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Method of Extremely Efficiently Using Materials of LBO and Quartz in SAW and Bulk Wave Resonator

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Abstract

The limit seems to come to ultrasonic electronics devices that control time and the frequency for the making to high performance. Therefore, it decided to review it from the essence of the piezoelectric materials. The method of making to high performance to optimize the fundamental property of lithium tetraborate ($Li_2B_4O_7$: LBO) and quartz used as stabilized materials for the SAW and bulk wave resonator is researched. The electromechanical coupling constant of LBO SAW is comparatively wide with 1%. The frequency shift is large and the temperature characteristic is not good though it is used as an IF filter. The in-plane anisotropy is positively used for the temperature change's improvement. The SAW chip does die bonding through the buffer layer. The temperature characteristic was found 1:4 or more being able to do the aspect ratio of the chip with 45°X-cut plate, and to be being improved at the ST-cut level. The method of exciting the space of LST-cut can exclude various influences that the mass loading has on the Leakey SAW property. This spatial excitation is examined about the optimum structure of the LST-cut SAW resonator that has third-order temperature coefficient. As the method of realizing high-Q bulk wave resonator near material Q of quartz, the lens processing of quartz is the only solution. The influence given to the temperature characteristic after the lens of double rotated SC-cut plate is processed and the Q-factor that can be realized are investigated.

Introduction

It is top priority to realize high performance and making of telecommunications equipment in the telecommunications sector micro. It is hoped to make to the device by using the material with extremely high stability level, and to suit the system that assumes necessary in the ultrasonic electronics field. Development of the device that has the inquiry and the new feature of a new material for this Imperial command title in each place and a new system are examined. Here, it bases on to the material side, and it considers it. The technique of a solution and a further performance improvement of a technical problem were examined about the surface acoustic wave and the bulk wave. It is impossible near to obtain the one to satisfy all the performances at first the development of a new material almost. The problem of appearing newly can be solved very well becomes important. To realize the high stabilization, LBO and the LST-cut quartz were examined about SAW. The Convex quartz is described about the bulk wave.

SAW Device on LBO[1-24]

LBO is a crystal with 4mm symmetry. The stability level is high in the material for the surface acoustic wave and the difference of speed of SAW in the wafer side is also extremely small. However, the frequency temperature characteristic is limited and the usage used has been limited badly. Therefore, the Langasite crystal whose frequency temperature characteristic is more excellent than LBO is investigated though the electromechanical coupling factor is below the half of LBO.

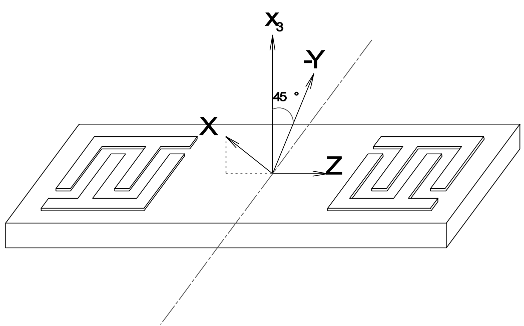

Figure 1. LBO SAW filter

It is examined that the electromechanical coupling factor improves the temperature characteristic of 1% and large LBO to ST-cut average quartz. When the surface acoustic wave velocity of SAW is assumed to be V and the linear expansion coefficient in the direction where the substrate spreads is assumed to be α, TCD of the structural SAW filter shown in Figure 1 is given by the following expression.

$$TCD = \alpha - \frac{1}{V}\frac{\partial V}{\partial T}$$

Here, it is

$$\alpha = \alpha_{11}(1 - \sin^2\theta \sin^2\varphi) + \alpha_{33}\sin^2\theta\sin^2\varphi).$$

In LBO of 45°X-cut (45,90,90), the linear expansion coefficient α becomes α_{33} (-4ppm/℃). Figure 2 shows the linear expansion curve in the direction of each LBO crystal axis of 45°X-cut.

