

Rapid thermal annealing for reduced leakage and enhanced endurance of reactive-sputtered, ferroelectric AlScN-based memory capacitors

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Aluminum–scandium nitride (AlScN) has emerged as a promising ferroelectric material for non-volatile memory and logic applications due to its strong polarization, CMOS compatibility, and excellent thermal stability. However, sputtered AlScN films often suffer from high leakage currents and limited endurance, which hinder their practical implementation. In this study, we systematically investigate the influence of rapid thermal annealing (RTA) in a nitrogen atmosphere on the electrical and structural properties of reactive-sputtered $\text{Al}_{0.5}\text{Sc}_{0.2}\text{N}$ metal–ferroelectric–metal capacitors.

The as-deposited films were subjected to RTA at 400 °C for 3 and 13 minutes, and their structural, chemical, and electrical characteristics were evaluated. Atomic force microscopy and X-ray diffraction revealed that RTA promoted grain growth, improved c-axis orientation, and introduced tensile strain, collectively mitigating grain-boundary defects. X-ray photoelectron spectroscopy confirmed a reduction in oxygen-related species and the formation of more stable Al–N bonds, along with evidence of Pt diffusion at the electrode interface. These modifications led to an ~11% increase in dielectric constant and enhanced ferroelectric switching behavior.

Electrically, RTA yielded a substantial decrease in leakage current density, from 152.63 to 71.37 mA/cm² at 3 MV/cm, and a significant endurance improvement from 1,000 to 5,000 cycles, while maintaining remanent polarization. The coercive field was also reduced, facilitating easier polarization switching.

Collectively, these results demonstrate that RTA in a nitrogen ambience is an effective post-deposition strategy for improving the performance and reliability of AlScN thin films, supporting their integration into next-generation ferroelectric devices.

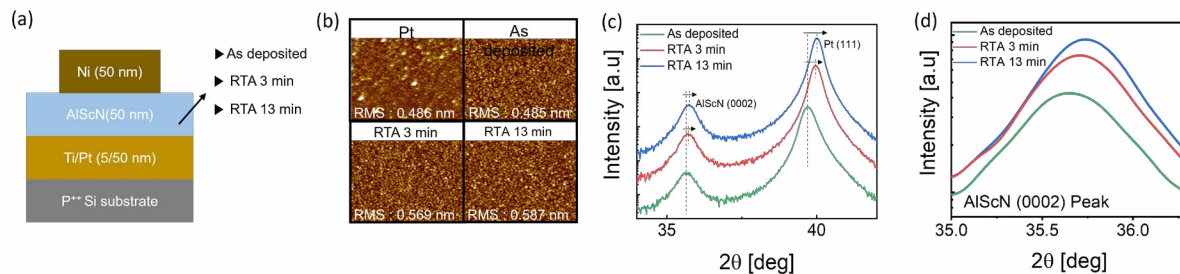


Figure 1. (a) Cross-sectional schematic of the MFM structure. (b) Comparison of AFM images and RMS roughness values. (c) XRD patterns ($2\theta = 32\text{--}42^\circ$) of as deposited, 3 min annealed, 13 min annealed AlScN film and (d) an enlarged view of the AlScN (0002) peak.

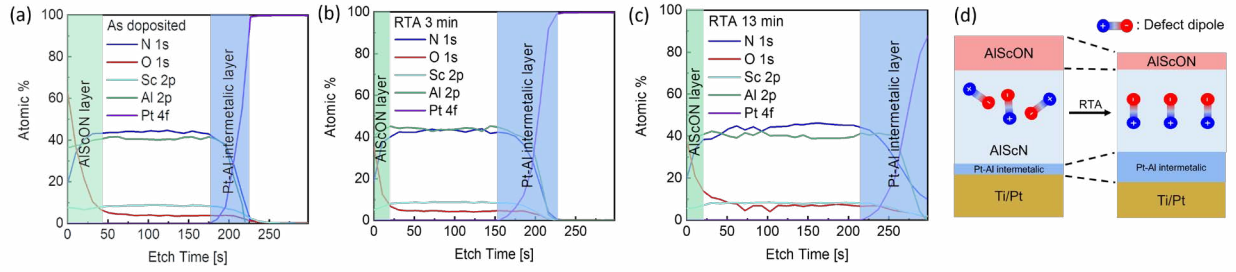


Figure 2. XPS depth profiles measured from (a) As deposited, (b) 3 min annealed, and (c) 13 min annealed AlScN MFM capacitors. (d) Schematic representation of chemical changes inside the AlScN.

