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Ar/N_2 gas flow ratio dependence on the high-k LaB_xN_y thin film characteristics formed by RF sputtering

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Abstract

In this paper, the Ar/N_2 gas flow ratio dependence on the high-k LaB_xN_y thin film characteristics formed by RF sputtering was investigated. The hysteresis and equivalent oxide thickness (EOT) were decreased from 32 mV to 16 mV and from 8.1 nm to 5.7 nm, respectively by increasing the Ar/N_2 gas flow ratio from 10/3 sccm to 10/7 sccm. Furthermore, the density of interface states (D_{it}) was decreased by increasing N_2 gas flow ratio.

1. Introduction

The nitrogen-doped (N-doped) LaB_6 has low resistivity, high melting-point and chemical stability. Furthermore, it was realized a low work function of 2.4 eV with oxidation immunity by suppressing the oxygen concentration below 0.3 % [1-2].

In the previous study, we have reported the improved N-doped LaB_6 thin film characteristics deposited on the SiO_2/p-Si(100) structures [3]. Furthermore, the high-k LaB_xN_y thin film formed by Ar/N_2 plasma reactive sputtering and its application to the floating-gate memory was investigated. However, the investigation of LaB_xN_y layer formation was still required to improve the dielectric characteristics [4-5].

In this paper, we investigated the effect of the Ar/N_2 gas flow ratio on the characteristics of the high-k LaB_xN_y gate dielectric layer with N-doped LaB_6/LaB_xN_y/p-Si(100) gate stack structure formed by RF sputtering.

2. Experimental Procedure

Figure 1 shows the experimental procedure of this research. The p-Si(100)(10-30 Ωcm) substrate was cleaned by SPM and DHF, and the rinse process was performed with ultra-pure water (UPW, ORGANO I) for 10 min after each cleaning process. Next, the N-doped LaB_6/LaB_xN_y structure with a thickness of 20/10 nm was in-situ deposited on p-Si(100) by RF sputtering at room temperature (RT). The N-doped LaB_6 target was used (N: 0.4%) in this study. In the case of the LaB_xN_y insulating layer, the sputtering power was 7 W and the Ar/N_2 gas flow ratios were changed as 10/3-10/7 sccm with the gas pressure of 0.37 Pa-0.45 Pa. The post-metallization annealing (PMA) process was carried out at 400°C/1 min with N_2 (1 SLM) ambient followed by the patterning with diluted nitric acid (HNO_3:H_2O=1:1). The pattern size was 30×30 μm^2. Finally, back Al electrode was formed by thermal evaporation.

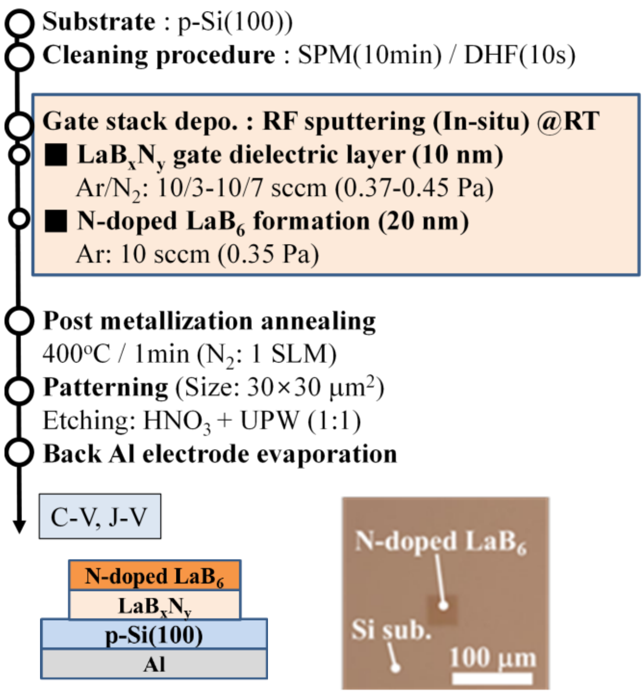

Fig. 1 Experimental procedure for the fabrication of the N-doped LaB_6/LaB_xN_y/p-Si(100) diodes.

The surface morphology was observed by optical microscopy. The C-V and J-V characteristics were measured by Agilent 4284A and 4156C, respectively.

3. Results and Discussion

Figure 2 shows the C-V characteristics for N-doped LaB_6/LaB_xN_y/p-Si(100) diode. The C-V curve was obtained from voltage range of ±1 V. The maximum capacitance was increased from 0.35 μF/cm^2 to 0.53 μF/cm^2 by increasing Ar/N_2 gas flow ratio from 10/3-10/7 sccm. From these results, the extracted equivalent oxide thickness (EOT) was decreased from 8.1 nm to 5.7 nm as shown in Fig. 3. Furthermore, the hysteresis was decreased from 32 mV to 16 mV by increasing Ar/N_2 gas flow ratio from 10/3 sccm to 10/7 sccm.

Figure 4 shows the extracted density of interface states (D_{it}) of N-doped LaB_6/LaB_xN_y/p-Si(100) diode through Terman method. The minimum D_{it} of Ar/N_2 gas flow ratio of 10/3 sccm was 2.1×10^{11} cm^{-2}eV^{-1}. On the other hand, in the case of the D_{it} of Ar/N_2 gas flow ratio of 10/7 sccm showed 8.2×10^{10} cm^{-2}eV^{-1}.

