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BRIEF NOTE

AN APPROXIMATION TO SURFACE ADMITTANCE OF Y-ROTATED LANGASITE

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New piezoelectric crystal, langasite, is expected to find many applications in piezoelectronics. An approximation to its electro-mechanical surface property is given that allows to analyze B-G waves in the crystal and corresponding SAW devices.

New piezoelectric crystal possessing interesting both optical and piezoelectric properties has been grown recently [1]. It is langasite, a trigonal crystal of 32 symmetry class (like quartz), which chemical formula is $La_3Ga_5SiO_{14}$. It is expected to have temperature compensated cuts, like quartz, what is important for applications in piezoelectric devices, resonators and some surface acoustic (SAW) filters. The langasite is much stronger piezoelectric and this will allow many new applications of such filters [2].

A number of SAW devices has been proposed exploiting Bleustein-Gulayev (BG) wave in Y-rotated quartz, which is the wave propagating on the crystal surface tangential to the crystallographic X axis, which axis is transversal to the wave propagation direction (the wave does not depend on X). Similar waves exist in langasite, and due to stronger piezoelectric effect, they can be even more interesting for applications.

In this paper we present certain useful characterization of electro-mechanical surface properties of Y-rotated langasite. This is a functional approximation to the surface Green's function in spectral domain, valid in certain small but important domain of spectral variable. Y-rotated crystal halfspace of langasite is considered, and all electro-mechanical quantities observed on its surface $y=0$ are involved in the approximated relationship, similar to that presented for quarts in [3]. Following [2, 4], the material constants of langasite important for our purposes are: mass density $\rho = 5.751$ [10^3 kg/m^3], e_{11}, e_{14} equal — .45 and .077 [C/m^2], c_{14}, c_{44}, c_{66} equal 14.7, 53.4, 42.35 [10^9 N/m^2], and ε_1, ε_3 equal 19 and 49.2, correspondingly:

These quantities are:

- electric potential φ,
- particle displacement (X-component) $u_3 = u$,
- surface traction (T_4 in matrix notation) $T_{23} = t$,

all on the surface of the substrate stretching out for $x_2 = y > 0$, and expressed in coordinate system which axes $x_1 = x$ and $x_3 = X$ (crystallographic axis) lay on the substrate surface. In what follows, we consider these quantites as harmonic functions of lime (t) and space (at $y=0$)

$$\exp(j\omega t - jrx)$$

where ω, r are angular frequency (given) and wave-number (a spectral variable), correspondingly. For convenience, the notations of complex amplitudes of the above enlisted quantities are applied the same.

On the reasons presented in [3], we postulate following approximated functional relationship involving the above quantities, dependent on spectral variable r,

$$\varphi = \frac{1}{\varepsilon_0 \varepsilon_e \sqrt{r^2}} \frac{\sqrt{r^2 - k_s^2} - \alpha\sqrt{r^2}}{\sqrt{r^2 - k_s^2} - \beta\sqrt{r^2}} D + \frac{1}{\sqrt{r^2}} \frac{a\sqrt{r^2 - k_s^2} - b\sqrt{r^2}}{\sqrt{r^2 - k_s^2} - \beta\sqrt{r^2}} T,$$

$$u = \frac{1}{\sqrt{r^2}} \frac{a^*\sqrt{r^2 - k_s^2} - b^*\sqrt{r^2}}{\sqrt{r^2 - k_s^2} - \beta\sqrt{r^2}} D + \frac{1}{\sqrt{r^2}} \frac{c\sqrt{r^2 - k_s^2} - \gamma\sqrt{r^2}}{\sqrt{r^2 - k_s^2} - \beta\sqrt{r^2}} T, \tag{1}$$

which can also be rewritten in form

$$D = \varepsilon_0 \varepsilon_e \sqrt{r^2} \frac{\sqrt{r^2 - k_s^2} - \beta\sqrt{r^2}}{\sqrt{r^2 - k_s^2} - \alpha\sqrt{r^2}} \varphi - e_0 e_e \frac{a\sqrt{r^2 - k_s^2} - b\sqrt{r^2}}{\sqrt{r^2 - \alpha\sqrt{r^2}}} T,$$

$$u = \varepsilon_0 \varepsilon_e \frac{a^*\sqrt{r^2 - k_s^2} - b^*\sqrt{r^2}}{\sqrt{r^2 - k_s^2} - \alpha\sqrt{r^2}} \varphi - \frac{1}{\sqrt{r^2}} \frac{d\sqrt{r^2 - k_s^2} - \eta\sqrt{r^2}}{\sqrt{r^2 - k_s^2} - \alpha\sqrt{r^2}} T, \tag{2}$$

which both approximations are assumed valid for $r \approx k_s$, where k_s is the cut-off wave-number of bulk transversal wave (for considered rotated halfspace), $\sqrt{\cdot}$ is chosen positive if real-valued, or negative if imaginary-valued.