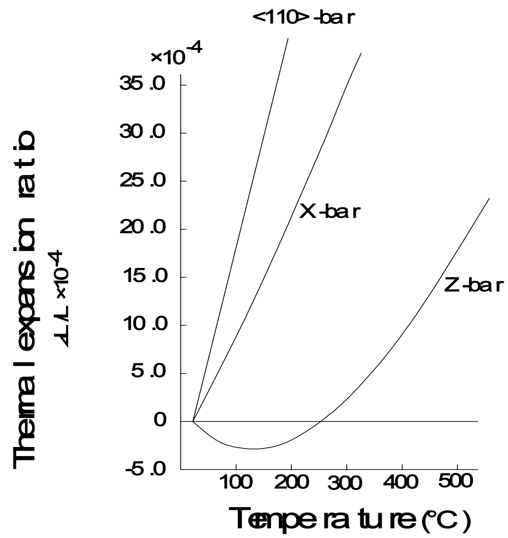

Figure 2. X-bar, Z-bar, and <110>-bar thermal expansion curves for LBO

The coefficient of linear expansion in <110> direction that is the direction of Y is +24ppm/℃. Figure 3 is structure of two dimensional sections when LBO is mounted on the ceramic substrate.

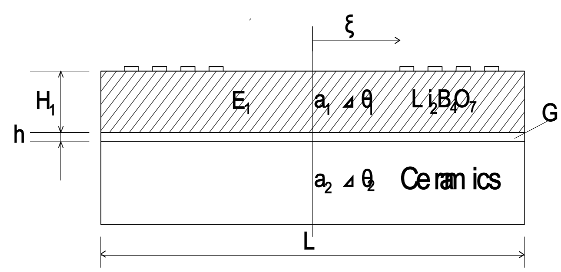

Figure3. Jointed structure of LBO SAW filter

This model is analyzed by using the theory of the shearing delay. The following expression is obtained about the stress σ caused in LBO of V by the gap transformation of the joint layer compared with shearing strain γ and Poisson ratio υ_1.

$$\gamma = \gamma_{\max} \cdot \sinh(\lambda\xi)/\sinh(\lambda)$$

$$\sigma = E_1(\alpha_2 \Delta\theta_2 - \alpha_1 \Delta\theta_1)[1-\cosh(\lambda\xi) / \cosh(\lambda)]/(1-\upsilon_1)$$

ξ is an infinite dimension coordinates.

$$\xi = 2x/L$$

λ is a dimensionless parameter in the ratio to the rigidity of LBO of the rigidity of the buffer layer.

$$\lambda = [(1-\beta)GL^2/(4E_1H_1h)]^{1/2}$$

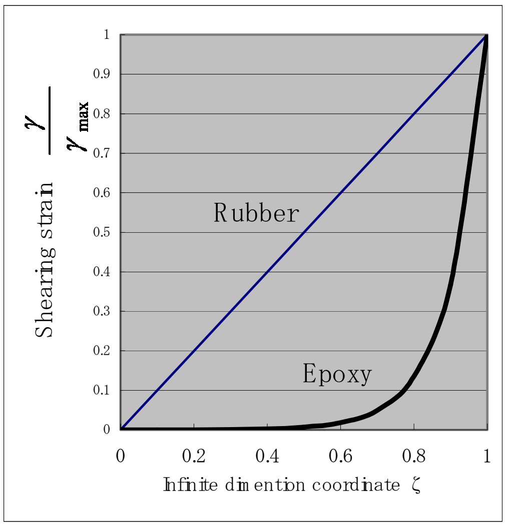

Figure 4. Shearing strain distribution in buffer layer

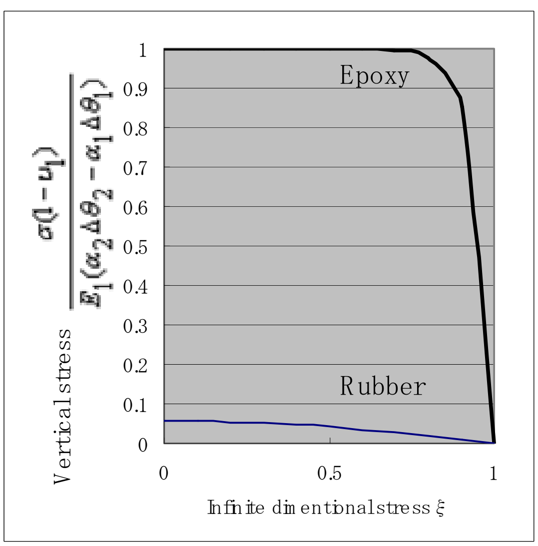

Figure 5. Vertical stress distribution of LBO

γ_{max} is the maximum shearing in buffer layer warp, and it obtains in the following expression.

