AN APPROACH TO CALCULATE REFLECTIVITY OF THE 2-D PHONONIC CRYSTALS REFLECTING GRATINGS IN TWO DIRECTIONS

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As a new structure, reflecting gratings based on two-dimensional (2-D) piezoelectric phononic crystals (PCs) have been studied for several years. This paper has proposed an approach to analyze the reflectivity of this reflecting grating in two directions. In the method, resonant modal was firstly analyzed with three-dimensional (3-D) finite element method (FEM) using the commercial software COMSOL Multiphysics, which was accurate and be suitable for 2-D PCs structures. With the resonant modal analysis, reflectivity can be obtained. The results show that the reflectivity of the 2-D reflecting grating is 2.2 times higher than 1-D reflecting grating in the x direction and 5.6 times in the y direction. These results demonstrate that the 2-D PCs reflecting grating can be used in SAW resonators to improve their performances. More researches are to be done to apply the 2-D PCs on the SAW resonators.

Keywords: Surface acoustic wave; Resonator; Phononic crystal; Reflecting grating

1. INTRODUCTION

The surface acoustic wave (SAW) resonators consisting of interdigital transducers (IDTs) and reflecting gratings are widely studied for many years, which can confine the energy effectively. As the aperture width of the IDT is not infinite, idealized plane waves can’t be obtained, which results in some energy leaking out of the resonator in other directions [1]. Therefore, reducing the energy loss is vital to improve the performance of resonators.

Phononic crystals (PCs) constituted of periodic elastic materials have gained much attention in recent years. Two dimensional (2-D) PCs with specified band gaps can be used as reflecting gratings for SAW resonators, in which any incident wave can be reflected effectively by the 2-D PCs when the working frequency is within the band gaps of the 2-D PCs [2-5].

Many researchers are working on the study of using 2-D PCs reflecting gratings instead of 1-D reflecting gratings to reduce the energy loss of SAW resonators. Jia-Hong Sun and Tsung-Tsong Wu [6] proposed a high performance reflecting grating structure with PCs of cylindrical holes and analyzed the reflection of this structure. Julien Gratier and Taeho Kook [7] proposed a 2-D PCs reflecting grating structure with tungsten stubs placing on the 1-D gratings periodically. But both the calculation models can’t accurately obtain the characteristic of 2-D reflecting gratings as they adopted the 2-D analysis model which approximated the 2-D PCs as one-dimensional (1D) IDTs and didn’t consider the reflection in all directions but only perpendicular to the reflecting gratings.

This paper has proposed a three-dimensional (3-D) finite element method (FEM) to calculate the character of the reflecting gratings structure based on 2-D PCs. It calculated reflectivity of the PCs reflecting gratings in both the x and y direction by analyzing its resonant modal with the finite element method.

2. MODEL FOR CALCULATING THE REFLECTIVITY IN TWO DIRECTION

In this paper, as an example, a reflecting gratings structure based on 2-D PCs was adopted. This reflecting grating consists of 128°YX Lithium Niobate substrate ($LiNbO_3$), aluminum strips with a period of 2μm and a thickness of 370nm on the substrate surface and tungsten stubs with a period of 2μm and a thickness of 30nm on the aluminum strips as shown in the figure1.

To analyze the reflectivity of this reflecting grating, resonant modal was firstly analyzed. As shown in the figure 2, to reduce the time and memory cost of the model, 3-D simplified model was built with a Cartesian coordinate system where the z axis is perpendicular to the substrate surface and the x axis is perpendicular to the reflecting gratings. In the figure 2 (a), the model containing a single period in the y direction and two periods in the x direction was used to analyze the resonant modal in the x direction. In the figure 2 (b) the model containing a single period in x direction and two periods in y direction was used to analyze the resonant modal in the y direction. Period boundary conditions (PBC) were used in both of the models in the x direction and in the y direction and the fixed constraint condition was used on the bottom face of the model.

The FEM was adopted to analyze the models built above with the commercial software COMSOL Multiphysics. Through the an analysis of the eigen frequencies, resonant modals including resonant modal and anti-resonant modal can be obtained.

Thus the reflectivity with a single period of reflecting gratings is given by

$$\kappa p = \pi \frac{f_{sc+} - f_{sc-}}{f_{sc+} + f_{sc-}} \qquad (1)$$

where f_{sc+} is the resonant frequency and f_{sc-} is the anti-resonant frequency [8].

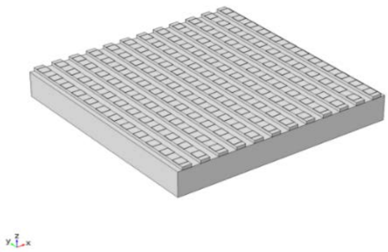
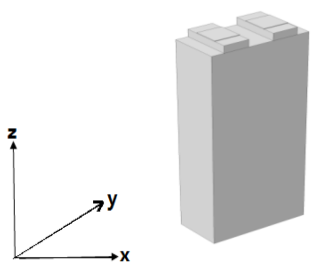
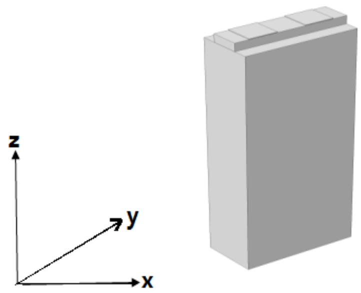


