Effect of different divalent cations on the piezoelectric and mechanical properties of *M*TiAlN-based thin films (*M* = Mg or Zn)

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Wurtzite-structured aluminum nitride (AlN) is an attractive functional thin film due to its promising potentials in MEMS applications as well as its wide implementation in bulk-acoustic resonator (BAR) and solidly mounted resonator (SMR) applications. However, despite the dramatically high piezoelectric response of $Sc_xAl_{1-x}N$ thin films [1], the expensive cost of scandium (Sc) has inhibited further commercialization of $Sc_xAl_{1-x}N$, while simultaneously has also inspired endeavors in finding alternative dopants for AlN that have relatively reasonable cost. Theoretically, magnesium (Mg)-based codopants has been touted as the potential codopants that may enhance the piezoelectric response of AlN [2]. Experimentally, MgNb has been proven to capable of generating similarly high piezoelectric response as Sc [3]. Recently, our group has also proposed the use MgTi as one of the Mg-based codopants that could also enhance the d_{33} of AlN [4]. However, the fact that Mg is prone to oxidation has caused hesitancy in the utilization of Mg-based-codopants to improve the piezoelectric response of AlN thin films. On the other hand, there is little study regarding the use of Zn, which has relatively lower reactivity toward oxidation when compared with Mg, as divalent cation of the codopant for AlN. Therefore, in this study, we investigated the effect of Zn as the divalent cation to substitute Mg in MgTi codopants for AlN (Fig. 1 (a)) on the piezoelectricity and the mechanical properties (i.e. stiffness and hardness).

All thin films were deposited on Si (100) wafer via RF magnetron sputtering system. 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). The Young's modulus was measured using nano indenter (Elionix, Japan). As shown in Fig. 1(b), incorporating MgTi into AlN enhanced the d_{33} up to 9 pC/N [4], while replacing Mg with Zn was found to resulted in slightly lower d_{33} than MgTi-doped-AlN but slightly higher than the non-doped AlN. In contrast to the piezoelectric response, codoping MgTi into AlN yielded a lower Young's modulus value than the non-doped AlN. However, alloying AlN with ZnTi generated higher Young's modulus value than MgTi. This value was also relatively similar with that of non-doped AlN (Fig. 1(c)). These results suggest that although substituting Mg with Zn could slightly lower the piezoelectric response, it could also slightly maintain the stiffness of the thin film comparable with the non-doped AlN. The effect of substituting Mg with Zn will be further investigated in terms of crystal structure and chemical surface state of each thin film.

References:

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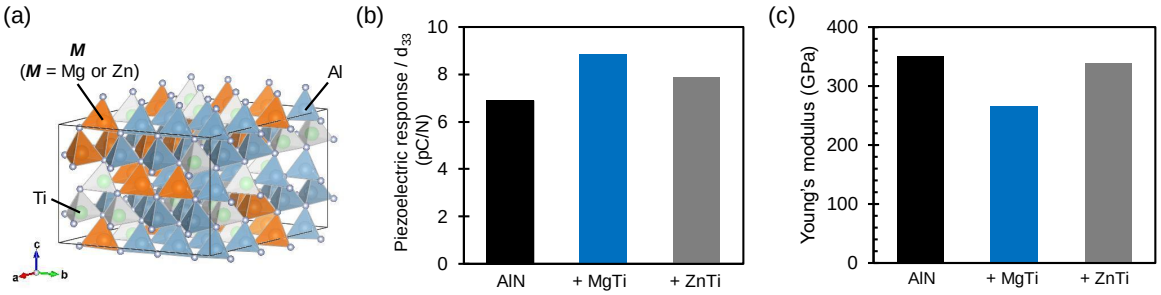

Figure 1 (a) Wurtzite structure $(\boldsymbol{M}Ti)_xAl_{1-x}N$ (***M*** is Mg or Zn) and the effect of codoping MgTi or ZnTi into AlN on (b) the piezoelectric response (d_{33}) as well as (c) the Young's modulus of the resulting $(\boldsymbol{M}Ti)_xAl_{1-x}N$ thin films.