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Experimental Investigation of Surface Acoustic Waves in Two-dimensional $SiO_2/LiNbO_3$ Layered Phononic Crystal

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1. Introduction

Phononic crystal (PnC) is an elastic composite consisting of matrix and filler materials. PnCs attracted researchers' eyes because they showed unusual propagation phenomenon such as anisotropic propagation and band gaps. PnCs with band gaps were able to block acoustic waves within one or more frequency ranges. This property was observed theoretically and experimentally in various PnCs for bulk acoustic wave (BAW), surface acoustic wave (SAW), and Lamb wave.

In recent years, micrometer-scale PnCs were fabricated via MEMS processes and applications such as filters and resonators were designed and examined. In the studies, SAW devices were usually used and combined with the PnCs. Interdigital transducers (IDTs) were fabricated on a piezoelectric material to excite and receive the SAW propagation. Because etching holes on the piezoelectric substrate is not easy, layered PnC structure was proposed and analyzed [1]. The experimental investiagation was reported in this paper. The PnC for SAW was designed as periodic cylinderical holes in the $SiO_2/LiNbO_3$ layered structure. A pair of slandted IDTs were designed to generate and receive wide band signal. Thus the SAW in the two-dimensional $SiO_2/LiNbO_3$ layered PnC were investigated experimentally.

2. $SiO_2/LiNbO_3$ Layered Phononic crystal

A two-dimensional square lattice PnC was used in this paper. Cylindrical holes were defined inside the SiO_2 layer covering on the Y128°-X $LiNbO_3$. Our previous study showed that the $SiO_2/LiNbO_3$ layered PnC performed a partial band gap for SAW. The range of the band gap was affected by the geometric size of layer thickness and radius of air cylinders.

By taking the fabrication limits into consideration, the thickness (h) of silicon dioxide film was chosen as 800 nm. The lattice constant (a) of PnC is 2 μm and the radius (r) of periodic cylindrical structure is 0.6 μm. The band gap range of Rayleigh mode of this size of PnC is between 923.09-961.43 MHz. The IDTs were made of 100 nm thickness aluminum film and located on the interface between SiO_2 layer and $LiNbO_3$ substrate. To measure the effects of layered PnC on the SAW of different frequency, a pair of slanted IDTs were made on both side of a PnC structure as shown in **Fig. 1**.

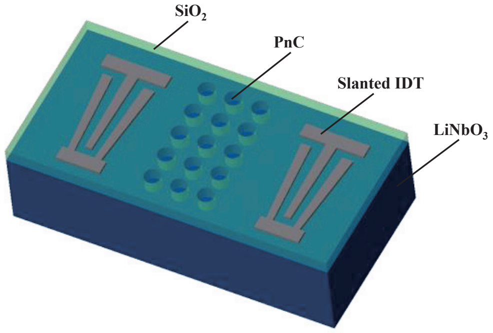

Fig. 1 The design of detecting wide band SAW signal encountering the layered PnC by a pair of slanted IDTs.

The size of PnC and thickness of silicon dioxide fabricated with MEMS process may occur difference in the fabrication. The inaccuracy may result in the deviation of band gap range. We estimated the variation of band gap by considering the changes of both layer thickness (h=0.35a-0.45a) and cylinderical holes (r=0.25a-0.35a). **Fig. 2** showed the band gaps of Rayleigh mode SAW along the Γ-X direction..

To avoid influence of the fabrication lapse, we designed the slanted IDTs to excite SAW covering the ranges of gaps. The excited frequency range of slanted IDT is about 880-1000 MHz. In other word, the line width of IDT is about 0.97-1.13 μm.

3. Fabrication of Slanted IDT and Layered PnC

Since the width of IDT is about only 1 μm, the definition of slanted IDTs was not done by the lithography process simply. The process was divided into two parts. The interdigital fingers were defined by the e-beam lithography. The bus bar of IDTs, and pads used to measure the signal were made by the lithography process with mask. The metal of the align mark for e-beam lithography process is made of gold with thickness of 150 nm.

