Finite element model of surface acoustic wave scattering from high-aspect-ratio irregularities

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Abstract

The properly defined reflection, transmission and scattering coefficients were numerically evaluated using COMSOL Multiphysics as functions of the reflector's thickness, from infinitively small to comparable with wavelength in the frequency range near 6 GHz [1]. It was shown that these dependencies for projections are quasi-periodic and related to excitation of Eigen resonance modes in array of reflectors [2]. In contrast to projections scattering from deep grooves does not have periodic behavior and with the depth's growth SAW scattering into volume increases while reflection coefficient doesn't reach more than 40%. The calculation of the 2D pattern of the scattered fields makes it possible to estimate the reflecting structures efficiency and clearly shows the range of the parameters for which an intensive SAW-energy radiation into the bulk occurs.

Description of the proposed method

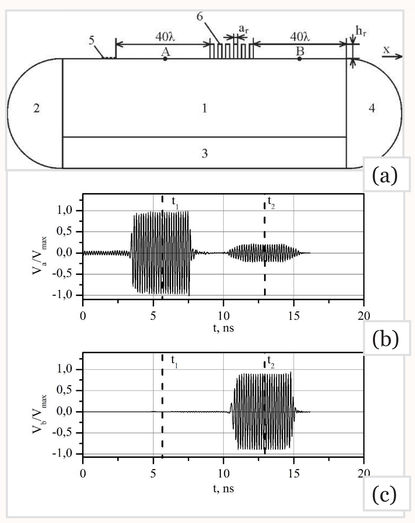


Fig. 1. (a) Geometry of the model under consideration for the case of RS in the form of rectangular projections: (1) – crystal substrate, (2-4) –critical attenuation regions (for suppression of reflections), (5) – electrodes of IDT, and (6) – elements of the RS; Time dependence of the normalized electric potential at points (b) A and (c) B: dashed lines correspond to the points of time t_1=6 ns and t_2=13 ns.

SAW reflection, transmission and scattering coefficients based on [3]

$$Cr = \frac{P_{refl}(t_1)}{P_{SAW}(t_1)};$$

$$Ct = \frac{P_{trans}(t_2)}{P_{SAW}(t_2)};$$

$$Cb = 1 - Cr - Ct.$$

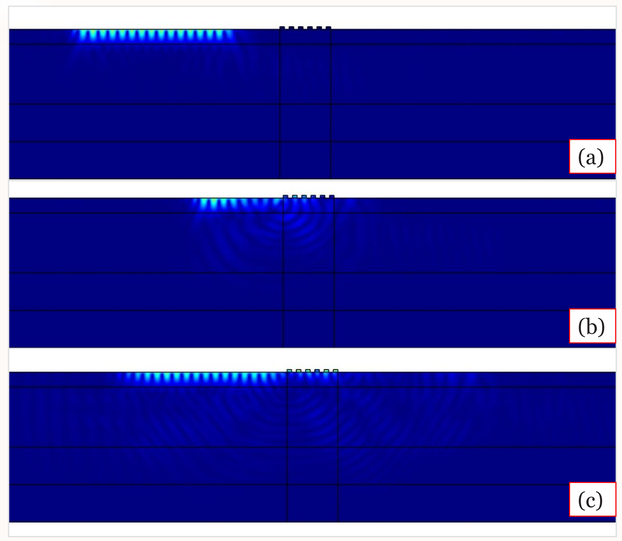


Fig. 2. Distributions of elastic deformations in different timepoints: 6 ns (a); 7 ns (b); 8 ns (c).