$$\gamma_{max} = [L(\alpha_2\Delta\theta_2 - \alpha_1\Delta\theta_1)/(2h)][\tanh(\lambda)/\lambda]$$

Figure 4 and Figure 5 show the result of calculating the distribution of γ and σ. From Figure 4 about buffer layer strain γ the buffer layer is distributed and the rubber system is distributed in the straight line. If LBO is fixed to the ceramic substrate with the epoxy adhesive, it is understood to cause the shearing strain only near $\xi = 1$ that is the edge of the buffer layer. On the other hand, the buffer layer becomes small stress σ caused from Figure 4 in LBO in the rubber system. The effect of the stress easing appears in this. In fixation with the epoxy adhesive, the LBO chip from center part $\xi = 0$ to the vicinity of $\xi = 0.5$ (The total length of the SAW pattern is occupied from about 6mm to $\xi = 0.48$ it) is equivalent to the stress at a complete restraint.

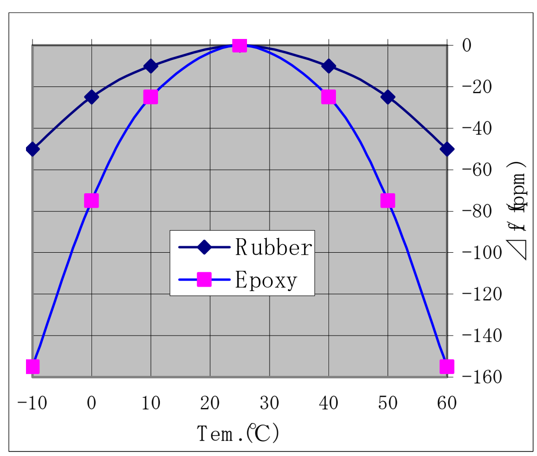

Figure 6. Frequency temperature characteristic of LBO SAW filter of 71MHz

Figure 6 is an investigation of the influence that the difference of the material in the adhesive line gives to the frequency temperature characteristic. The LBO chip (The size of the chip: a=12.3mm, b=2.7mm, and t=0.4mm) is fixed to the ceramic substrate in the adhesive line of two kinds of rubber systems and the epoxy adhesives. Because linear expansion coefficient α_{11}, α_{33} have counterbalanced the sound wave velocity of the elasticity surface wave by the effect of the stress easing of the rubber system bonding layer, the amount of the change of TCD has become small.

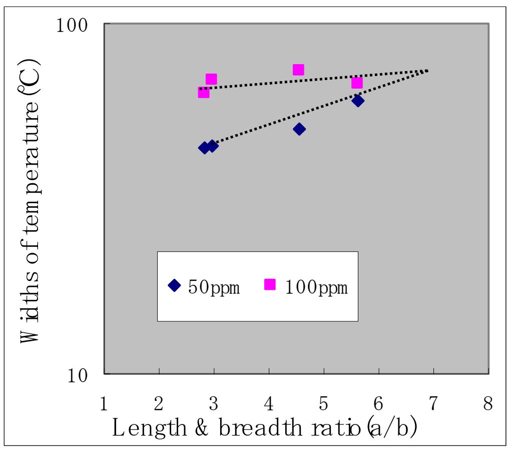

Figure 7. Relation of width of temperature compared with the vicinity of LBO SAW chip

