2P3-2

Design of double layered thickness-shear resonator using Langasite-type piezoelectric single crystal -Selection of optimal substrate orientation-

ランガサイト系圧電単結晶を用いた二層構造厚み滑り振動子の設計　-最適基板方位の選択-

Yusuke Owada[1†], Yuji Ohashi[2,3], Masaya Omote[3], Yuui Yokota[2], Shunsuke Kurosawa[2],
Kei Kamada[2], Hiroki Sato[2], Satoshi Toyoda[2], Masao Yoshino[1], Akihiro Yamaji[1],
Akira Yoshikawa[1,2]([1]IMR, Tohoku Univ.; [2]NICHe, Tohoku Univ.; [3]XMAT)
大和田悠介[1†]，大橋雄二[2,3]，面政也[3]，横田有為[2]，黒澤俊介[2]，鎌田圭[2]，佐藤浩樹[2]，
豊田智史[2]，吉野将生[1]，山路晃広[1]，吉川彰[1,2]([1]東北大金研, [2]東北大 NICHe, [3]XMAT)

1. Introduction

Langasite-type single crystals have 2 to 3 times higher electromechanical coupling factors than that of α-quartz, no phase transition up to their melting points, and superior temperature stability in use of resonator. Therefore, several applications have been expected such as combustion pressure sensors and low power consumption resonators. Focusing on $Ca_3TaGa_3Si_2O_{14}$[CTGS], one of the ordered langasite-type single crystals, we have developed $Ca_3Ta(Ga_{1-x}Al_x)_3Si_2O_{14}$[CTGAS] and $Ca_3Ta(Ga_{1-x}Sc_x)_3Si_2O_{14}$[CTGSS] in which Al and Sc are substituted at the Ga site of CTGS in order to improve its characteristics.[1, 2] As a result, we have found a possibility of application to a thickness-shear mode resonator with smaller size and less power consumption than the quartz resonator. However, the temperature stability in resonant frequency of these resonators was not always sufficient, and it is not easy to improve temperature characteristics by the above element substitution.

In this study, we propose a novel thickness-shear mode resonator with double layered structure consisting of two different cut angle substrates with different temperature coefficients of resonant frequencies to compensate the temperature characteristics (Fig. 1). CTGS single crystal was taken as specimens and the optimum cut angles for the bonded structure were predicted by numerical calculation and determined from experimental results.

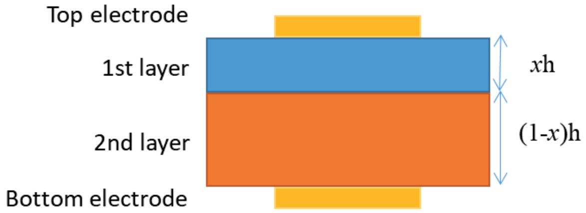

Fig. 1 Concept of double layered resonator

2. Numerical calculation

The temperature dependence of the resonant frequency for each direction was estimated from the rotated Y-axis propagating X-axis polarized shear wave velocity calculated from the material constants (elastic constant, piezoelectric constant, dielectric constant, density) and their temperature coefficients for CTGS, and the coefficient of thermal expansion (CTE) along the corresponding direction.[3, 4] In the calculated results of resonant frequency changes, both of positive and negative temperature coefficients existed depending on the orientation. From the obtained results, a combination of cut angles of the substrates that minimizes frequency change with temperature was determined by adjusting the thickness ratio between two layers. When a cut angle of 122ºY was selected as the positive temperature coefficient and 171ºY was selected as the negative temperature coefficient, and the thickness ratio x = 0.245, the maximum frequency

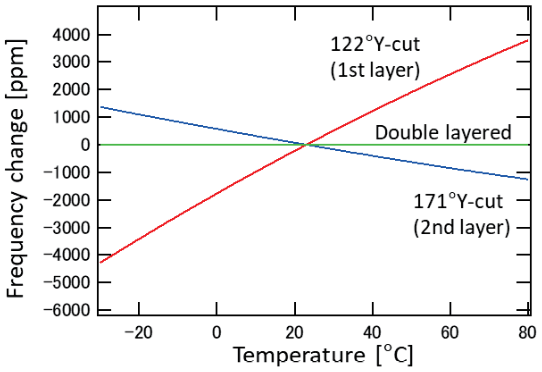

Fig. 2 Resonant frequency changes calculated for 122°Y-cut, 171°Y-cut, and double layered resonators.

