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First Demonstration of β-Ga_2O_3 Schottky Barrier Diode with Field Plate Edge Termination

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Abstract

We fabricated a β-Ga_2O_3 Schottky barrier diode with field plate edge termination for the first time. The device had a high breakdown voltage of 920 V, with a specific on-resistance of 5.0 mΩ•cm^2 and forward voltage of 1.35 or 1.85 V at 100 or 200 A/cm^2. These device characteristics clearly indicate the great potential of Ga_2O_3 for power device applications.

1. Introduction

Gallium oxide (β-Ga_2O_3) has received a lot of attention as a power device material because it has excellent material properties [1] and high quality and low cost wafers can be fabricated using the melt-growth method. Recently, we reported the device characteristics of Ga_2O_3 Schottky barrier diodes (SBDs) using single-crystal β-Ga_2O_3 [2, 3]. Although these devices had good characteristics, they had slightly low breakdown voltages because edge termination for the anode electrode was not used. In this study, we fabricated and tested a high breakdown voltage Ga_2O_3 SBD utilizing field plate edge termination for the first time.

2. Experimental method

We used a Sn-doped n^+-Ga_2O_3 (001) substrate that was 600-μm thick with N_d-N_a of 4 × 10^{18} cm^{-3} and prepared from a bulk crystal grown using the edge-defined film-fed growth method. The n^--Ga_2O_3 drift layer with N_d-N_a of 1.1 × 10^{16} cm^{-3} was grown on the substrate at 1000°C by halide vapor phase epitaxy (HVPE) [4, 5]. The source gases were GaCl and O_2 transported by N_2 carrier gas. GaCl was generated in the upstream region of the reactor by the reaction between high-purity Ga metal and chlorine (Cl_2) gas at 850°C. $SiCl_4$ was simultaneously supplied during the growth as an n-type dopant gas. The growth rate of the Ga_2O_3 film was set at 10 μm/h. After the HVPE growth, chemical mechanical polishing (CMP) was performed to flatten the surfaces of the epitaxial film. The post-CMP drift layer thickness was about 8 μm.

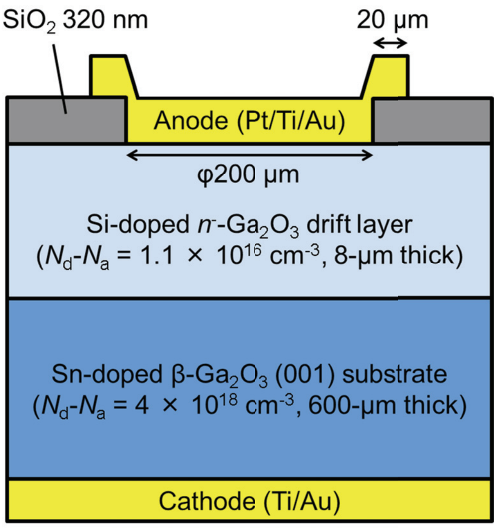
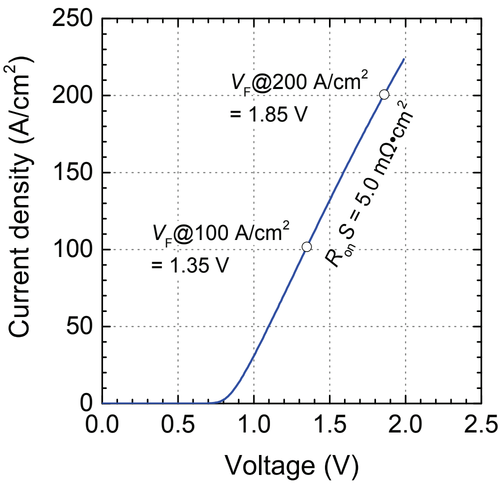


Fig. 1 Schematic cross section of a Ga_2O_3 SBD.

