Effect of MgTa addition on the piezoelectric response of aluminum nitride thin films

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The ever-growing smartphone and wireless communication devices demand a continuous improvement in performance of bulk acoustic wave (BAW) filter which consequently also induce development of highly functional aluminum nitride (AlN) thin films as an integrated component in BAW filter. Other than having a highly c-oriented wurtzite structure, the functionality of AlN-based thin film can be tuned by alloying it with other elements while maintaining the optimum crystallinity. The most successful endeavor in enhancing the piezoelectric response of AlN was done by incorporating Sc, where doping 50 at.% Sc into AlN could raise the piezoelectric properties up to about 500% [1]. However, the use of relatively expensive such as Sc may raise the manufacturing cost, hence hindering a wider utilization of ScAlN. This has motivated numerous efforts in finding an inexpensive alternative dopant to substitute Sc. As an alternative dopant, Mg-based codopants are among the most investigated elements ever since it was proposed as the prospective dopants [2]. Addition of MgNb, MgTi, MgHf as codopants for AlN has been studied and confirmed to capable increasing the piezoelectric response of AlN [3-5]. Inspired by these findings, in this study, the effect of MgTa addition into AlN on the piezoelectric properties of the thin films is investigated.

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 effect of MgTa addition on AlN is not only examined in terms of the piezoelectric response (d_{33}), but also in terms changes in crystal structure as well as surface chemical state of each elements. Investigation was started by examining the effect of each elements as single dopant. Addition of either Mg [6] or Ta at lower concentration was found to able to slightly enhance the piezoelectric response of AlN (Fig. 1(a)). However, when Mg and Ta was codoped into AlN at an appropriate dopants concentration and ratio, the resulting $(MgTa)_xAlN_{1-x}N$ thin films was found to have higher piezoelectric response than AlN (Fig. 1(b)). The enhanced piezoelectric response exhibited by $(MgTa)_xAlN_{1-x}N$ should make this material a prospective candidate for future piezoelectric applications.

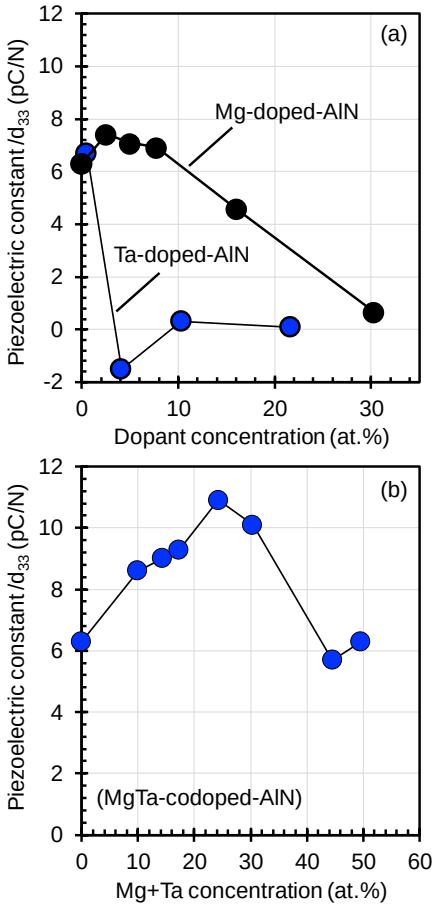

Figure 1 (a) Changes of piezoelectric response (d_{33}) as a function of Mg or Ta concentration as single dopant and (b) effect of MgTa addition into AlN as codopant on the d_{33}.

References:

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