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owada@imr.tohoku.ac.jp

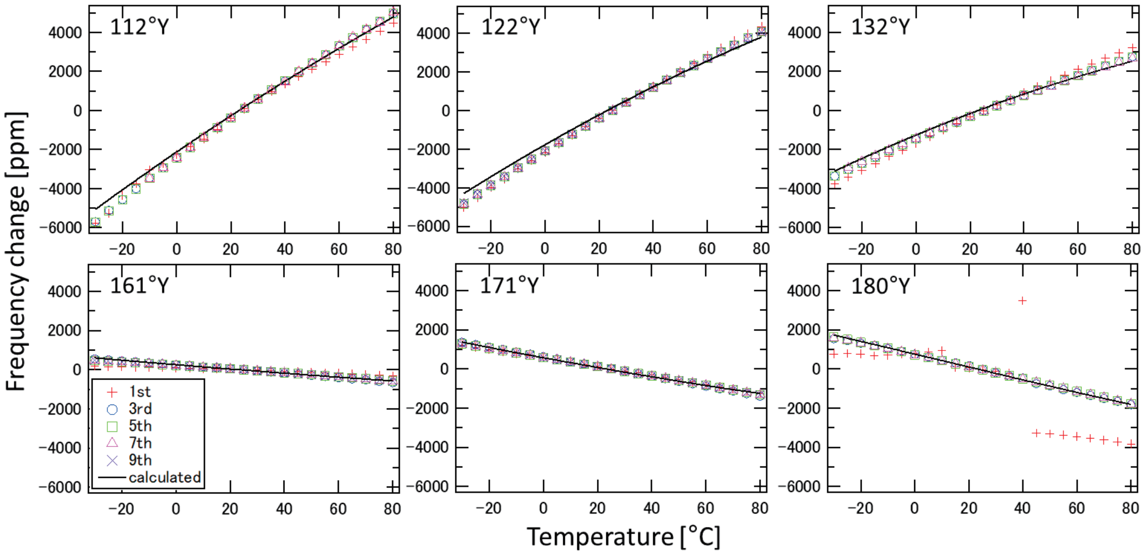

Fig. 3 Resonant frequency changes for six rotated Y cut specimens. Solid line: calculated, marker plot: measured.

change of the resonator was 20 ppm (Fig. 2).

3. Experimental consideration

Specimens were prepared by cut out actually at angles near 122°Y and 171°Y (112°Y, 122°Y, 132°Y, 161°Y, 171°Y, 180°Y). The thickness of the cut specimens were 0.12 mm to 0.23 mm. Au/Cr electrodes were fabricated at both surfaces of each specimen. Using an impedance analyzer (HP 4294A), temperature dependence of the resonant frequency were measured for the specimens at the range from -30℃ to 80℃. Taking into account the case when the correct resonant frequency could not be obtained due to the effect of spurious, measurements were also performed for the higher order resonant frequency (~9th) as high as possible. The experimental results were shown in Fig. 3 addition to the calculated results. Although the 1st resonant frequency change for 180°Y specimen was not obtained correctly because of spurious, the other results were almost consistent with the calculated values.

4. Discussion

Resonant frequency changes of the double layered resonators were estimated by using the experimental results in Fig. 3 and the optimal combination of substrate orientation for bonding was determined. Fig. 4 shows the result for the bonding 122°Y-cut and 171°Y-cut substrates with different thickness ratio. Although the maximum frequency change was expected to be 20 ppm at the thickness ratio x = 0.245 as shown in Fig. 2, the values estimated in Fig. 4 was 100 ppm at the thickness ratio x = 0.23. This difference is considered to be insufficiency in the 2nd order temperature coefficient of the material constants used in the numerical calculation.

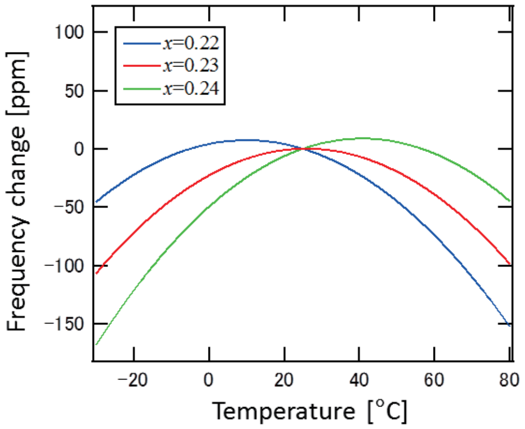

Fig. 4 Resonant frequency changes for the double layered resonators consisting of 122°Y and 171°Y substrates estimated from the experimental results in Fig. 3.

5. Summary

A novel device structure in the thickness-shear resonator was proposed. The optimal substrate orientation for bonding was determined from the numerical calculation and experimental consideration. Hereafter, we will fabricate the bonded resonator and will demonstrate its performance.

Reference

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