_3) is an attractive material for its large wide band gap. There are five types of crystal polymorph in Ga_2O_3 that is α, β, γ , δ and ε [1]. Among them, β- phase is most stable, therefore being widely-used in researches. According to recent progress, Higashiwaki *et al* demonstrated of Schottky diodes and field-effect transistors with high breakdown voltage by using of β-Ga_2O_3 substrates [2,3]. It indicated a possibility to realize power devices beyond SiC or GaN because of larger band gap with 4.9 eV. However, in terms of industrial applications, there are some demands to realize Ga_2O_3 power devices. For example, large-scale β-Ga_2O_3 wafer has not realized yet, so it is expensive at the moment. One of the solutions to overcome these problems is using of commercially available substrate for example sapphire (α-Al_2O_3). From our previous studies, highly-crystalline α-Ga_2O_3 thin films were successfully grown on c-plane sapphire substrates by using of Mist Epitaxy technique [4,5] and it was also accomplished to fabricate on large-scale sapphire wafers[6]. Recently high-quality α-Ga_2O_3 thin films with very small values of full-width at half maximum of X-rat diffraction $2\theta/\theta$ scanning which are 23 arcsec were obtained. It is a great advantage to realize commercially available α-Ga_2O_3 power devices on large-scale sapphire substrates with much lower cost compared to β-Ga_2O_3 wafer. From our previous report, SBD based on α-Ga_2O_3 had already demonstrated[6]. In addition, by using of Mist Epitaxy technique we can use carbon free source such as gallium halide. This is also advantage to realize low carbon concentration film in comparison with Metal Organic Chemical Vapor Deposition

In this conference, we report the characteristic of SBD which had been improved about device process method,

2. Experiment

α-Ga_2O_3 thin films were grown on c-plane sapphire substrates by using of Mist Epitaxy technique. Oxygen gas was used as carrier and dilution gases with the flow rates of 5.0 and 0.5 L/min, respectively. The film was consisted of non-doped n- layer with thickness of 900 nm for shottky contact and Ge-doped n+ layer with thickness of 2 μm for ohmic contact as shown in Figure 1and 2. The contact metals of Pt/Au for Shottky and Ti/Au for Ohmic contact were fabricated by electron beam vapor deposition method.

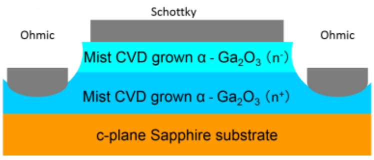

Fig. 1 Schematic image of SBD structure based on α-Ga_2O_3.

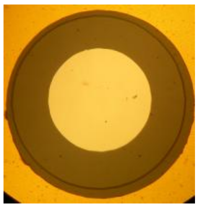

Fig. 2 Plane-view image of contact electrode of SBD. The diametter of shottky electrode is 120 μm and ohmic one is 180 μm.

3. Results and discussions

J–V characteristics of a α-Ga_2O_3 SBD is shown in Fig. 3(a)(b). Because of low carrier concentration (6×10^{15} cm^{-3}) of α-Ga_2O_3 which is calculated from C-V method and 2 μm n+ layer, the current density is not so much. On the other hand, the reverse characteristics showed the leakage current density is approximately 1μA/cm^2 at 500V. We also observed that the break down voltage was up to 500V in other diodes. This diode exhibits the barrier height Φ_B of around 1.2 eV and ideality factors of *n* were around 2.3. This value of an ideality factor is a little bit large. We observed some frequency dispersion in CV characteristics of this diode. Then our process of shottky contact might be not optimized yet. We will optimize n- layer/n+ layer thickness and carrier concentration to improve the current density.

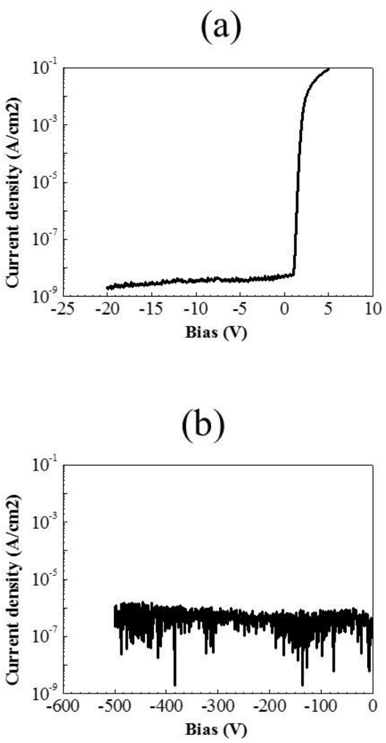

Fig. 3 (a) Forward and (b) reverse *J–V* characteristics of a α-Ga_2O_3 SBD .

4. Conclusions

We achieved high crystalline α-Ga_2O_3 layers grown by the Mist Epitaxy method on sapphire substrate. The Schottky diode based on n-/n+ α-Ga_2O_3 layers successively grown exhibited the reverse breakdown voltage as high as 500 V. The results encourage the promising potential of Mist Epitaxy as a simple, low energy consumption, and cost-effective device fabrication technology contributing to supply a variety of devices at low cost.

References

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Appendix

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