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**Brief Notes**

# ON A POSSIBILITY OF REALIZATION OF SAW RESONATOR WITH SURFACE MODES CONVERSION

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It is shown that surface mode conversion can take place in the reflecting grating on some piezoelectric crystals. When one of the modes is piezoelectrically coupled, while the other is not, the resonator performance will not be sensitive to the IDT position in the resonator cavity region.

## 1. Introduction

It is known that the *Q*-factor of surface acoustic wave (SAW) resonator is highly sensitive to the interdigital transducer (IDT) position in the resonator cavity region which can be a problem in resonator design. A layered structure [1] with Rayleigh to Sezawa mode conversion can overcome the above-mentioned difficulty, but another problem arises, namely that concerning the quality of the layered structure.

It is shown below that, at least for some cases of piezoelectric crystals, a similar concept for a SAW resonator can be implemented by operating with a pair of surface modes propagating on a piezoelectric halfspace, namely the generalized Rayleigh, and the generalized Bleustein-Gulayev (B-G) modes.

## 2. A pair of surface modes

A pair of piezoelectrically coupled and uncoupled modes exists in many crystals. Usually, the first one is a B-G mode, and the second one is a Rayleigh mode, the particle displacement vectors of which on the substrate surface are perpendicular to each other. This makes the coupling between them impossible in grooved, or metal strip grating reflector [2, 3].

But consider the case of GaAs, or $LiNbO_3$ substrates with cut, and wave propagation direction given by the Euler's angles as shown in Table 1. We see that

**Table1.** Data for SAW on Metallized Substrate Surface (field amplitudes concern the harmonic wave having an angular frequency $1s^{-1}$ and having power flux density equal to 1 W/m, their values are given for the substrate surface, TCD means the temperature coefficient of delay)

| Material | $LiNbO_9$ | | GaAs | |
|---|---|---|---|---|
| Euler's angles | (90°, 90°, 51.9°) | | (45°, 35.7°, 0°) | |
| Mode | Rayleigh | B-G | Rayleigh | B-G |
| Displacement vector components [nm]: | | | | |
| – in propag. direct. | 2.347 | 0.082 | 1.145 | $-.012+j2.410$ |
| – norm. to surface | j3.137 | j0.390 | j2.137 | $-2.644-j.017$ |
| – transv. horizont. | $-1.401$ | 1.256 | j1.928 | 2.953 |
| el. flux dens. [$nC/m^2$] | 0 | 0.707 | 0 | $-0.136$ |
| TCD [ppm/°C] | 80 | 71 | 38 | 44 |
| $\Delta v/v$ | 0 | .00242 | 0 | .00035 |
| Velocity | 3.5645 | 3.9489 | 2.4452 | 3.0379 |
| Beam steering [°] | $-6.4$ | $-6.1$ | 0 | 0 |

both modes, one of which is piezoelectrically uncoupled ($\Delta v/v = 0$), have all three components of displacement vector on the substrate surface different from zero. Both are surface modes for a metallized substrate surface (the coupled mode, having $\Delta v/v \neq 0$ is of the SSBW [4] type for the case of a free substrate surface).

Following [3], the coupling between these two modes in a metal strip grating can be evaluated as having about 1/3 of the value for SAW-to-SAW coupling in a similar grating on ST-cut quartz. This week coupling is still acceptable for SAW resonator operation. (It should be noted however, that the theory [3] concerns SAW to SAW coupling, where the wavenumber of a SAW is well above the cut-off wavenumber of bulk waves. This is not the case for the B-G mode, so that the theory [3] can give only an approximation for the coupling coefficient in the case considered [5]).

## 3. The resonator frequency response

Let us consider a resonator with a single IDT placed in the cavity region between two reflecting metal strip grating. The grating period $\Lambda$ is chosen to fulfill the Bragg's condition concerning both modes which are to be coupled and propagating in opposite directions, that is

$$1/\lambda^{(1)} + 1/\lambda^{(2)} = 1/\Lambda, \tag{1}$$

where $\lambda^{(1)}$ is the wavelength of the $i$-th mode. This ensures the "reflection" of the incident mode with simultaneous conversion to the second mode.

The interdigital transducer radiates the piezoelectrically coupled mode only, which propagates to the grating reflector where mode conversion occurs. The "reflected" mode is piezoelectrically uncoupled so that it reaches the second grating reflector without being "noticed" by the IDT, when the wave is passing by. The second reflector converts this mode to the coupled one propagating back to the cavity region and the IDT in it, generating electric charge on the IDT fingers.

Let the reflecting grating performance be characterized by $\Gamma$, where $\Gamma^2$ describes the power of the reflected and converted mode as compared to the incident mode power. The above consideration and the theory of IDT [6] leads to the formula for the resonator input admittance as follows

$$Y = j\omega C + \frac{G}{1+\Gamma^2\exp(\tau)}, \tag{2}$$

where $\tau$ is the phase shift of the harmonic wave on the way from the IDT, through double reflection and conversion, back to the IDT, $C$ is the IDT capacitance and $G$ is the transducer radiation conductance (on a free substrate, whithout reflectors).

As we see, the transducer position in the cavity region is not a parameter in the above formula, so it has no influence on the resonator performance.

## Reference

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