ScAlN polarization inverted resonators and enhancement of k_t^2 in new YbAlN materials for BAW devices.

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Background, Motivation and Objective

In the RF acoustic filter applications, both high electromechanical coupling k_t^2 and low mechanical loss $1/Q_m$ are required. Therefore, low loss AlN films are used in the BAW filters in spite of their low k_t^2. ScAlN films [1] are attracting interest as BAW [2] and SAW devices because of their high k_t^2 [2]. Here, I introduce the polarization inverted ScAlN BAW resonators. I also report the discovery of new doping of Yb as an alternative element to the Sc.

[1] M. Akiyama., *Adv. Mater*. **21**, 593 (2008). [2] T. Yanagitani, et al., *Proc. IEEE IUS*. pp. 2095 (2010).

Statement of Contribution/Methods

Polarity inverted N-polar ScAlN on Al-polar ScAlN resonator excites second overtone mode. This resonator is attractive for high power handling due to the twice thicker stuck compared with standard fundamental mode resonators at same operating frequency and may be also useful for canceling a nonlinear effect of the resonator. Extraordinary N-polar growth can be induced by low energy ion bombardment during the sputtering film growth [3]. Figure 1 shows the admittance of the standard ScAlN FBAR and polarity inverted ScAlN FBAR with same total thickness. We can see the twice increase of the operating frequency.

In 2014, we reported the enhancement of k_t^2 in the YbGaN in the GHz range [4]. We also found high k_t^2 of 11% in the YbAlN films in 2015 [5]. After that, in this spring, a replication study by Akiyama confirmed the large piezoelectric constant in the YbAlN [6].

[3] M. Suzuki, et al, *APL*, **104**, 172905 (2014). [4] T. Yanagitani and M. Suzuki, *APL*,**104**, 082911 (2014). [5] *US Patent Application* 20190089325. [6] Y. Amano, et. al., *JSAP Spring Meeting* 10a-PA4-8, (2019).

Results/Discussion

Figure 2 shows the relationship between Yb atomic concentration and k_t^2. We can see apparent increase of k_t^2 of the films. Rocking curve FWHM determined by XRD were also shown. k_t^2 were extracted using the HBAR conversion loss method [2, 4] in the 0.5-1 GHz. Figure 3 shows an example of the resonant characteristics of YbAlN SMR. These new wurtzite nitride piezoelectric materials are promising for lead-free high performance ultrasonic devices.

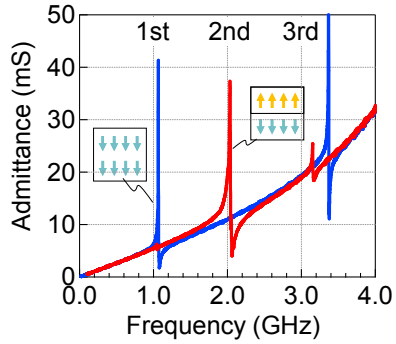

Fig. 1 Admittance of the monolayer ScAlN FBAR and bilayer polarity inverted ScAlN FBAR with same total thickness.

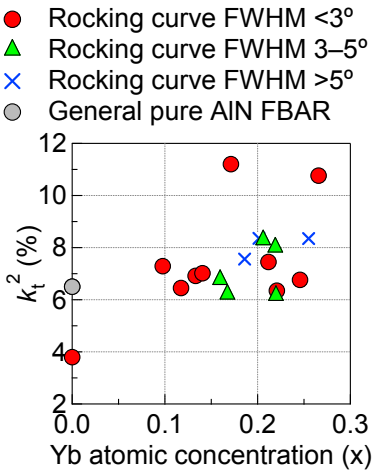

Fig. 2 A relationship between Yb concentrations (x) and k_t^2 in the $Yb_xAl_{1-x}N$.

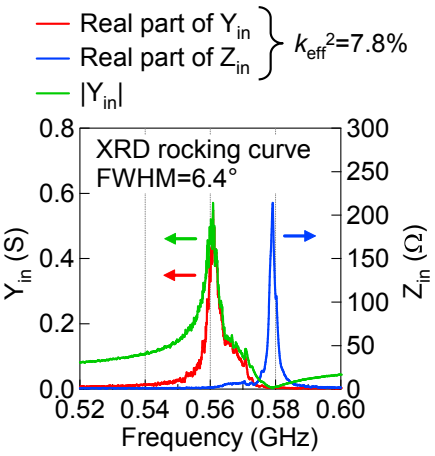

Fig. 3 An example of the resonant characteristics of YbAlN SMR. k_{eff}^2 is 7.8% (which is higher than standard AlN FBAR k_{eff}^2 =6.4%)