# Surface Acoustic Wave Scattering Matrix Evaluation Using COMSOL Multiphysics®: Application to Surface Acoustic Wave Transmission Through 2D Surface Phononic Crystal

S. Yankin[1], A. Talbi[2], V. Preobrazhensky[3], P. Pernod[2], O. Bou Matar[2], A. Pavlova[2]

[1] 1.Joint International Laboratory LICS/LEMAC, IEMN UMR CNRS 8520, EC Lille,Villeneuve d'Ascq, France; 2.Saratov State University, Saratov, Russia

[2] Joint International Laboratory LICS/LEMAC, IEMN UMR CNRS 8520, EC Lille,Villeneuve d'Ascq, France

[3] 1.Joint International Laboratory LICS/LEMAC, IEMN UMR CNRS 8520, EC Lille,Villeneuve d'Ascq, France; 2. Wave Research Center, Russian Academy of Sciences, Moscow, Russia

## Abstract

Introduction: The application of 2D surface phononic crystal (PnC) to the control of surface acoustic wave (SAW) propagation is of great interest from both science and technology point of view and should open new perspectives in high-frequency acoustoelectronics. Finite element method is nowadays one of most common tool for numerical analysis of PnC structures. The device under investigation consists of two aluminum dispersive interdigital transducers (IDT) and 2D square lattice of ferromagnetic metal pillars realized on 128°YX $LiNbO_3$. In addition to PnC dispersion curves calculations this work describes the results of original 3D finite element modeling of the electrical properties of such SAW device via evaluation of SAW propagation through observed structure that can give quantitative characteristics of wave transmission.

Use of COMSOL Multiphysics®: The main objective of this study is to compute the SAW band diagram and electrical transmission spectra for 2D surface PnCs deposited on a piezoelectric substrate. Figure 1a illustrates the schematics of the unit cell, the complete structure is an infinite repetitive arrangement of the cell along the x- and y- directions. The band diagram of the perfect 2D surface PnC is analyzed using the eigenfrequency solver in the General Form PDE interface of COMSOL Multiphysics®. Transmission of surface waves through the PnC is calculated using the frequency domain solver. This model (Figure 1b) assumes finite size of PnC in the x-direction, and an infinite size along y direction by considering periodic boundary condition. The incident waves are excited by applying harmonic voltage to the first IDT, the transmitted waves are detected by measuring the voltage of second receptor IDT. This permits to evaluate the transmission spectra S21=|S21|*exp(j*PH). The additional model without PC is investigated to receive reference characteristics S21r=|S21r|*exp(j*PHr) and calculate relative transmission S21rel=|S21r|-|S21| and accumulated phase difference APD=PH-PHr.

Results: Pillar based nickel structure with period a=10µm, radius r=4µm and height h=4µm was chosen to demonstrate applicability of described method. For such PnC two SAW band gaps are suggested - after 88 and 140MHz. Dispersive delay line for 80-200MHz was designed and transmission through N=10 pillars was simulated. |S21rel| (Figure 2) shows that first local gap begins after 90MHz and lead to the losses of about 16dB. It's important to note the local maximum and minimum at 90MHz and 91MHz that correspond to resonance and antiresonance of the pillar array. The Bragg gap appears after 145MHz and the losses are about 30dB. The dependence of APD (Figure 3) provides additional information. One can notice its big increase at the beginning of the gaps. Local maximums near 90 and 149MHz can be evidence of SAW group velocity decreasing to zero near these frequencies.

Conclusion: In this contribution, we demonstrated that this model permits to evaluate electrical response of PnC based electro-acoustic devices. Obtained results show a good agreement between band diagram and transmission computations. The experimental validation on such structure was also performed (not shown in this contribution) and its results are close to calculations. The model can be used for further advance designing of phononic structures.

## Figures used in the abstract

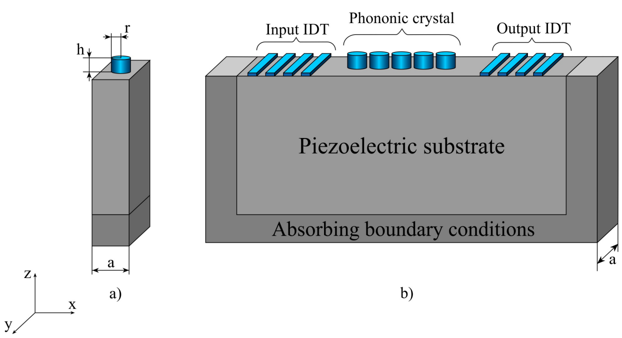


**Figure 1**: a) Unit cell of the square periodic pillar based structure; b) The model of dispersive delay line with phononic crystal for transmission calculation

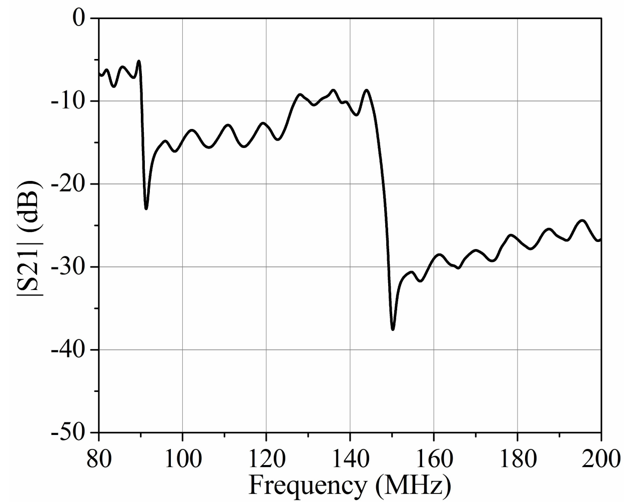


**Figure 2**: Relative transmission |S21rel| through square array of N=10 Ni pillars with a=10μm, r=4μm and h=2.2 μm

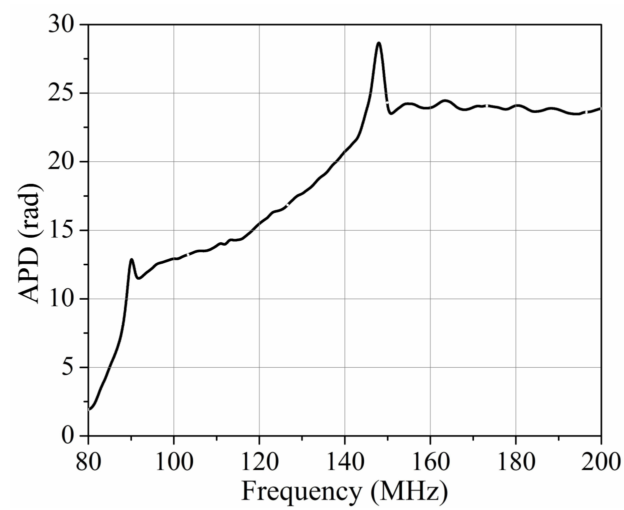


**Figure 3**: Accumulated phase difference APD through square array of N=10 Ni pillars with a=10μm, r=4μm and h=2.2 μm