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The investigation of nitrogen-doped LaB_6 thin film formation on n-Si(100) substrate utilizing RF sputtering

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Abstract

In this paper, the nitrogen-doped LaB_6 (N-doped LaB_6) thin film deposited on n-Si(100) substrate utilizing RF sputtering was investigated. The resistivity was decreased from 1.31 mΩcm to 0.79 mΩcm by increasing the deposition temperature from room temperature (RT) to 150°C. Furthermore, the high work function of 4.38 eV was obtained from $1/C^2$-V characteristic of N-doped LaB_6/n-Si(100) Schottky diode was probably caused by the pinning at the interface.

1. Introduction

Lanthanum hexaboride (LaB_6) is well known as a low work function metal with high conductivity. It was reported that the metal work function of 2.4 eV was realized by nitrogen concentration at 0.4% of LaB_6 [1]. Furthermore, the N-doped LaB_6 layer deposited by the RF sputtering was found to improve the electrical characteristics of pentacene film [2-4].

In previous research, the metal work function of 2.4 eV was obtained from N-doped LaB_6/SiO_2/p-Si(100) structure. However, the high metal work function of 4.3 eV was obtained from N-doped LaB_6/p-Si(100) structure [5].

In this paper, we investigated the deposition temperature dependence of N-doped LaB_6/n-Si(100) structure utilizing RF sputtering.

2. Experimental Procedure

Figure 1 shows the experimental procedure of this research. The n-Si(100)(1-10 Ωcm) substrate was cleaned by SPM and DHF, and the rinse process was performed with ultra-pure water (ORGANO I) for 10 min for each cleaning. The 50-nm-thick SiO_2 layer was formed by thermal oxidation. Then, SiO_2 layer was patterned for field oxide layer. A 30-nm-thick N-doped LaB_6 film was deposited on n-Si(100) by RF sputtering utilizing N-doped LaB_6 target. The nitrogen concentration in the target is 0.4%. The sputtering power was 50 W and the Ar gas flow rate was 10 sccm with a gas pressure of 0.35 Pa. The substrate temperature during deposition was RT, 100°C and 150°C, respectively. Then, N-doped LaB_6 layer was patterned for electrode with diluted nitric acid (HNO_3:H_2O=1:1). The N-doped LaB_6 electrode size was 100 × 100 μm^2. Finally, Al back-gate electrode was formed by thermal evaporation.

The surface morphology of N-doped LaB_6 film was evaluated by optical microscopy. Resistivity was observed

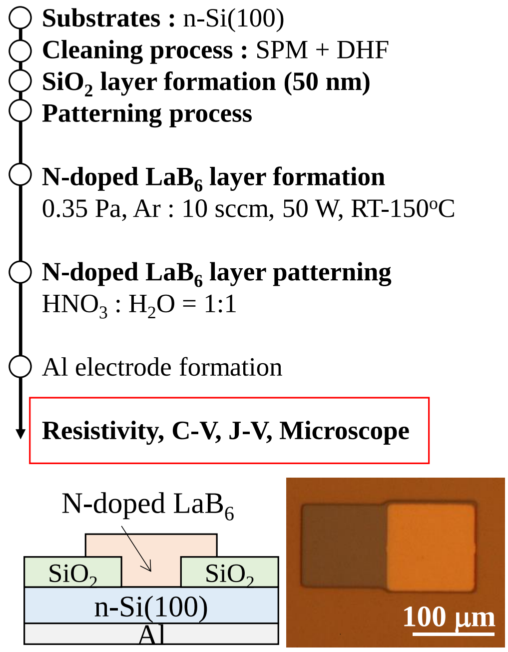

Fig. 1 Experimental procedure for the fabrication of the Schottky diodes.

by 4-point probe method. The C-V and J-V characteristics were measured by Agilent 4156C and 4284A, respectively.

3. Results and Discussion

Figure 2 shows the deposition temperature dependence of resistivity for N-doped LaB_6 thin film deposited on the n-Si(100) substrate. The resistivity was decreased from 1.31 mΩcm to 0.98 mΩcm with increasing the deposition temperature from RT to 100°C. Then, the lowest resistivity of 0.79 mΩcm was obtained for the sample with deposition temperature of 150°C.

Figure 3 shows the J-V characteristics for the Schottky diode. The Schottky characteristics were observed for all the RF sputtering conditions of N-doped LaB_6 thin film formation. Furthermore, the saturation current of Schottky diode was changed from 1.34×10^{-6} A/cm^2 to 1.47×10^{-4} A/cm^2 when the deposition temperature was increased from RT to 150°C. Then, the calculated Schottky barrier height (SBH) for electron was decreased to 0.77 eV, 0.75 eV, and 0.64 eV when deposition temperature was RT, 100°C, and 150°C, respectively. The calculated metal work functions were decreased from 4.82 eV to 4.69 eV.