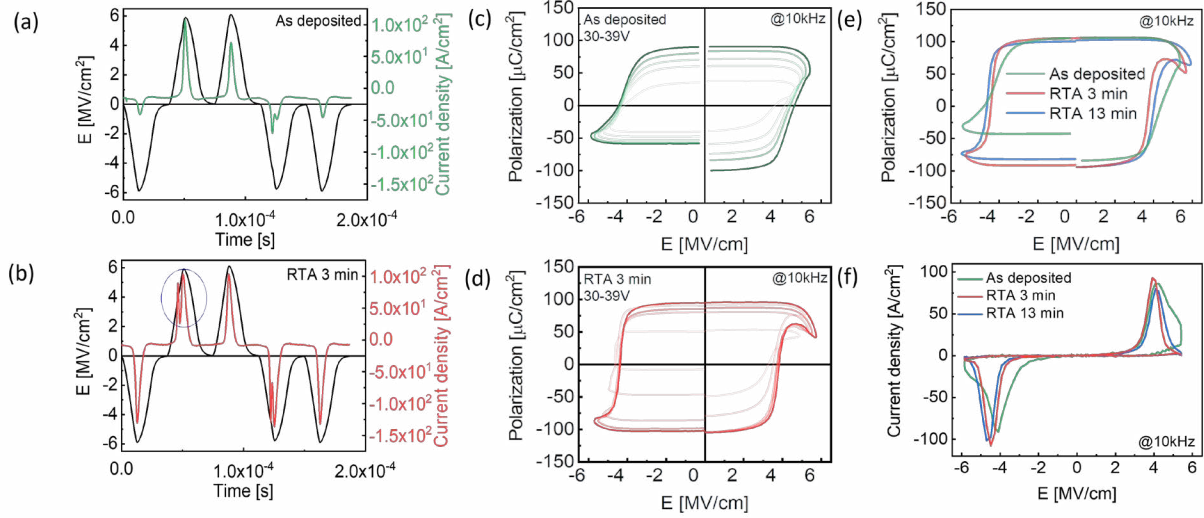


Figure 3. Output current from PUND measurements of (a) as deposited and (b) 3 min annealed devices. (c), (d) P-E loops measured in the voltage range of 30–39 V for as-deposited and 3 min annealed. (e) P-E loops at 39 V for devices with different annealing times. (f) Switching current characteristics as a function of annealing time.

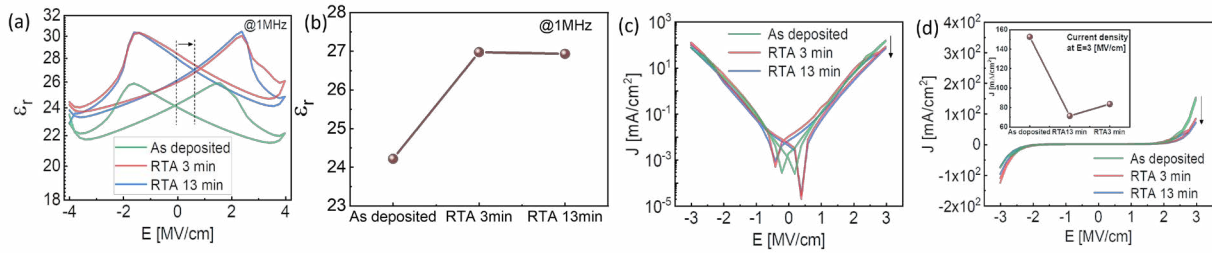


Figure 4. (a) Relative permittivity-electric field (ϵ_r -E) curves of AlScN devices annealed for different durations. (b) Variation of relative permittivity (ϵ_r) as a function of annealing time. (c) Log-scale leakage current of AlScN devices as a function of annealing temperature. (d) Linear-scale leakage current with an inset showing the leakage current at $E = 3$ MV/cm.

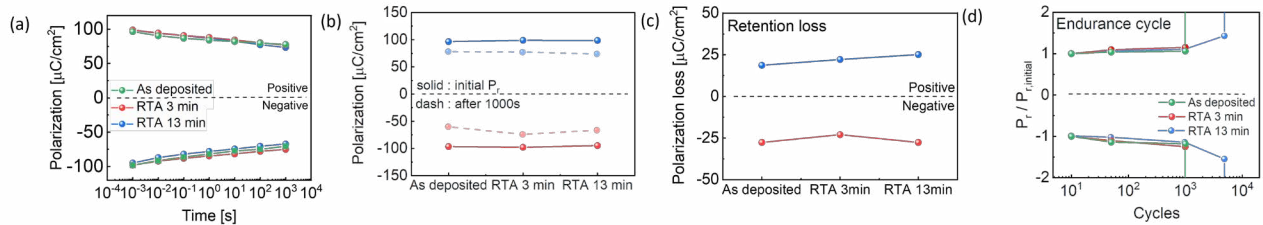


Figure 5. Retention characteristics of AlScN devices with different annealing times: (a) overall retention performance, (b) change in remanent polarization (P_r) after 1000 s, and (c) retention loss at 1000 s. (d) Endurance cycling characteristics.

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