Fig.1 Reflecting gratings based on 2-D PCs



(a)x direction



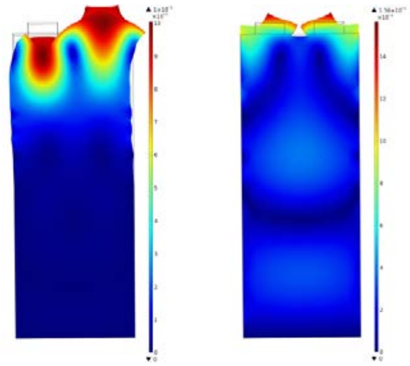
(b) y direction

Fig.2 Models of 2-D PCs reflecting gratings analysis

3. RESULT

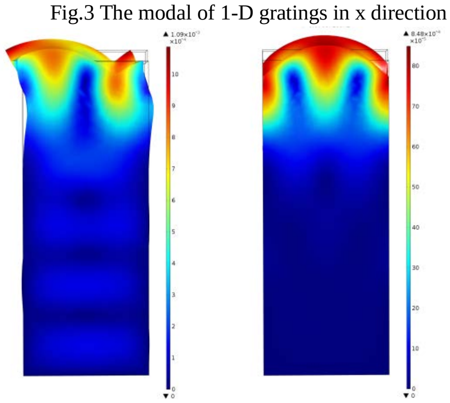
In order to compare the properties of this structure with the 1-D gratings, reflectivity with a single period of 1-D reflecting grating and the 2-D PCs reflecting grating were calculated respectively in both the x and y direction.

The resonant and anti-resonant frequencies of 1-D reflecting grating, as shown in the figure 3, are 915.93MHz and 982.82MHz in the x direction, and the reflectivity is 11.07% obtained by the formula (1). They are 997.68MHz and 1001.36MHz in the y direction, as shown in the figure 4, with the reflectivity of 0.58%.



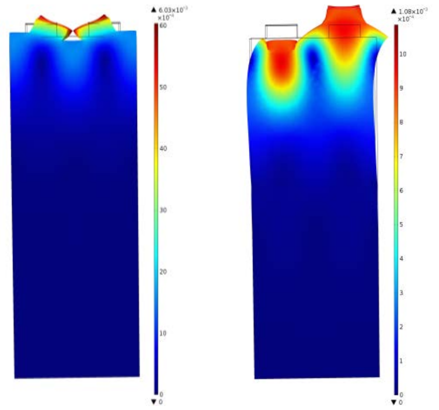
(a) resonance (b) anti-resonant

Fig.3 The modal of 1-D gratings in x direction



(a) resonance (b) anti-resonant

Fig.4 The modal of 1-D gratings in y direction



(a) resonance (b) anti-resonant

Fig.5 The modal of 2-D PCs reflecting grating in x direction

The resonant and anti-resonant of the 2-D PCs reflecting grating in x and y direction are shown respectively in the figure 5 and figure 6, with the reflectivity of 24.37% and 3.24%.

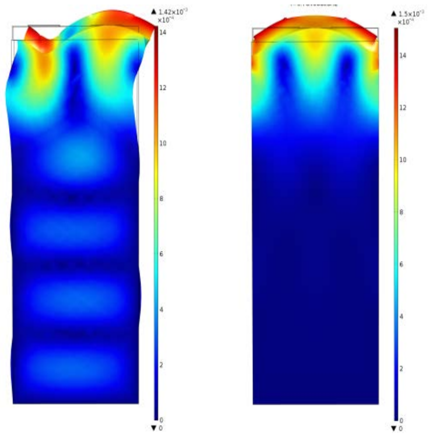


Fig.6(a) resonance Fig.6(b) anti-resonant

Fig.6 The modal of 2-D PCs reflecting grating in y direction

Table 1 the resonant and anti-resonant frequency of 1-D and 2-D reflecting gratings both in x and y direction

	resonant frequency (MHz)	anti-resonant frequency (MHz)	reflectivity
1-D reflector in the x direction	915.93	982.82	11.07%
1-D reflector in the y direction	997.69	1001.35	0.58%
2-D reflector in the x direction	826.45	965.45	24.37%
2-D reflector in the y direction	978.41	998.82	3.24%

Comparing the reflectivity of 1-D reflecting grating and the 2-D PCs reflecting grating both in the x and the y direction as shown in the Table 1, it can be seen that the reflectivity of the 2-D reflecting grating is 2.2 times higher than 1-D reflecting grating in the x direction and 5.6 times in the y direction.

4. DISCUSSION AND CONCLUSION

An approach was proposed to calculate the reflectivity of 2-D PCs reflecting grating in two directions. From the calculated result of 2-D PCs consists of 128°YX Lithium Niobate substrate, aluminum strips and tungsten stubs, it demonstrate that the 2-D PCs reflecting grating can be used in SAW resonators to improve their performances as they have higher reflectivity than 1-D reflecting gratings in both x and y directions. More researches are to be done to apply the 2-D PCs on the SAW resonators.

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