

## Characterization of Ferroelectricity in M-polar ScAlN and N-polar ScGeAlN Thin Films

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The discovery of ferroelectric behavior in wurtzite-structured scandium aluminum nitride (ScAlN) has renewed interest in nitride-based ferroelectric thin films [1]. Since the remnant polarization ( $P_r$ ) of ScAlN is greater than hafnia (HfO<sub>2</sub>)-based ferroelectric thin films, ScAlN is then touted as an advantageous alternative to hafnia-based ferroelectric material [2]. Furthermore, there has been growing interest in nitrogen (N)-polar ScAlN since the use of N-polar ScAlN is expected to bring more benefits for several electronic devices such as HEMT, compared with that using metal (M)-polar thin film [3]. Recently, our group has reported that addition of germanium (Ge) into ScAlN inverted the polarity from M-polar to N-polar (Fig. 1(a)) [4]. While polarity inversion is evident, the ferroelectric behavior of N-polar ScGeAlN is unknown and how it differs from the ferroelectricity of M-polar ScAlN has never been studied before. Therefore, we investigated the ferroelectricity of N-polar ScGeAlN in comparison with M-polar ScAlN. In this study, ScAlN and ScGeAlN thin films were deposited on the surface of Si (100) by using RF sputtering method using multiple targets, with the thickness is approximately 500 nm. The piezoelectric response was examined using Piezometer and the polarization-electric field ( $P$ - $E$ ) measurement were conducted using ferroelectric measurement system.

From the hysteresis loops in Fig. 1 (b) and (c), it is evident that both thin films exhibited ferroelectric behavior. The  $P_r$  value for Sc<sub>0.3</sub>Al<sub>0.7</sub>N is found to be approximately 100  $\mu\text{C}/\text{cm}^2$ , which is in good agreement with the previously reported  $P_r$  value for similar material [1]. Sc<sub>0.3</sub>Ge<sub>0.1</sub>Al<sub>0.6</sub>N showed a slightly higher  $P_r$  value than that for Sc<sub>0.3</sub>Al<sub>0.7</sub>N. These results demonstrated that addition of Ge into Sc<sub>0.3</sub>Al<sub>0.7</sub>N did not deteriorate its ferroelectricity. The detail comparison on ferroelectric behaviors of these Sc<sub>0.3</sub>Al<sub>0.7</sub>N and Sc<sub>0.3</sub>Ge<sub>0.1</sub>Al<sub>0.6</sub>N is also further examined in this study.

### References:

[1] S. Fichtner et al, *J. Appl. Phys.* 125 (2019) 114103 [2] N. Sun et al, *Appl. Phys. Letter* 125 (2024) 032904

[3] P. Wang et al, *Appl. Phys. Letter* 121 (2022) 023501 [4] S. A. Anggraini et al, JSAP 2021, 22a-P01-4.

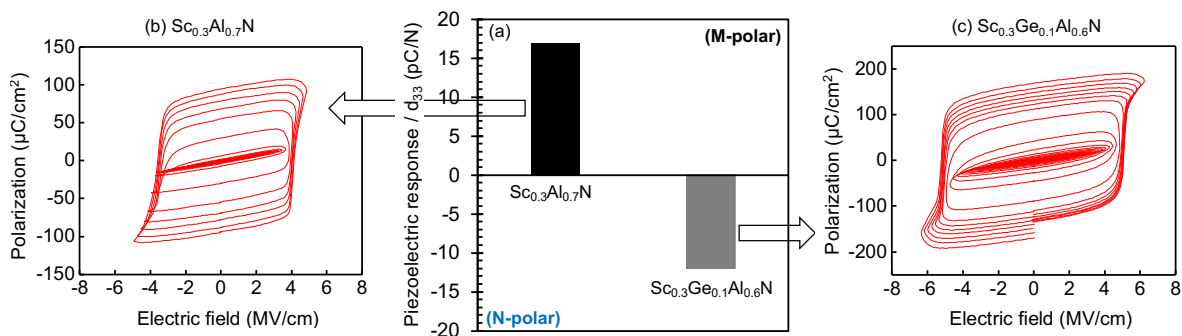


Figure 1 (a) The piezoelectric response ( $d_{33}$ ) and  $P$ - $E$  hysteresis for (b) Sc<sub>0.3</sub>Al<sub>0.7</sub>N and (c) Sc<sub>0.3</sub>Ge<sub>0.1</sub>Al<sub>0.6</sub>N thin films measured at 10 kHz. (Fig. 1(a) is reproduced from [4])