SAW scattering from different irregularities

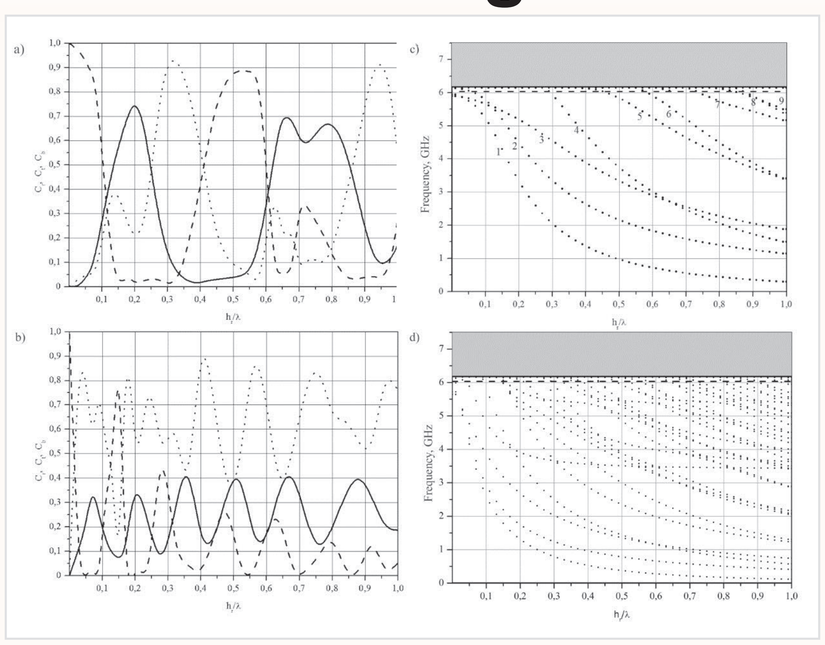
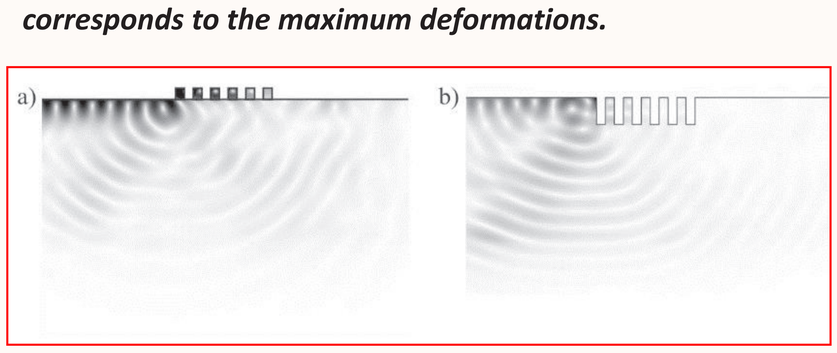


Fig. 3. Coefficients of reflection C_r (solid line), transmission C_t (long dashed line) and scattering C_b (short dashed line) for a system of (a) aluminum and (b) gold reflectors as functions of the normalized height h_r/λ; Frequencies of surface acoustic modes excited in the grating of (c) aluminum and (d) gold electrodes as functions of the electrode height. Dashed line corresponds to a frequency of 6.032 GHz, for which the reflection, transmission, and scattering coefficients are calculated; grey tone marks the region where only bulk modes are excited.

Fig. 4. Distributions of elastic deformations in the reflecting structure in the form of (a) aluminum electrodes with the height h_r/λ = 0.3 that correspond to the maximum of scattering into bulk; (b) periodic sequence of grooves with the depth h_r/λ = 0.74. White color corresponds to zero deformations, and the black area corresponds to the maximum deformations.



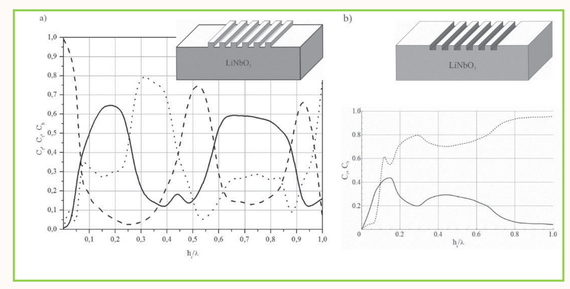


Fig. 5. Coefficients of reflection C_r (solid line), transmission C_t (long dashed line) and scattering C_b (short dashed line) for (a) system of rectangular projections as functions of the normalized height h_r/λ; (b) sequence of grooves.

Conclusions

❖Method of calculation of SAW scattering coefficients in **COMSOL Multiphysics** was suggested and verified;

❖Dependencies of SAW reflection coefficient on normalized height of projection **are quasi-periodic and related to excitation of Eigen resonance modes** in array of reflectors;

❖Processes of reflection and scattering for the case of big (h_r/λ>0.2) reflectors **depend on the density of its material and elastic parameters:**
for aluminum reflection reaches 70% (with small bulk scattering of 5%) but for heavy metals (molybdenum, gold) reflection is reduces to 42% with strong level of scattering into volume (>40%);

❖**In contrast to projections** scattering from the array of **deep grooves doesn't have quasi-periodic** behavior: *with the growth of depth SAW scattering into volume increases while reflection coefficient doesn't reach more than 40%*

Acknowledgments and references

The reported study was supported by RFBR, research project No. 16-32-00120 мол_а.

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