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Thickness Scaling on Ferroelectric $Al_{0.8}Sc_{0.2}N$ Films

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Abstract

Thickness scaling on ferroelectric properties of sputter-deposited $Al_{0.8}Sc_{0.2}N$ film less than 50 nm has been examined. A highly c-axis oriented wurtzite structure has been confirmed with a 50-nm-thick $Al_{0.8}Sc_{0.2}N$ film. A breakdown field of about 4.5 MV/cm has been measured with the $Al_{0.8}Sc_{0.2}N$ thickness from 20 to 47 nm. Ferroelectric behaviors in both CV and PV curves show gradual degradation when the thickness is less than 30 nm. In contrast, the coercive field kept a constant value of 4 MV/cm.

1. Introduction

$Al_{1-x}Sc_xN$ films ($0.2<x<0.46$) with wurtzite crystal have shown the ferroelectricity with box-like characteristics [1]. A high remnant polarization (P_r) of over 100 μC/cm^2 is attractive for future non-volatile memory applications. One of the common issues of oxide-based and organic material based ferroelectric films is that the ferroelectricity degrades when the thickness of the films decreases [2-4]. As the reported ferroelectric $Al_{1-x}Sc_xN$ films were still thick (~400 nm), we investigated the thickness scaling of sputter-deposited $Al_{1-x}Sc_xN$ films.

2. Device fabrication

First, an n$^+$Si substrate was chemically cleaned with H_2SO_4+H_2O_2 for 10 min and 1% HF for 1 min. Then, a TiN bottom electrode was deposited by sputtering. An $Al_{0.8}Sc_{0.2}N$ film was sputter-deposited from an $Al_{0.57}Sc_{0.43}$ target with Ar and N_2 mixture in the same chamber with different thickness ranging from 20 to 50 nm. Another TiN layer was deposited onto the $Al_{0.8}Sc_{0.2}N$ film. All the deposition process temperature was set to 400°C. The top TiN layer was patterned by wet etching to form electrodes. The fabrication process flow of fabricated ferroelectric capacitor is shown in **fig. 1**.

3. Results and Discussion

Fig. 2 shows the out-of-plane and in-plane XRD of a 50-nm-thick $Al_{0.8}Sc_{0.2}N$ film with a TiN bottom electrode. The presence of the (002) peak shown in the out-of-plane spectra suggests the formation of a c-axis-aligned $Al_{0.8}Sc_{0.2}N$ film. **Fig. 3** shows the leakage current and breakdown field of the $Al_{0.8}Sc_{0.2}N$ ferroelectric capacitors with various thicknesses. Relatively high leakage current is due to a small Schottky barrier height at TiN/ $Al_{0.8}Sc_{0.2}N$ interface [5]. The breakdown field shows little effect on the $Al_{0.8}Sc_{0.2}N$ thicknesses. **Fig. 4** shows the capacitance-voltage (*CV*) curves measured at 10 kHz of the $Al_{0.8}Sc_{0.2}N$ ferroelectric capacitors with various thicknesses. Ferroelectric-type hysteresis is observed from all the *CV* curves with various thicknesses. This suggests that $Al_{0.8}Sc_{0.2}N$ films do not lose the ferroelectricity with scaling down to 20 nm. However, from polarization-voltage (*PV*) measurement, as shown in **Fig. 5,** the hysteresis loops start to diminish with thickness scaling, especially when the film thickness is less than 30 nm. At a thickness of 20 nm, P_r was hard to be measured due to the presence of large leakage current. On the other hand, almost constant coercive field of 4 MV/cm was obtained for all the samples. Fi**g. 7** shows the switching cycle endurance test of the $Al_{0.8}Sc_{0.2}N$ ferroelectric capacitors. A switching cycle of fewer than 100 times did not show any improvement nor degradation with thickness scaling.

4. Conclusion

The effect of thickness on the ferroelectric properties of a highly c-axis oriented $Al_{0.8}Sc_{0.2}N$ layer has been examined. The breakdown field of about 4.5 MV/cm hardly changed with thickness scaling. Hysteresis-like CV curves were obtained with all the film thickness, whereas the hysteresis loops obtained by PV curves show degradation when the thickness is less than 30 nm.

References

[1] S. Fichtner, et al., J. Appl. Phys., 125, 114103 (2019).
[2] P. Gao, et al., Nature Comm., 8, 15549 (2017).
[3] X. Tian, et al., Appl. Phys. Lett., 112, 102902 (2018).
[4] F. Xia, et al., Appl. Phys. Lett, 78, 1122 (2001).
[5] S. Tsai, ECS Trans., 97, 45 (2020).

- Chemical cleaning of n^+Si substrate
- Sputter-deposition of a bottom electrode TiN
- Sputter-deposition of an $Al_{0.8}Sc_{0.2}N$ layer at 400°C (thickness 10 ~ 50nm)
- Sputter-deposition of a TiN layer
- Top electrode photolithography and etching
- Etching by wet etching
- Backside Al evaporation

Fig. 1 Fabrication process flow of $Al_{0.8}Sc_{0.2}N$ ferroelectric capacitors.

