Surface Acoustic Wave Ferroelectric Phononic Crystal Based on Electric Field Induced Periodic Domains

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Abstract

Introduction:
This report dedicated to COMSOL Multiphysics® simulation a novel type of switchable SAW filters based on phononic crystals with periodic domains induced by external DC electric field. It's well known that ferroelectrics in the paraelectric phase has no spontaneous polarization. DC electric field applied to a ferroelectric in the paraelectric phase cause to piezoelectric phenomena in film. This effect is used in tunable bulk acoustic wave resonators [1, 2]. Applied DC electric field influence on the elastic and piezoelectric moduli of the ferroelectric film.

Use of COMSOL Multiphysics®:
Proposed switchable phononic crystal schematically depicted in Fig. 1.
We have performed the 2D numerical simulations using the MEMS Module of COMSOL Multiphysics® kindly provided by Saint Petersburg Electrotechnical University "LETI". Simulation time is 2 hours. Simulation were carried out with using PC with 8 cores Intel processors OS Windows 7 Professional, 16 Gb RAM.
The problem was divided into two steps. At the first step an electric field distribution has been found by solving the electrostatic problem. At the second step the piezoelectric problem was solved using the electric field distribution stored at previous step. The material constants of $BaTiO_3$ were taken from [1-3].
COMSOL simulation results of the electric field distribution depicted in Fig. 2. We can see from Fig. 2 that there are edge effects on the electrodes and electric field distribution is not homogenous. These effects can be taking into account due to numerical simulation only.

Results:
Phononic crystal transmission coefficient as frequency function shown in Fig. 3. The phononic crystal stopband is about 7 MHz. Dispersion curves and band gap for two SAW modes at first Brillouin zone depicted in Fig. 4. Bulk acoustic wave modes are not taken into account. As clearly from Fig 3, the "switching" of band gap occurs when an electric field is applied to the phononic crystal. Changing the width of Bias electrodes we can change the frequency of band gap. Thereby we have an opportunity for develop the switchable and tunable photonic crystal.

Conclusion:
Finite-element modeling in COMSOL Multiphysics® revealed presence of the phononic band gap for surface acoustic waves in structure consisting of electrically induced periodic ferroelectric domains. This effect can be used in tunable surface acoustic wave filters. Electric field and number of electrodes influence on band gap will be investigated further.

Reference

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2. John Berge and Spartak Gevorgian. Tunable Bulk Acoustic Wave Resonators Based on Ba0.25Sr0.75TiO3 Thin Films and a HfO2/SiO2 Bragg Reflector. IEEE Transactions on Ultrasonics, Ferroelectrics, and 2768 Frequency Control, vol. 58, no. 12, December 2011.
3. Andreas Noeth, Tomoaki Yamada, Alexander K. Tagantsev, and Nava Setter. Electrical tuning of dc bias induced acoustic resonances in paraelectric thin films. Journal of Applied Physics 104, 094102 (2008).

Figures used in the abstract

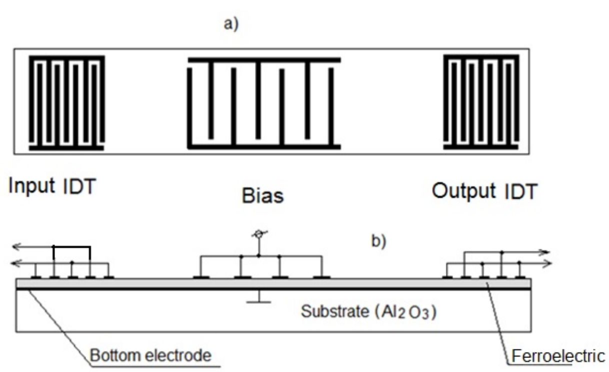

Figure 1: Electric field tunable phononic crystal. a) Top view. b) Side view

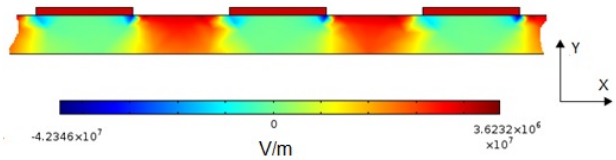

Figure 2: Electric field (Y component) distribution in phononic crystal. Bias 5 Volts.

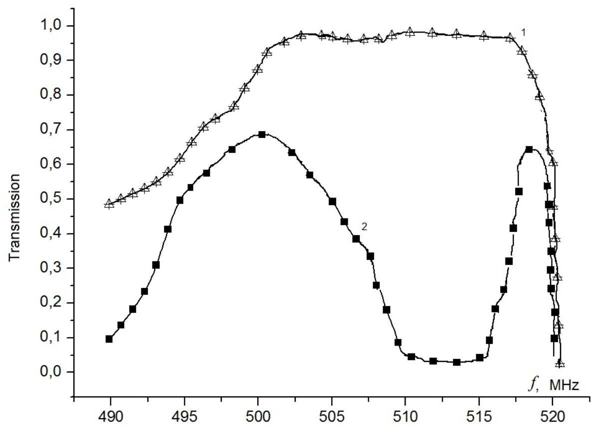

Figure 3: SAW transmission versus frequency in phononic crystal. 1- Electric field off (Bias 0 V). 2 - Electric field on (Bias 5 V).

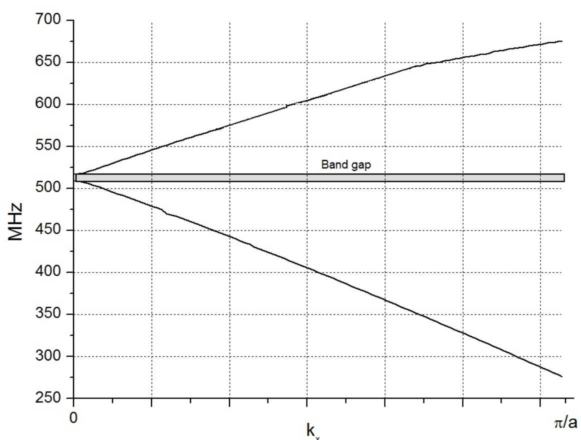

Figure 4: Dispersion curves for SAW