2E1-1

Use of Heavy Dielectric Material in Solidly Mounted A1 Mode Resonator Based on Lithium Niobate

Zhaohui Wu[1†], Yawei Li[1], Keyuan Gong[1], Qi Liang[1], Yu-Po Wong[2], Jingfu Bao[1] and Ken-ya Hashimoto[2,1]
([1]Univ. Elect. Sci. Technol. China; [2]Chiba Univ)

1. Introduction

Recently, A_1 Lamb mode resonators using $LiNbO_3$ (LN) thin plates have been studied extensively for realization of extremely wideband filters for operation in the sub 6 GHz range[1,2].

Use of the solidly mounted resonator (SMR) configuration seems vital for making the device structure robust and power durable. Traditionally, tungsten (W) is used as a high acoustic impedance material in the SMR structure [3]. However, its conductivity creates parasic capacitances, and degrades the device performance when W is applied to Lamb mode resonators. Recently use of heavy dielectric materials such as tunsten oxide [4] and hafnium nitride [5] were proposed for the use in SMR.

This paper discusses application of these dielectric materials in the Bragg reflector for LN-based A_1 Lamb mode resonators.

2. Impact of Conductivity on Performance of A_1 Lamb mode SMR

Fig. 1 shows the sturcture of laterally excited A_1 Lamb mode SMR employing 128°YX-LN [2] with the ~480 nm thickness. The base substrate is Silicon. 100-nm Aluminum is chosen as the top electrodes with periodicity is 6.6 μm. Since this configuration offers extremely large effective electromechanical coupling factor k^2 close to 40%, the acoustic reflector should also operate in a wide frequency range for adaptation. Hereafter, SiO_2 is chosen as the soft material.

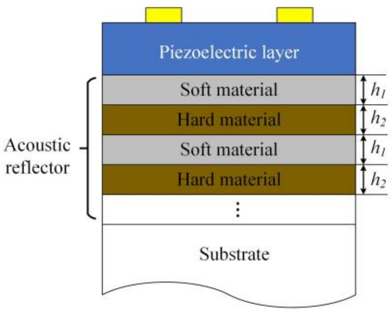

Fig. 1 Laterally excited A_1 mode SMR employing 128°YX-LN (with 8 layers in this work).

†baojingfu@uestc.edu.cn

Fig. 2 shows, as a reference, the admittance curve of this devices when W is employed as the hard material. Two curves are shown; (i) original, and (ii) conductivity of W is eliminated in the numerical simulation. It is seen that the conductivity causes (1) dramatic decrease of the effective k^2, and (2) increase of the total capacitance.

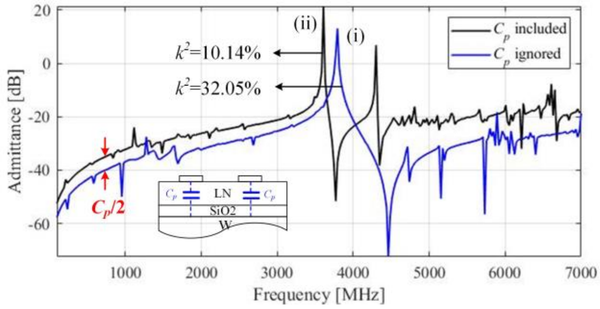

Fig. 2 Admittance curves of A1 Lamb mode resonator using the SiO_2/W reflector. (i) original, and (ii) when conductivity of W is eliminated in the numerical simulation.

Fig. 3 show the electric flux lines in these two cases. Their comparison reveals that the decrease of k^2 is due to (a) creation of vertical electric field between W and electrode layers, and (b) decrease of lateral electric field between two electrodes.

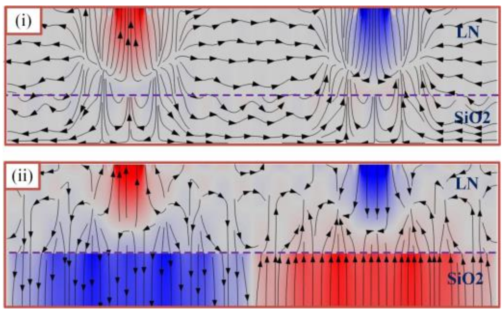

Fig. 3 Distribution of electric flux lines and its y component (colorful region). (i) when conductivity of W is eliminated in the numerical simulation and (ii) original tungsten not only considered mechanically.

3. Application of Heavy Dielectric Materials

Table 1 shows parameters of dielectric materials used in the following analysis. In the table, ρ and G are the mass density and shear modulus respectively.

Thicknesses of soft and hard materials, h_1 and h_2, respectively, are set to be the quarter wavelength at 3.3 GHz for the shear wave.