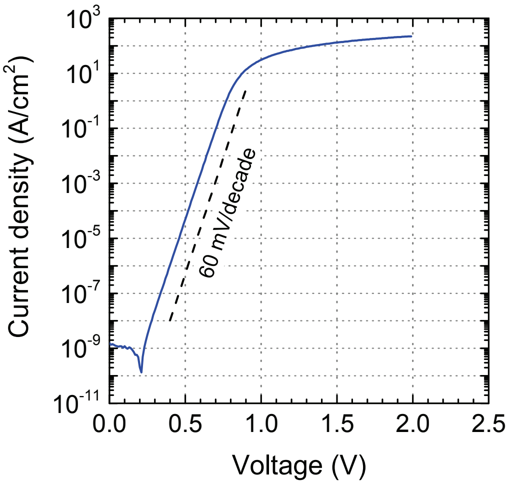
Figure 1 shows a schematic cross-sectional view of the SBD structure. First, SiO_2 dielectric film of 320-nm thick was deposited on the n^--Ga_2O_3 films by plasma-enhanced chemical vapor deposition. Then, a 200 μm diameter Schottky contact hole was opened in the SiO_2 film by using buffered HF. Next, BCl_3 reactive ion etching was performed on the back side of the substrate, followed by evaporation of a Ti(20 nm)/Au(230 nm) ohmic metal stack. Finally, a Schottky anode electrode was fabricated by standard photolithographic patterning, evaporation of a Pt(15 nm)/Ti(5 nm)/Au(250 nm) stack, and liftoff. The field plate length was 20 μm.

3. Results

Figures 2(a) and (b) show the forward current density-voltage (J-V) characteristics of the SBD at room temperature on linear and single logarithmic scales. From linear fits to the curve in Fig. 2(a) within the range of J=100-200



(a)



(b)

Fig. 2 Forward *J-V* characteristics of a Ga_2O_3 SBD plotted on (a) linear and (b) single logarithmic scales.

A/cm^2, the specific on-resistance ($R_{on}S$) was estimated to be 5.0 mΩ•cm^2. Forward voltages (V_F) at J=100 and 200 A/cm^2 were 1.35 and 1.85 V, respectively. An ideality factor of 1.01 was obtained from linear fits to the *J-V* curve in Fig. 2(b). The Schottky barrier height of 1.14 eV was estimated from the saturation current density. Figure 3 shows the reverse *J-V* characteristic at room temperature. A high breakdown voltage of 920 V was obtained. Note that the breakdown was catastrophic resulting in a burned anode electrode. These device characteristics clearly indicate the great potential of Ga_2O_3 as a material for high breakdown voltage devices.

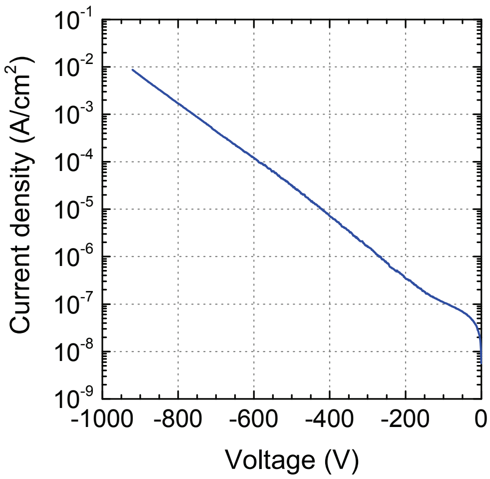


Fig. 3 Reverse *J-V* characteristic of a Ga_2O_3 SBD.

4. Conclusions

We fabricated β-Ga_2O_3 SBDs with field plate edge termination. The device had a breakdown voltage over 900 V. In the future, we hope to demonstrate Ga_2O_3 SBDs with both a high breakdown voltage and low $R_{on}S$ by optimizing the n^--Ga_2O_3 film thickness and donor concentration.

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References

[1] M. Higashiwaki, K. Sasaki, A. Kuramata, T. Masui, and S. Yamakoshi, Appl. Phys. Lett. **100** (2012) 013504.

[2] K. Sasaki, M. Higashiwaki, A. Kuramata, T. Masui, and S. Yamakoshi, IEEE Electron Device Lett. **34** (2013) 493.

[3] K. Sasaki, M. Higashiwaki, A. Kuramata, T. Masui, and S. Yamakoshi, J. Cryst. Growth **378** (2013) 591.

[4] K. Nomura, K. Goto, R. Togashi, H. Murakami, Y. Kumagai, A. Kuramata, S. Yamakoshi, and A. Koukitu, J. Cryst. Growth **405** (2014) 19-22.

[5] H. Murakami, K. Nomura, K. Goto, K. Sasaki, K. Kawara, Q. T. Thieu, R. Togashi, Y. Kumagai, M. Higashiwaki, A. Kuramata, S. Yamakoshi, B. Monemar, and A. Koukitu, Appl. Phys. Express **8** (2015) 015503.