In the above approximation, ε_e, α, β, γ, η, c, d are real-valued parameter, and a, b — complex parameters which should be replaced by their complex-conjugated values if r is negative. All the approximation parameters, and cut-off wave-number k_s can be evaluated with help of the method presented in [3] (note however the difference in relationships presented in this paper, there is D_2 involved instead of $\Delta D_\perp$ in [3], this is applied for convenience of analysis of interfacial waves [5]. They are presented in Fig. 1 as a function of rotation angle θ (if $\theta=0$ then $x=Y$ and $y=Z$, and if $\theta=90°$ then $x=Z$ and $y=-Y$), while in Fig. 2 we present corresponding parameters for Y-rotated quartz, for comparison.

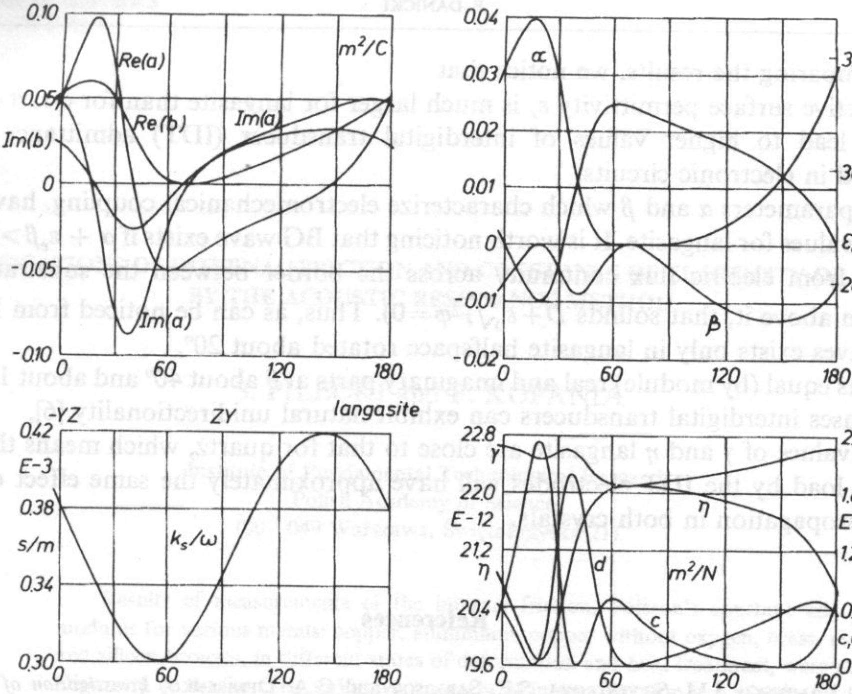

Fig. 1 Dependence of the approximation parameters for langasite on rotation angle θ.

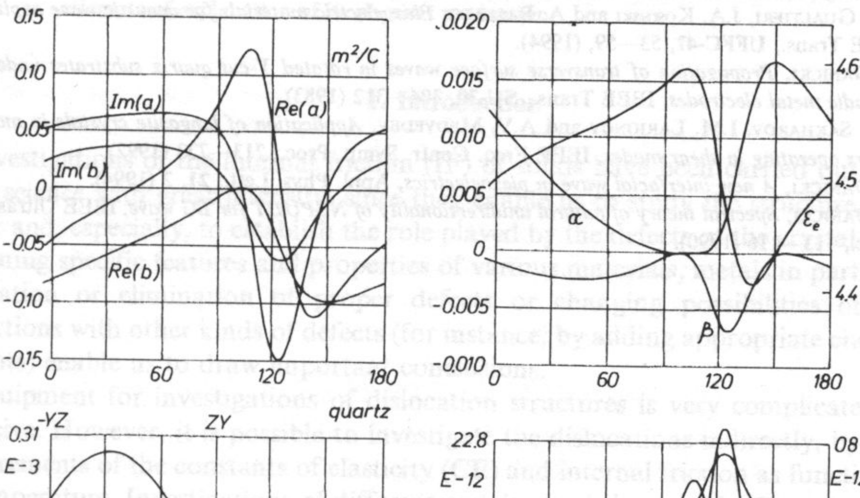

Fig. 2 Approximation parameters for *Y*-rotated quartz.

Comparing the results, we notice that

• effective surface permittivity ε_e is much larger for langasite than for quartz. This would lead to higher values of interdigital transducer (IDT) admittance often required in electronic circuits,

• the parameters α and β which characterize electromechanical coupling, have also higher values for langasite. It is worth noticing that BG wave exists if $\alpha + \varepsilon_e\beta > 0$ (this results from electric flux continuity across the border between the substrate and vacuum above it, that sounds $D + \varepsilon_0\sqrt{r^2}\varphi = 0$). Thus, as can be noticed from Fig. 1, BG waves exists only in langasite halfspace rotated about 20°,

• b has equal (by module) real and imaginary parts at θ about 40° and about 150°, in both cases interdigital transducers can exhibit natural unidirectionality [6],

• the values of γ and η langasite are close to that for quartz, which means that the crystal load by the IDT electrodes will have approximately the same effect on BG wave propagation in both crystals.

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