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Broadband Piston Mode Operation Of Thickness Shear Bulk Acoustic Resonator On Lithium Niobate

LN を用いた厚みすべり波共振子の広帯域ピストンモード動作

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1. Introduction

Recently, RF bulk acoustic resonators using lithium niobate (LN) thin plate are paid much attention for extremely wideband operation in the SHF range. Matsumoto et al., reported use of the thickness extension mode[1] while Gorisse, et al. reported use of the shear mode[2].

In RF resonators, one of the most important design challeges is suppression of transverse mode resonances without sacrificing lateral energy confinement.

This year, Wong et al., reported[3] that in A1 Lamb mode resonators (XBAR) on LN[4], release windows (via holes) placed near electrode tips are effective for the suppression of transverse mode resonances and lateral energy leakage. Surprisingly, the suppression works for extremely wide frequency ranges. This is owed to the fact that free edges (X plane of LN) offer the total reflection without mode conversion for SH waves, and are ideal for the piston mode operation[5] giving the transverse mode suppression.

This paper discusses applicability of this technique named the broadband piston mode (BPM) to the thickness shear bulk wave resonators (TSBARs). Both the free standing and solidly mounted resonator (SMR)[6] structures are discussed.

2. BPM operation in free standing TSBAR

Fig. 1 depicts a configuration of a TSBAR with release windows placed at side edges of active region. 108° YX LN is chosen as the piezoelectric layer giving the largest k^2 (>39%). Al is chosen as the electrode materials.

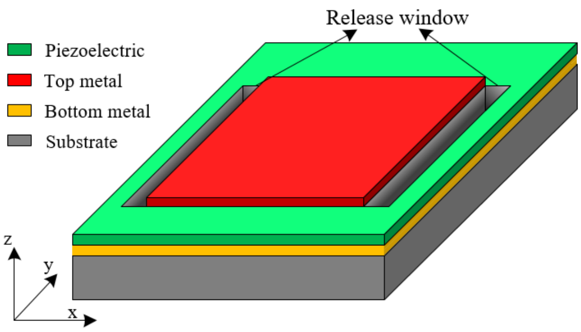

Fig. 1 TS BAR with release windows

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First, the free standing structure is analyzed by the 2.5D FEM, where the periodic boundary condition is applied to the *y*-direction.

Fig. 2(a) shows calculated input admittance *Y* and conductance *G* for standard edge design (without release window). Series of strong spurious responses due to transverse mode resonances are seen at frequencies above the main resonance. Fig. 2(b) shows the results when BPM is applied. Impact of BPM is obvious, and transverse resonances are mostly suppressed for the whole frequency range.

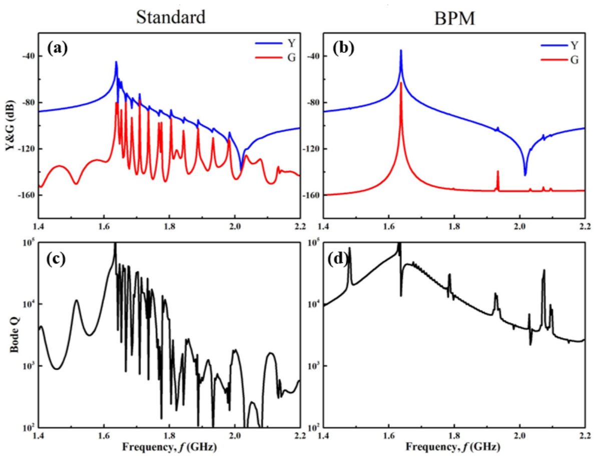

Fig. 2 Simulated amplitude of admittance (*Y*), conductance (*G*), and Bode *Q* of free standing TSBAR

Figs. 2(b) and (d) show the estimated Bode *Q* [7] for these structures. Although *Q* near the main resonance is not sensitive to the edge design, *Q* near the antiresonance changes drastically with the design. Namely, BPM gives much better *Q* than the standard design above the main resonance. This difference is due to suppression of the lateral energy leakage and/or mode conversion at side edges.

Release windows are producible by chemical or reactive ion etching. These technologies often make the sidewalls oblique and/or rough, which may cause wave scattering[8].

Fig. 3 shows influence of the slope angle θ to the TSFBAR admittance. It is seen that spurious responses become obvious with an increase in θ. Nevertheless, influence of the slope is small when θ is smaller than 15°.