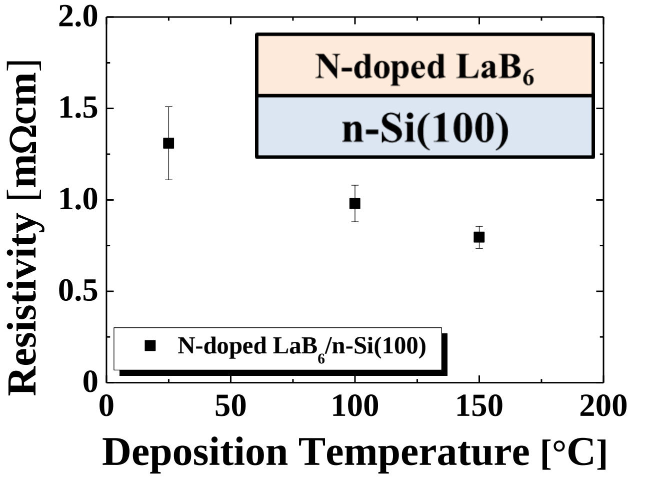

Fig.2 Deposition temperature dependence of resistivity for N-doped LaB_6 thin film.

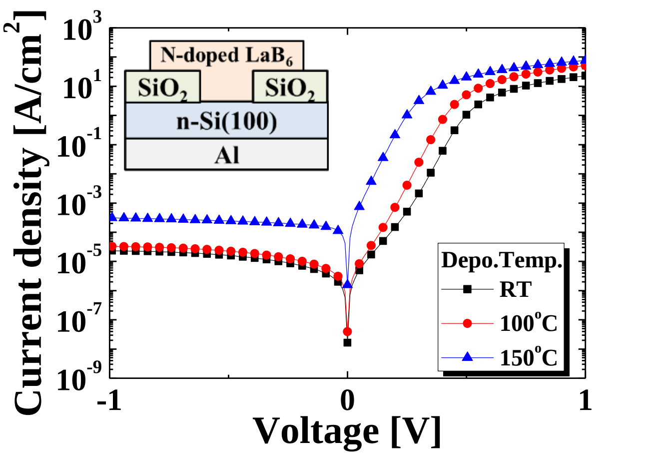

Fig.3 Deposition temperature dependence of J-V for the Schottky diodes with N-doped LaB_6 electrode

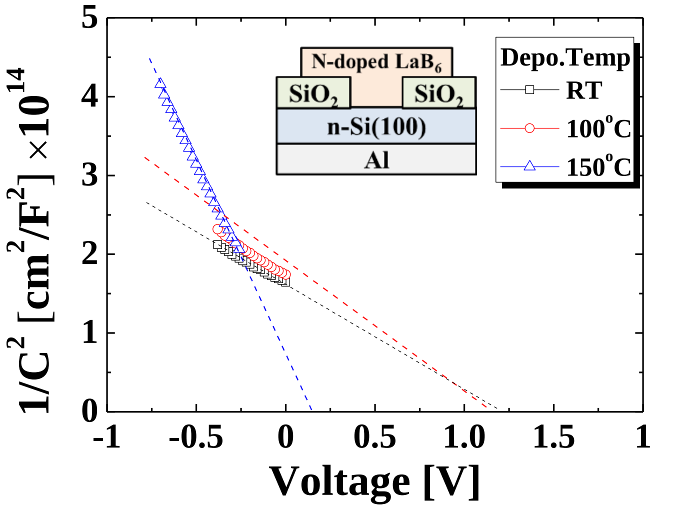

Fig.4 Deposition temperature dependence of $1/C^2$-V for the Schottky diodes with N-doped LaB_6 electrode.

Figure 4 shows the $1/C^2$-V characteristics for N-doped LaB_6/n-Si(100) Schottky diodes. The Schottky barrier heights were obtained from the built-in voltage (V_{bi}). In the results, extracted Schottky barrier heights were decreased from 1.43 eV to 0.33 eV when the deposition temperature was increased from RT to 150°C. Furthermore, the 4.38 eV of metal work function was calculated from Schottky barrier heights. It is probably caused by the pinning effect at the interface of N-doped Lab_6/n-Si(100) structure.

4. Conclusion

In this study, we investigated the Schottky characteristics with N-doped LaB_6 thin film formation on n-Si(100) substrate utilizing RF sputtering. The lowest resistivity of 0.79 mΩcm was obtained when the deposition temperature was 150°C. It should be noted that the quality of N-doped LaB_6 was improved by the RF sputtering condition. Furthermore, Schottky barrier height for electron and metal work function of N-doped LaB_6 film were extracted from J-V and $1/C^2$-V characteristics for Schottky diode. In case of the metal work function, the metal work function of 4.38 eV was obtained from N-doped LaB_6/n-Si(100) structure. We expected that the Ohmic characteristic has occurred when deposition temperature was increased to 150°C. Because of the Schottky characteristics were obtained from N-doped LaB_6/p-Si(100) MS structure [5]. We assume that these results were from the pinning effect at the interface of N-doped LaB_6 and Si(100) substrate

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