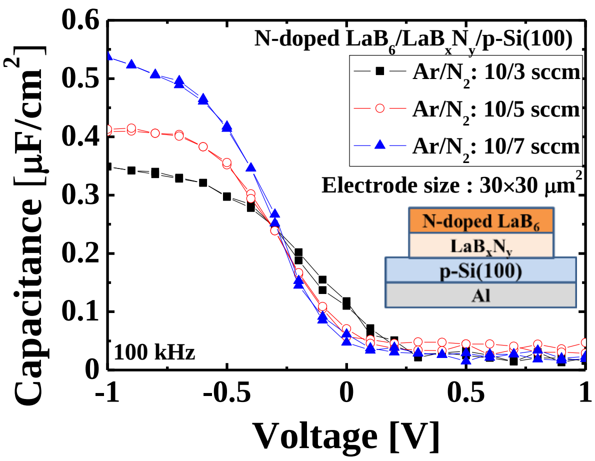

Fig.2 C-V characteristics of N-doped LaB_6/LaB_xN_y/p-Si(100) diodes.

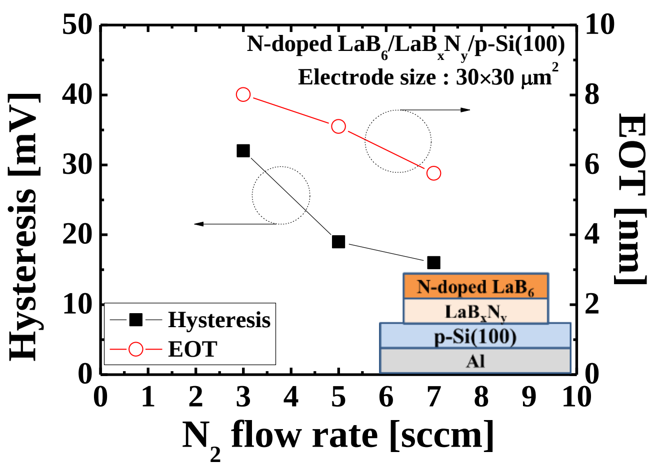

Fig.3 Results of the hysteresis and EOT dependence on the Ar/N_2 sputtering gas flow ratio.

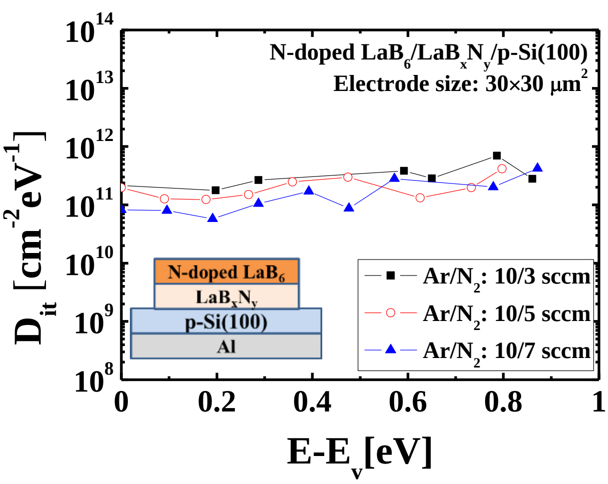

Fig.4 Interface state densities of N-doped LaB_6/LaB_xN_y/p-Si(100) diode obtained by Terman method.

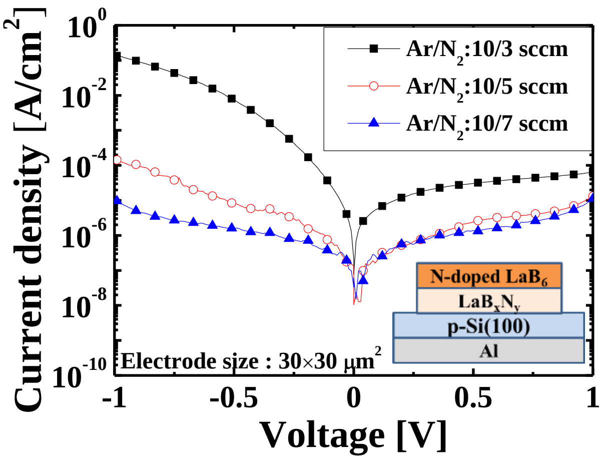

Fig.5 J-V characteristics of N-doped LaB_6/LaB_xN_y/p-Si(100) diodes.

Figure 5 shows the J-V characteristics of N-doped LaB_6/LaB_xN_y/p-Si(100) diode. The current density at 1 V was decreased from 6×10^{-5} A/cm^2 to 1×10^{-5} A/cm^2 by increasing Ar/N_2 gas flow ratio from 10/3 to 10/7 sccm.

These results indicate that the increasing of N_2 gas flow ratio is effective to improve the dielectric characteristics of the LaB_xN_y gate insulating layer.

4. Conclusion

In this study, we investigated the Ar/N_2 gas flow ratio dependence on the high-k LaB_xN_y thin film characteristics formed by RF sputtering. The dielectric characteristics of the LaB_xN_y gate dielectrics were improved by increasing N_2 sputtering gas flow ratio. Therefore, the control of the N_2 sputtering gas flow ratio would be effective to realize the thinning of the LaB_xN_y tunnel layer to improve the memory characteristics of N-doped LaB_6/LaB_xN_y/N-doped LaB_6/LaB_xN_y/p-Si(100) structure of floating gate device [4-5].

Acknowledgements

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