META 2021 Warsaw - Poland

The 11th International Conference on Metamaterials, Photonic Crystals and Plasmonics

Proceedings

ISSN 2429-1390

metaconferences.org

Phononic band gap of longitudinal acoustic waves in one-dimensional crystal for ultrasonic applications

Ahmed Kahlouche, Mounir Bouras*, Nassim Dermeche, Abdesselam Hocini

Laboratoire d'Analyse des Signaux et Systèmes (LASS), Département d'Electronique,
Faculté de Technologie, Université Mohamed Boudiaf de M'sila,
BP.166, Route Ichebilia, M'sila 28000, Algeria
*corresponding author, mounir.bouras@univ-msila.dz

Abstract

Nowadays, sensor technology has attracted great interest in various domains. In this work, we have analyzed phononic band gaps of one-dimensional phononic crystal made by a stack of N bi-layers of $LiNbO_3/SiO_2$. The transmission spectrum of acoustic waves is calculated by using the transfer matrix method (TMM).

The results clearly demonstrate the existence of phononic band gap of which the position and the width are strongly affected by many physical parameters. Our results are useful in various applications such as acoustic barriers and sensor materials.

1. Introduction

Phononic crystals (PnCs) are a new class of materials that exhibit periodic distributions in their density and elastic properties in one, two or three dimensions of space [1]. These structures are called 1D, 2D and 3D phononic crystals respectively. Such crystals allow to modifying the propagation of acoustic/elastic waves and prohibiting the propagation of acoustic/elastic waves in certain directions and frequency ranges [2].

It has long been known that elastic waves cover many wave phenomena in different states of matter: sound in air, acoustic waves in water and liquids, phonons in solids. In recent years, phononic crystals have been inspired much interest due to their potential for controlling the propagation of acoustic waves [3]. Phonoic crystal can be used for many different applications such as acoustic filtering, waveguides or sensor applications [4-6].

The aim of this paper is to give an analysis and study of the phononic band gap of the one dimensional periodic structures. Firstly, we have studied the propagation of the longitudinal acoustic waves through 1D-PnCs by two methods; the expanding plane wave (PWE) method adopted for diagram dispersion and the Transfer matrix method (TMM) which adopted for 1D periodic structures.

Secondly, using the transfer matrix method (TMM), the transmission coefficients are calculated and plotted for longitudinal waves in order to studying the effects of different physical and geometrical parameters such as the lattice constant, the contrast in densities and the contrast in longitudinal speed of waves in matrix material. Finally, special interest was devoted on the phenomenon of local resonance inside the phononic band gap in order to use such structure for sensing applications.

2. Structure design

The one-dimensional phononic crystal (1D-PnC) structure, which is composed of periodically alternating layers of $LiNbO_3$ and SiO2 with thicknesses of a_1 and a_2, respectively, is presented in Figure 1.

Where a_1 the thickness of the $LiNbO_3$ layer and a_2 is the thickness of the SiO2 layer. The lattice constant is $a=a_1+a_2=1$mm.

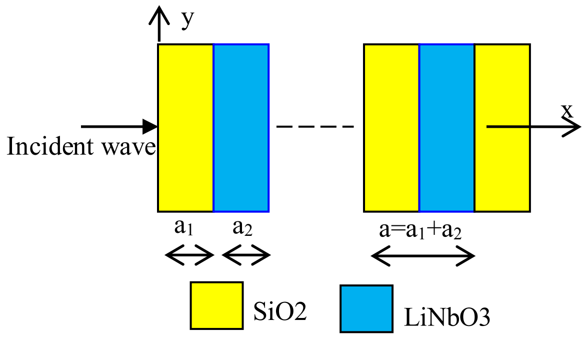

Figure 1: A schematic diagram of a perfect 1D-PnCs

The elastic constants of the matrix and of the inclusions constituting the 1D crystal are illustrated in Table 1.

Table 1: This is an example of a table.

Material	ρ (kg/m3)	v_T (m/s)	v_L (m/s)
$LiNbO_3$	4674	4030	6574
SiO_2	2600	3370	5840

3. Results and Discussion

3.1. 1D Phononic band gap

Using the transfer matrix method (TMM) and the plane wave expansion method (PWE) we can calculated the phononic band gap in the case of the propagation of a longitudinal wave. Figure 2 (a) illustrates the transmission spectrum as a function of frequency obtained with TMM method, while Figure 2 (b) shows the dispersion diagram of 1D-PnC. The blue bands represent the phononic prohibited bands which appeared for longitudinal wave.

