Polarity inversion of scandium aluminum nitride (ScAlN) piezoelectric thin films by using Ge addition

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Stacking N-polar and Al-polar layers could improve the performance of a solidly mounted resonator BAW (SMR-BAW) compared with that using a single layer Al-polar thin film [1]. Since scandium aluminum nitride (ScAlN) has been touted as a promising material for various applications including the radio frequency (RF) resonators [2-3], controlling the polarity of ScAlN-based thin films will encourage the development of more advanced broadband BAW filter that is suitable for higher frequency range in 5G communication technology. As a method to control the polarity, addition of silicon (Si) into AlN has been reported to inverse the polarization direction of non-doped aluminum nitride (AlN) from Al-polar to N-polar [4], which was also effective to control the polarity of ScAlN piezoelectric thin film [5]. Since Si and germanium (Ge) belong to the same group in the periodic table, we hypothesized that addition of Ge should be capable of inversing the polarization direction of ScAlN. For a non-doped AlN, addition of Ge has been confirmed to successfully inverse the polarity from Al-polar to N-polar [1]. Therefore, in this study we would like to further investigate Ge addition can also be used as a method to inverse the polarization direction of ScAlN.

All thin films were deposited on Si (100) wafer via RF magnetron sputtering system. The concentration of Sc and Ge was controlled by adjusting the power of cathodes for each corresponding target during thin film deposition. All elements in thin films were investigated by using energy dispersive spectroscopy (Horiba, Japan). The piezoelectric response (d_{33}) was examined using Piezometer (Piezotest PM300, UK). Positive d_{33} value indicates that the thin film has Al/Sc-polar while negative d_{33} value indicates that the thin film has N-polar. The positive d_{33} values exhibited by $Sc_xAl_{1-x}N$ suggest that the polarity of the thin film is Al/Sc-polar. However, depending on the concentration of Sc and Ge as well as the ratio of Sc/Ge, co-doping Sc and Ge into AlN was found to result in thin films with negative d_{33} values, which indicate that ScGeAlN thin films have N-polarity (Fig. 1). Since addition of Ge exhibited similar results with Si addition, we believe Ge addition can also be used to control the polarity of ScAlN.

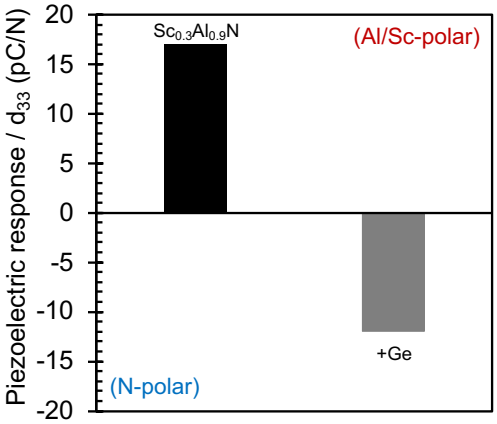

Figure 1 Effect of Ge addition on polarity change of ScAlN from Al/Sc-polar to N-polar.

References:

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