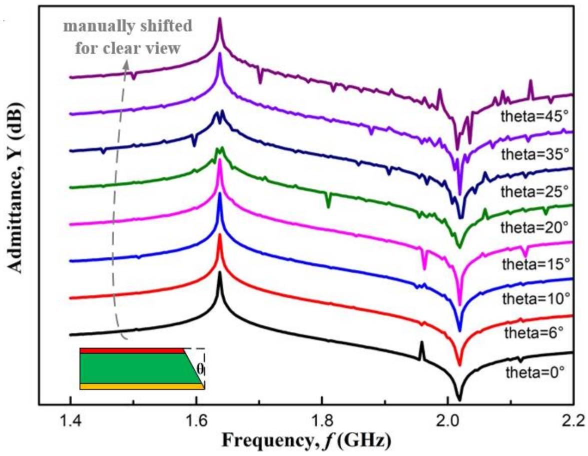

Fig. 3 Variation of Y with the sloped angle θ

3. BPM operation in SMR TSBAR

Next, BPM is applied to the SMR TSBAR, whose configuration is shown as an inset in Fig. 4, where SiO_2 and W are chosen as SMR members with low and high acoustic impedance, respectively. Their thicknesses are set at a quarter wavelength approximately.

Fig. 4 also shows variation of the resonator admittance with the number of SMR layer pairs N. It is seen that resonances become steep with N, while no obvious change is observed on the transverse mode resonances. Namely, BPM works properly also for the SMR TSBAR.

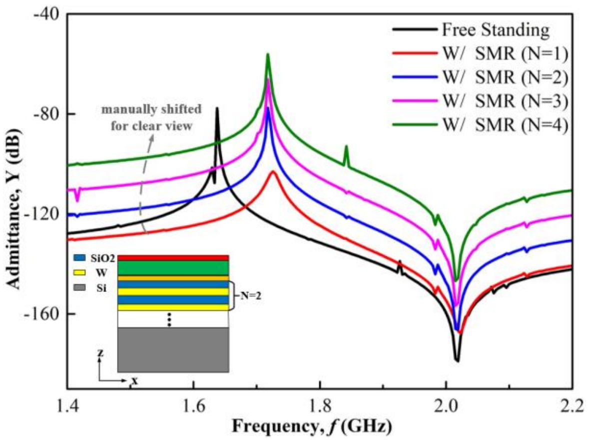

Fig. 4 Variation of admittance Y of SMR TSBAR with N.

Fig. 5 shows variation of the Bode Q with N. It is seen that the Bode Q mostly saturates at N=3.

Further analysis indicated that removal of a few reflection layers is enough to create side trenches for the BPM operation.

In Figs. 4 and 5, the results of free standing TSFBAR are also shown for comparison. Although the effective k^2 reduces from 39% to 32%, the SMR

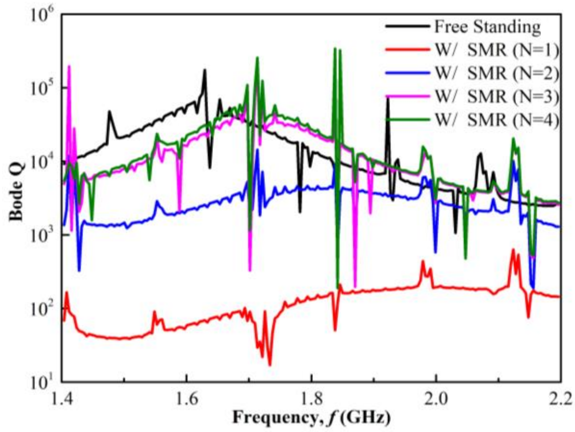

Fig. 5 Variation of Bode Q of SMR TSBAR with N.

TSBAR offers comparable Bode Q and transverse mode suppression with free standing one. Note that the k^2 reduction can be recovered to some extent by use of heavy and stiff electrodes instead of Al.[8]

4. Conclusion

This paper demonstrated effectiveness of BPM for suppression of transverse more resonances in both free standing and SMR TSBARs.

BPM is applicable only to the X-plane, and the standard piston mode design is necessary for the other side edges. Further discussions will be presented on this matter near future.

Acknowledgment

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