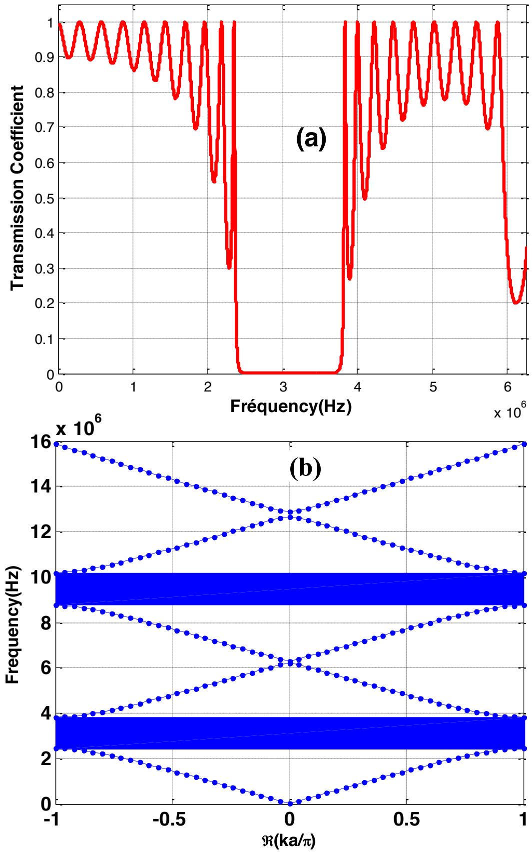

Figure 2: (a) Transmission spectrum as a function of frequency for a longitudinal wave, (b) Dispersion diagram obtained by the PWE method for a 1D-PnC.

3.2. Effects of physical properties

Using transfer matrix method, we are interested to studying the influence of some acoustic/elastic parameters notably the contrast in density and in the speed of longitudinal wave on the properties of phononic band gap.
Figure 3 reports the variations of the phononic band gap properties as a function of density contrast between $LiNbO_3$ and SiO_2 materials (red dashed curves). While, the solid green curves show the effects of longitudinal speed in the matrix material on the width and position of the Pn-BG. The results demonstrate clearly that density contrast and longitudinal speed in matrix have a great influence on the location and bandwidth of Pn-BG.

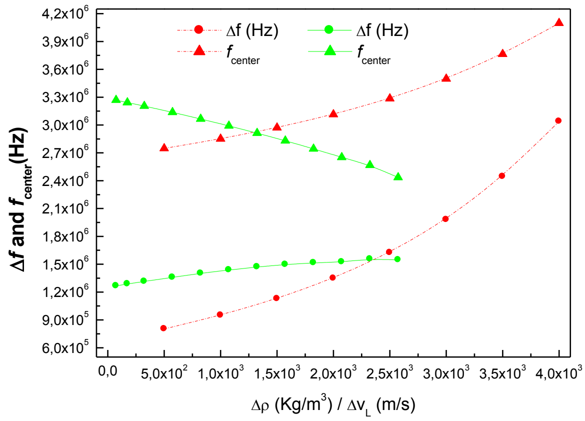

Figure 3: (a) width and position of 1D phononic band gap as a function of density contrast (red curves), (b) variations of 1D Phononic band gap properties as a function of longitudinal speed in matrix material (green curves).

4. Conclusions

In this work, an analysis of a perfect 1D-PnCs formed by the stack of 10 bi-layers of $LiNbO_3/SiO_2$ has been studied, using transfer matrix method and PWE method.
The various calculations show clearly that the physical properties; in particular density contrast and the longitudinal speed in matrix material have a great influence on the position and on the size of phononic band gap which proves the ability to use the 1D-PnCs with defect in sensors applications.

References

[1] M. Sigalas, M.S. Kushwaha, E.N. Economou, M. Kafesaki, I.E.Psarobas, W. Steurer, “Classical vibrational modes in photonic lattices: theory and experiment”, Z. Kristallogr 220, 765–809, 2005.

[2] T. Miyashita, “Sonic crystals and sonic wave-guides”, Meas. Sci.Technol 16, 47–63, 2005.

[3] W. Liu, X. Su, “Collimation and enhancement of elastic transverse waves in two-dimensional solidphononic crystals”, Physics Letters A 374/29, 2968-2971,2010.

[4] W. Liu, X. Su, “Collimation and enhancement of elastic transverse waves in two-dimensional solidphononic crystals”, Physics Letters A 374/29, 2968-2971, 2010.

[5] W. Liu, X. Su, “Collimation and enhancement of elastic transverse waves in two-dimensional solidphononic crystals”, Physics Letters A 374/29, 2968-2971, 2010..

[6] W. Liu, X. Su, “Collimation and enhancement of elastic transverse waves in two-dimensional solidphononic crystals”, Physics Letters A 374/29, 2968-2971, 2010.

META 2021 in Warsaw – Poland

The 11th International Conference on Metamaterials, Photonic Crystals and Plasmonics

July 23, 2021

Attendance Certificate

This letter certifies that **Mounir Bouras** participated in META 2021, the 11th International Conference on Metamaterials, Photonic Crystals and Plasmonics held on-line, during July 20 – 23, 2021.
Co-authors : **Ahmed Kahlouche**, **Dermeche Nassim, Abdesselam Hocini.**
Presented paper :

- Phononic band gap of longitudinal acoustic waves in one-dimensional crystal for ultrasonic applications

Prof. Said Zouhdi
META 2021 General Chair