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Solidity mounted plate wave resonator with wide bandwidth using 0-th shear horizontal mode in $LiNbO_3$ plate
$LiNbO_3$基板のSH_0モードを用いた音響多層膜構造広帯域板波共振子

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1. Introduction

Cognitive radio is researched to use vacant TV channels (called white space) in a frequency range from 470 MHz to 710 MHz [1]. To cover this frequency range, cognitive radio requires tunable filters with wide tunable range. For this application, the authors reported that 0th shear horizontal (SH_0) mode of a plate wave resonator in a (0º, 120º, 0º) $LiNbO_3$ ultra-thin plate of 0.5 μm thickness had a wide bandwidth of 22% and a large impedance ratio of 80 dB in TV band frequency [2]. The resonators consists of a self-suspended 0.5 μm thick $LiNbO_3$ plate and an underlying cavity, but this is structure is fragile and difficult to fabricate.

On the other hand, two kinds of film bulk acoustic resonator, a cavity type and a solidly mounted resonator (SMR) type, have been reported [3][4][5]. The latter has a robust structure compared with the former. The authors reported an SMR type 0th symmetric (S_0) mode Lamb wave resonator, which has an advantage of a high velocity of 6,000 m/s, but the bandwidth is as narrow as 6.4% [6]. It is considered that an SMR type SH_0 mode plate wave has a larger coupling factor than the SMR type S_0 mode Lamb wave as is the case with the cavity type. In this study, the authors performed finite element method (FEM) simulation to investigate SMR type SH_0 mode plate wave resonators in a $LiNbO_3$ plate to obtain a wide bandwidth.

2. FEM simulation

Figures 1 (a) and (b) show schematic figures of a cavity type and an SMR type plate wave resonators, respectively. The latter is composed of an interdigital transducer (IDT), a $LiNbO_3$ thin plate, alternately laminated acoustic impedance quarter wave multilayer, and a glass substrate. The multilayer consists of low- and high-acoustic-impedance layers, which are made of three layers of SiO_2 film of 0.05λ thickness and three layers of AlN film of 0.11λ thickness, respectively.

Figure 2 shows the bandwidths (BWs) of SH_0 mode SMR plate wave resonators using different metal IDTs

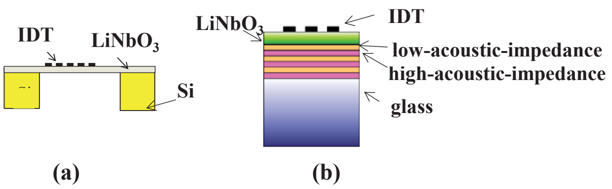

Fig. 1 Structures of (a) cavity and (b) SMR types plate wave.

as a function of Euler angle of $LiNbO_3$ of 0.33λ thickness is shown by a broken line. The resonance (f_r) and anti-resonance (f_a) frequencies are calculated by FEM, and the BW is defined as $(f_a - f_r)/f_r$ [7]. Although the cavity type resonator has a wide bandwidth around an Euler angle of (0º, 120º, 0º), Euler angle around (0º, 90º, 0º) gives the widest bandwidth for the SMR type.

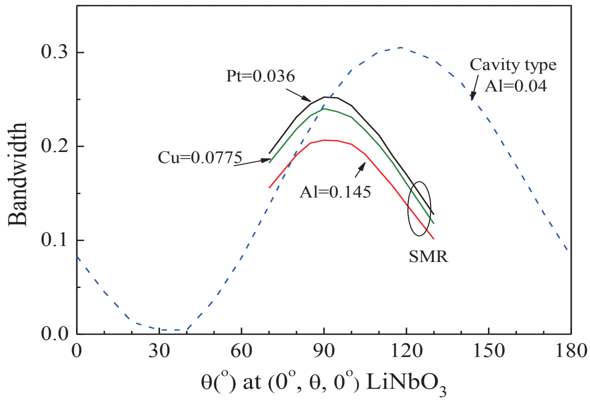

Fig. 2 BWs of SH_0 mode SMR (solid lines) and cavity (broken line) types plate wave resonators at different metal IDTs as a function of Euler angle of $LiNbO_3$.

Figure 3 shows the BWs of the SMR resonator using different metal IDTs on a (0º, 90º ,0º) $LiNbO_3$ as a function of $LiNbO_3$ thickness. As a reference, those of the cavity type SH_0 mode resonator using Al-IDT/(0º,118º,0º) $LiNbO_3$ structure is shown by a broken line. Although the widest BW is obtained by the cavity type at a $LiNbO_3$ thickness of 0.05λ, that of 0.33~0.4λ is the best for the SMR type with any metal

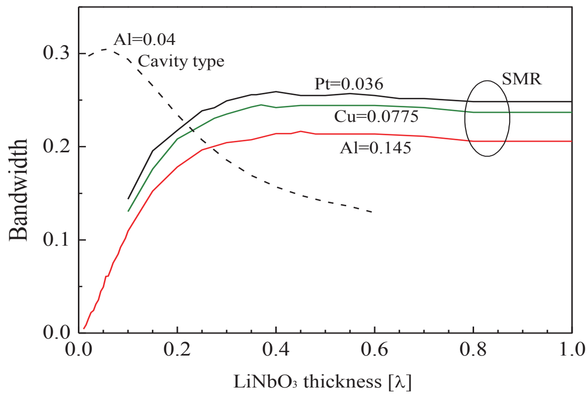

Fig. 3 BWs of SH_0 mode SMR (solid lines) and cavity (broken line) types plate wave resonators at different metal IDTs as a function of $LiNbO_3$ thickness.