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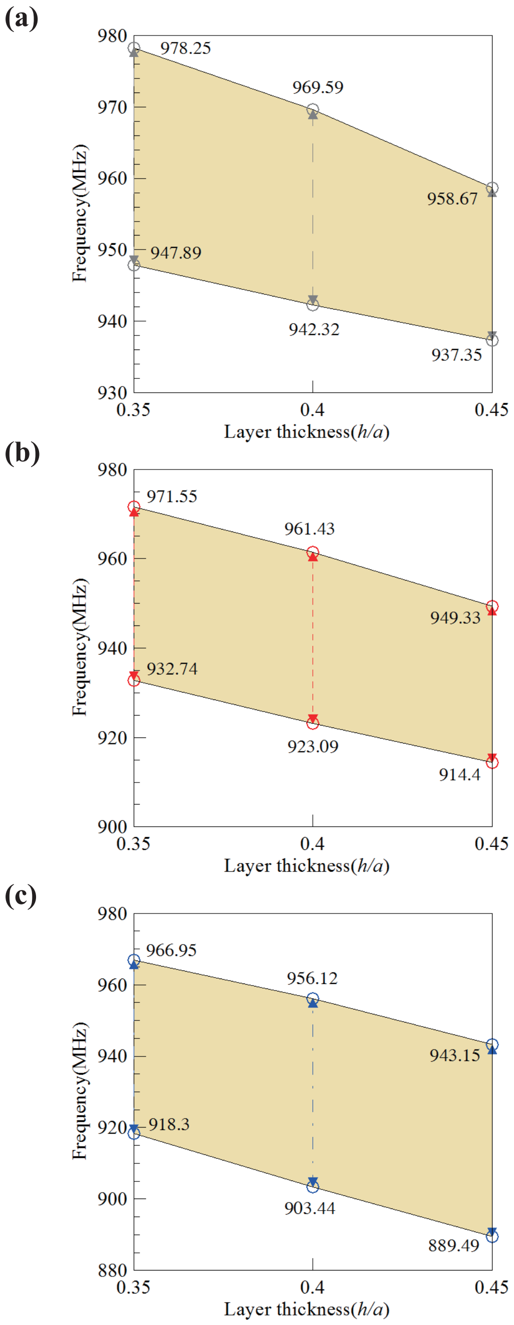

Fig. 2 The variation of band gap with different layer thickness h and cylinder radius: (a) r=0.25a, (b) r=0.3a, (c) r =0.35a

In addition, 10-nm-thick chromium was deposited between the substrate and aligning marks to enhance the adhesion. After defining the patterns, the lift off process was used to make align marks and IDTs.

After the process of previously two patterns, an 800-nm-thick silicon dioxide would be deposited on the whole substrate by using a RF sputter system. Then a 10 nm chromium lay would be made and used as hard mask for later dry etching process. The pads and PnC structure would be defined by a mask and e-beam lithography respectively. The chromium etchant is used to etch the chromium covered on the area where the lithography process is defined. The ICP dry etching process would be applied to etch the silicon dioxide exposed in the air on the substrate. Finally, the chromium used to be the hard mask can be removed to complete the whole fabrication process. The SAW device with PnC structure was shown in **Fig. 3**.

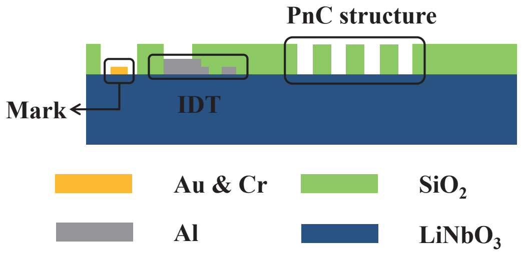

Fig. 3 The side view sketch of device after fabrication.

4. Measurement

In this study, band gap deviation caused by process had been concerned. The fabrication process of SAW device with PnC structure was proposed. Followed the fabrication procedures, the measurement of SAW encountering the layered-PnC could be achieved. By using the slanted IDTs, the transmission of SAW at different frequencies is available. Then the band gap of the PnC can be observed experimentally and compared to the numerically results. Based on the result, the applications such as resonators would be designed and fabricated.

Acknowledgment

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References

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