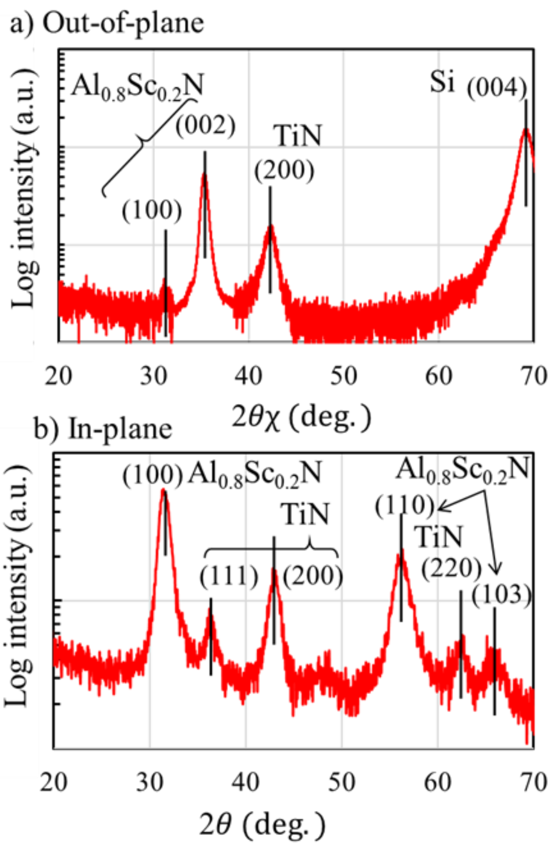

Fig. 2 a) Out-of-plane and b) in-plane XRD for 50-nm-thick $Al_{0.8}Sc_{0.2}N$ ferroelectric capacitors.

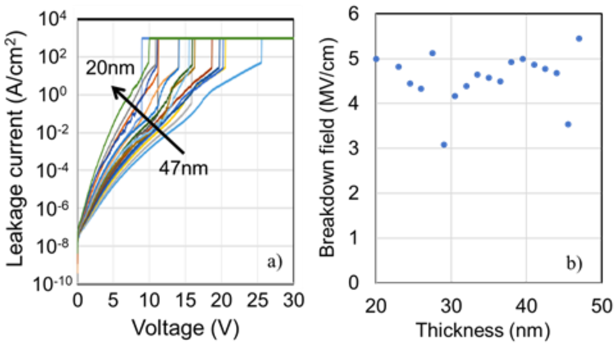

Fig. 3 a) Leakage current and b) breakdown field of $Al_{0.8}Sc_{0.2}N$ ferroelectric capacitors with different thicknesses.

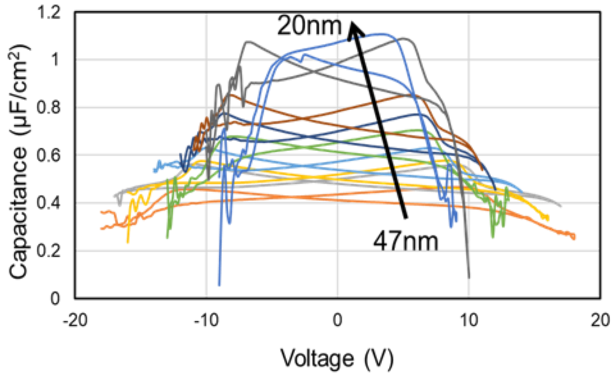

Fig. 4 Capacitance voltage curves of $Al_{0.8}Sc_{0.2}N$ ferroelectric capacitors with different thicknesses.

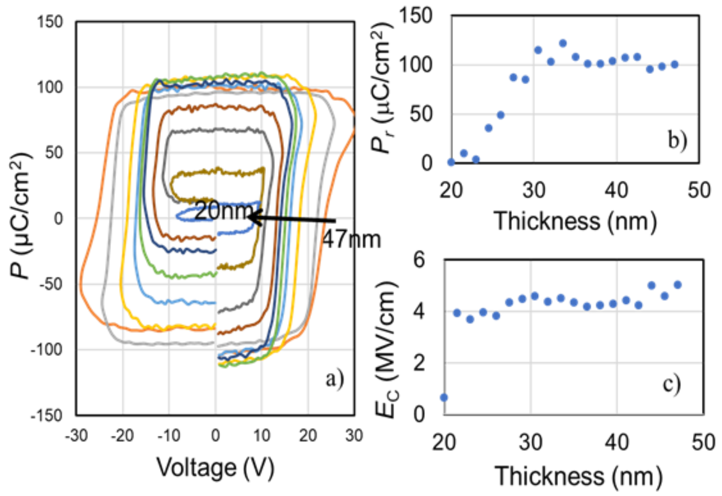

Fig. 5 a) Polarization-voltage curves of $Al_{0.8}Sc_{0.2}N$ ferroelectric capacitors with different thicknesses. b) Remnant polarization and c) coercive field of the capacitors.

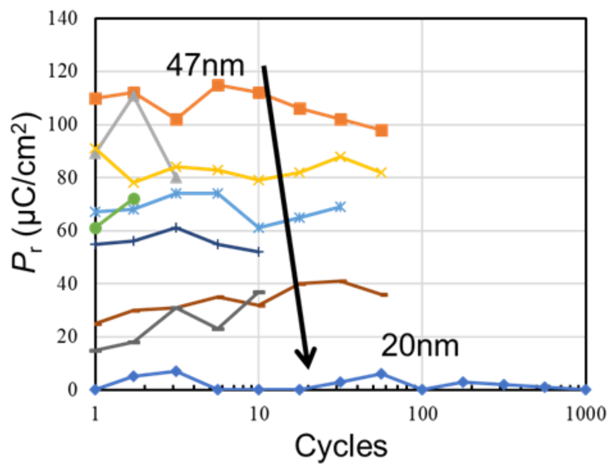

Fig. 6 Switching cycle test of $Al_{0.8}Sc_{0.2}N$ ferroelectric capacitors with different thicknesses.