IDTs. A 7~8 times larger thickness of $LiNbO_3$ for the SMR type is convenient from fabrication and robustness points of view.

Figures 4 and 5 show the BWs of the SMR and cavity type resonators versus the thickness of different metal IDTs, respectively. Each type of resonator uses the best Euler angle of a $LiNbO_3$ plate, i.e. (0º, 90º, 0º) for the SMR type and (0º, 118º, 0º) for the cavity type. Heavy IDTs such as Pt and Mo show larger bandwidth for the SMR type, while light metal or thin IDTs are suitable for the cavity type. For example, a Pt IDT of 0.036λ thickness and a Mo IDT of 0.075λ thickness are the optimized designs. As summarized in Table I, the optimized design for the SMR and cavity type SH_0 resonators are significantly different in terms of Euler angle, $LiNbO_3$ thickness, and IDT structure. Figure 6 shows the frequency characteristic of the optimized SMR type SH_0 resonator calculated by FEM.

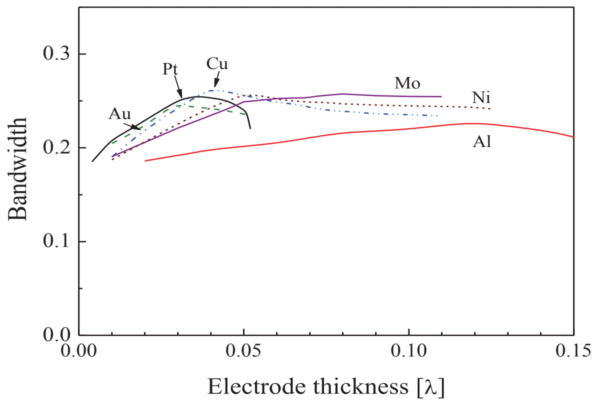

Fig. 4 BWs of SH_0 mode SMR type plate wave resonators as a function of different IDT electrode thickness ($LiNbO_3$: 0.33λ).

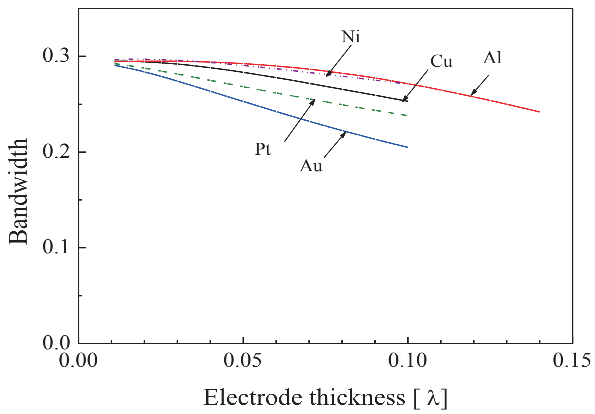

Fig. 5 BWs of SH_0 mode cavity type plate wave resonators as a function of various IDT electrode thickness ($LiNbO_3$: 0.1λ).

Table I. Comparison of suitable parameters between SMR and cavity type plate wave resonators.

	SMR type	Cavity type
Suitable Euler angle	(0°, 90°, 0°)	(0°, 120°, 0°)
Suitable LN thickness	0.33 to 0.4λ	0.05 to 0.1λ
Suitable electrode	Heavy metal	Light metal
Suitable electrode	Pt: 0.036λ	thinner than Al: 0.02λ
thickness	Mo: 0.075λ	
Bandwidth	0.26	0.3

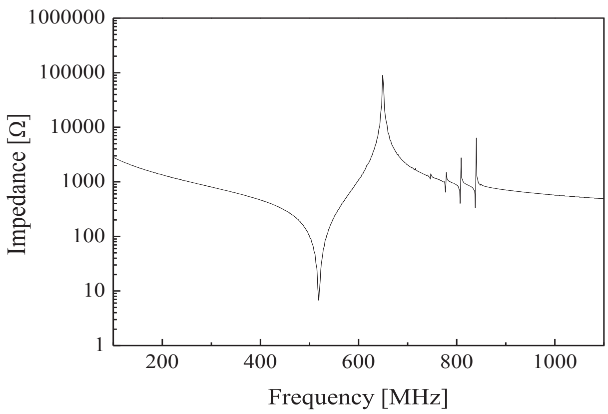

Fig. 6 Simulated frequency characteristic of SH_0 mode SMR plate wave resonators with a Pt IDT of 0.036λ thickness and a metallization ratio of 0.4 on a (0º, 90º, 0º) $LiNbO_3$ plate of 0.33λ thickness.

3. Conclusion

The feasibility of SMR type SH_0 mode plate wave resonators was investigated systematically by FEM simulation. The design including the Euler angle and thickness of a $LiNbO_3$ plate and the material and thickness of an IDT was optimized. With the best design, a bandwidth of 26% is obtained, which is a bit smaller than that of the optimized cavity type resonators (30%). However, the robustness of the SMR type is attractive for wideband and tunable filter applications.

Acknowledge

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