Effect of Kr plasma sputtering for Pt gate electrode deposition on the ferroelectric property of 5 nm thick nondoped HfO_2 directly formed on Si(100)

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1. Introduction

Ferroelectric HfO_2 has been widely investigated to realize the metal-ferroelectric-semiconductor field-effect-transistor (MFSFET) due to its CMOS compatibility and scalability. Previously, we realized 5 nm thick ferroelectric nondoped HfO_2 directly formed on Si(100) substrates using Kr/O_2 plasma sputtering [1,2]. The ferroelectric property was improved by reducing the sputtering power of Ar gas sputtering for Pt electrode deposition [2]. However, the sputtering damage is still issue for ferroelectric HfO_2 films especially below 10 nm.

In this research, we investigated the effects of Kr plasma sputtering for Pt gate electrode deposition on the ferroelectric properties of 5 nm thick nondoped HfO_2.

2. Experimental procedure

A 5 nm thick ferroelectric HfO_2 film was directly formed on Si(100) substrates at room temperature (RT) by RF magnetron sputtering with Hf target. Kr/O_2 gas flow ratio and the sputtering power were 2.0/0.2 sccm and 50 W, respectively. Then, 20 nm thick Pt gate electrode was deposited by Ar [1,2] and Kr plasma sputtering with the sputtering power of 40 W without breaking vacuum. Pt films were etched by aqua regia with the electrode size of 30×30 μm^2. Then, post-metallization annealing (PMA) process was carried out at 500 °C/30 s in N_2 ambient. Finally, Al electrode was evaporated on the back side of substrate. The fabricated MFS diodes were characterized by P-V, J-V, and the density of interface states (D_{it}) was extracted from C-V.

3. Results and discussion

P-V characteristics of $Pt/HfO_2/P^+$-Si(100) diodes utilizing Ar and Kr plasma sputtering are shown in Fig. 1(a). The remnant polarization ($2P_r$) was increased to 7.5 $\mu C/cm^2$ by Kr plasma sputtering for Pt gate electrode deposition, while $2P_r$ was 5.9 $\mu C/cm^2$ in the case of Ar sputtering under V_G of ±5V at the frequency of 10 kHz. Furthermore, the gate leakage current at V_G of -1.5 V was reduced from 2.1×10^{-8} A/cm^2 for Ar sputtering to 1.1×10^{-8} A/cm^2 by Kr plasma sputtering. This is probably due to the improvement of interface property with lower D_{it} of 2.8×10^{11} $cm^{-2}eV^{-1}$ in the case of Kr plasma sputtering for Pt gate electrode deposition.

4. Conclusions

In this study, the effect of Kr plasma sputtering for Pt gate electrode deposition was investigated. Kr plasma sputtering for Pt electrode deposition was effective to improve the ferroelectric property of 5 nm thick ferroelectric nondoped HfO_2 with decreasing the sputtering damage.

Acknowledgements

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References

[1] J. W. Shin *et al.*, The 82nd JSAP Autumn Meeting, p. 11a-N205-2 (2021).

[2] J. W. Shin *et al.*, IWDTF, p. 49 (2021).

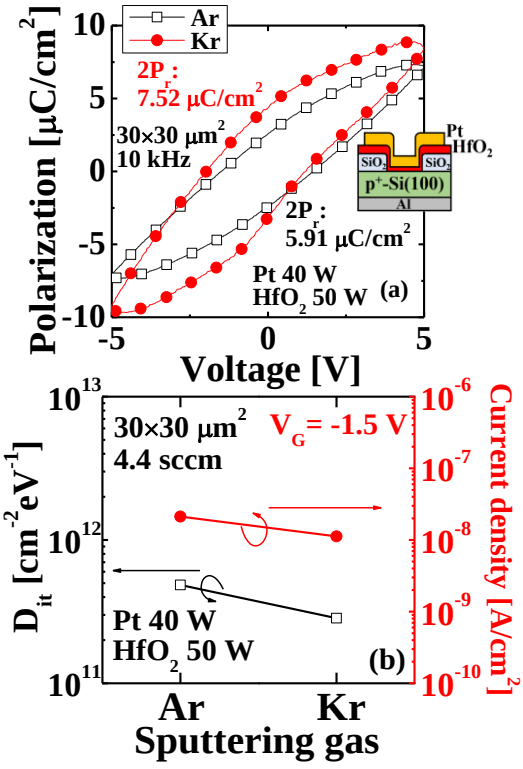

Figure 1. (a) Comparisons of P-V characteristics and (b) D_{it} and leakage current of MFS diodes with Pt gate electrode deposited by Ar and Kr plasma sputtering.