Table. 1 Material parameters used in calculation.

Material	ρ [kg/m^3]	G [GPa]
HfN	11,000	153
WN	12,100	163
WO_3	7,160	97
Ta_2O_5	8,200	76
AlN	3,300	125*

Fig. 4 shows calculated shear-wave transmittance of reflectors with 8 layers using different heavy materials. It is seen that HfN and WN give wider stop bandwidth and lower transmittance than WO_3 and Ta_2O_3, and AlN (*c_{44} is used for evaluation).

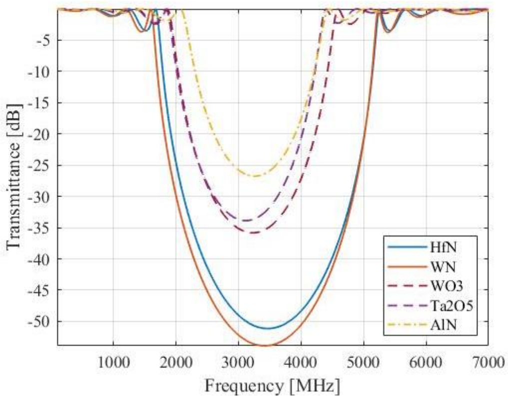

Fig. 4 Variation of calculated shear-wave transmittance of reflectors using different heavy dielectric materials.

Fig. 5 shows variation of the impedance response of A1 Lamb mode resonator with the employed heavy dielectric materials. Owing to use of dielectric materials instead of conductive W, wide separation between f_r and f_a can be achieved for all these cases.

Note that responses above the main resonance are mainly due to higher order Lamb modes, and are suppressed when AlN, Ta_2O_5, or WO_3 is employed. This is because these higher order modes become leaky at this frequency region due to transmission to the Si substrate (see **Fig. 4**).

Fig. 6 shows the effective k^2 evaluated for each case as a function of acoustic impedance Z_a ($=(\rho G)^{0.5}$) of the employed dielectric material for the shear wave. It is seen that larger Z_a offers larger k^2. This can be understood from the fact that larger Z_a offers smaller energy penetration to the reflector layer.

4. Conclusion

This paper discussed application of heavy dielectric materials in the Bragg reflector for LN-based A_1 Lamb mode resonators.

It was shown that HfN and WN possess relatively large Z_a for the shear-wave, and give large k^2 when they are used in the Bragg reflector.

Note that the number of reflector layers can be reduced when the transmittance is small enough. Use of HfN and WN seems also preferable from this aspect.

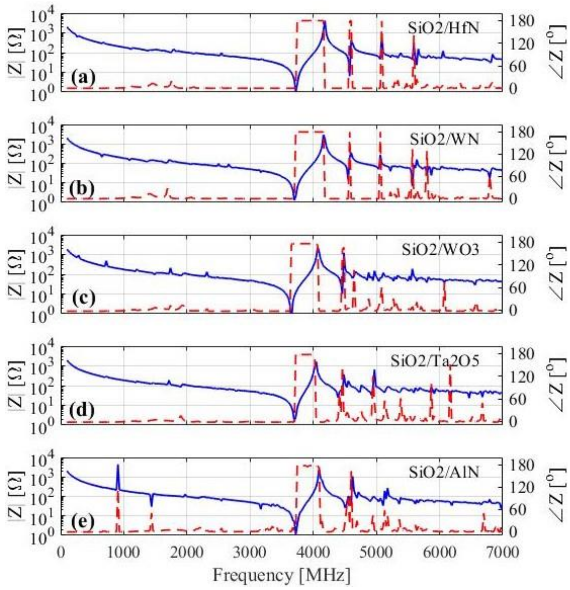

Fig. 5 Calculated impedance Z and its phase per IDT period, based on 2D FEM.

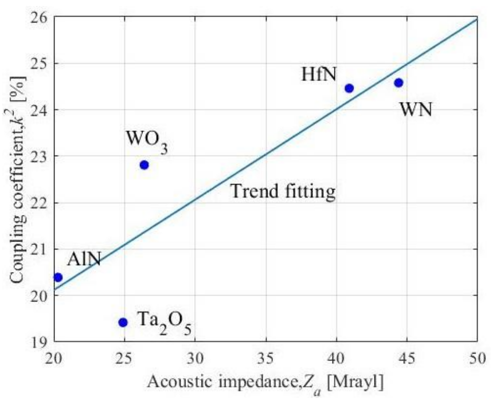

Fig. 6 Variation of estimated k^2 with acoustic impedance Z_a of used heavy dielectric materials for the shear wave

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