Sc-Rich Monocrystalline ScGaN Grown by MBE Exhibits Attractive Ferroelectric Properties

Samuel Yang*, Shubham Mondal, Jae Hun Kim, Zetian Mi* (samjyang@umich.edu, ztmi@umich.edu)
Department of Electrical Engineering and Computer Science, Ann Arbor, MI, 48109, United States of America

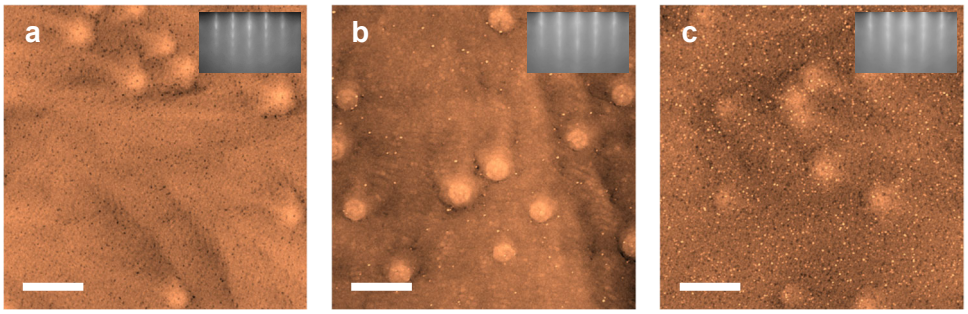

Figure 1. AFM scans of the ScGaN/GaN structure in a 25 μm^2 area for Sc compositions of (a) 35%, (b) 47%, and (c) 56%. The surface exhibits moderate granularity typical of nitrogen-rich growth. The rms roughness is 0.64, 0.81, and 0.79 nm, respectively. The insets show RHEED patterns along the <110> azimuth immediately following growth. The scalebars represent 1 μm.

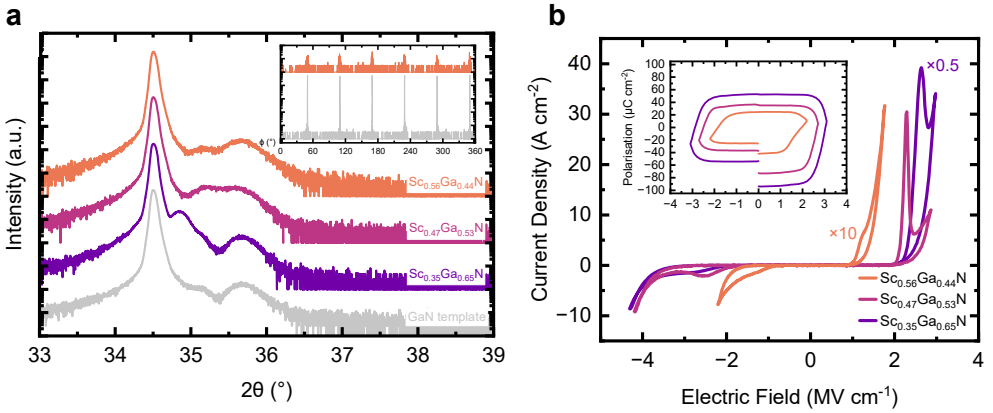

Figure 2. (a) XRD (002) 2θ scans of the ScGaN/GaN structure. The peak at ~35.7° is due to a sputtered AlN buffer layer within the substrate. The inset shows ϕ scans about (102) for the $Sc_{0.56}Ga_{0.44}N$/GaN sample, indicating exceptional epitaxial registry of $Sc_{0.56}Ga_{0.44}N$ to GaN and in-plane crystallinity without undesirable phases. (b) Current density vs electric field loops at 40 Hz showing clear ferroelectric switching with coercive fields from ~2.5 MV cm^{-1} at $Sc_{0.35}Ga_{0.65}N$ to nearly 1.2 MV cm^{-2} at $Sc_{0.56}Ga_{0.44}N$. The inset shows polarisation vs electric field hysteresis loops at 1 kHz, evidencing a reduction in both coercive field and remanent polarisation with increasing Sc.

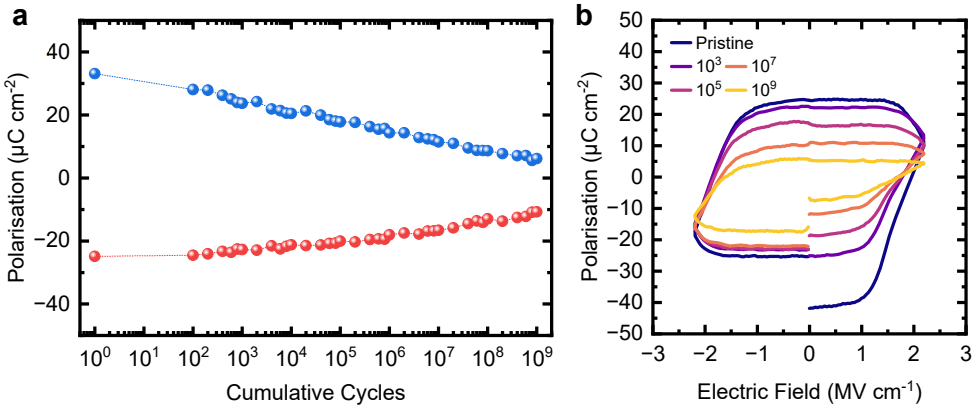

Figure 3. (a) Fatiguing behaviour of the $Sc_{0.56}Ga_{0.44}N$/GaN structure obtained via a bipolar square waveform with E_{max} = 2 MV cm^{-1} at 8 kHz. Fatiguing is gradual with non-zero polarisation remaining after 10^9 cycles. (b) Evolution of the polarisation vs electric field hysteresis (measured at 1 kHz) with bipolar cycles.