Figure 7 to make (a/b) compared with the vicinity of the LBO chip a parameter, and is showing of the width of the temperature of 50ppm and the width of the temperature of 100ppm. There is a report example with different value of linear expansion coefficient α_{33} of LBO and H, and the value of the heat expansion curve of LBO of Figure 1 is adopted here. The linear expansion coefficient of b in width of -4ppm/℃ and the LBO chip is +24ppm/℃. When a/b compared with the vicinity of the LBO chip is six, the counterbalanced phenomenon is caused by the shrinkage of length that is the surface area on the surface where the SAW pattern of LBO with which the IDT pattern is formed was formed even if the temperature changes and side. It is understood that the width of the temperature of 50ppm and the width of the temperature of 100ppm are almost corresponding by a/b=7. The frequency temperature characteristic of the ST-cut quartz level is obtained within the range of the temperature of -10℃ to +60℃ in a/b=6. The value of linear expansion coefficient α_{33} that an original LBO crystal possesses is compulsorily changed, and it is suggested that there be a possibility of improving the temperature characteristic further by changing the coefficient of linear expansion in <110> direction for instance by the shape processing of the chip. It simulates by the finite element method, and the best shape is inquired into.

LST-cut SAW[25]

The development of the oscillator that made both of SAW pendulums oscillation source was not able to realize the oscillator that was able to oscillate at first of development of the SAW device by the ST-cut quartz. LST-cut that is rotation Y-cut once that uses the leaky wave has the third temperature characteristic. The influence on the temperature characteristic by the effect of the mass addition greatly became a problem at first of the discovery as well as AT-cut on the character to have the high stability. The electrode that excites the leaky wave because it doesn't add mass to the LST-cut quartz is adopted, and 1μm or fewer gaps is installed from the surface and the method of spatial excitation is adopted. It is understood to surpass the frequency temperature characteristic of the AT-cut quartz like the frequency temperature characteristic of the obtained SAW device being shown in Figure 8 compared with AT-cut that inflection point that the frequency change is small is in the normal temperature on the high temperature side.

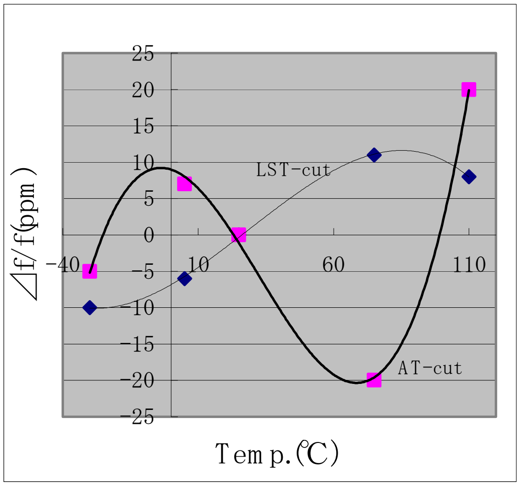

Figure 8. Temperature characteristic comparison between LST-cut SAW and AT-cut quartz resonator

High-Q quartz resonator[26]

As the method of realizing high-Q resonator near material Q (internal friction) of the quartz, the lens processing of the quartz is the only solution.

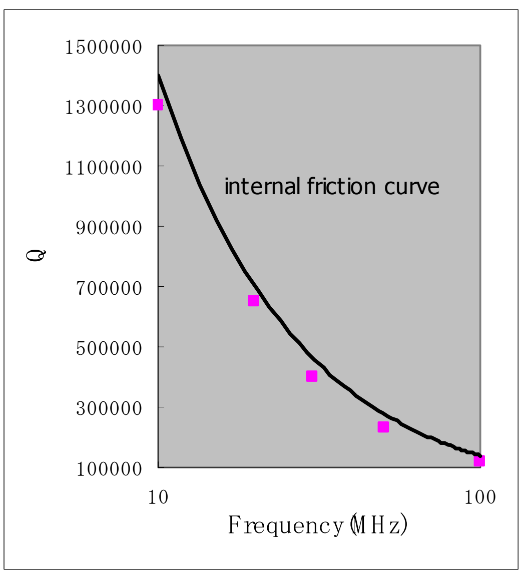

Figure 9. shows the influence given to the temperature characteristic after the lens of double rotated SC-cut is processed and Q value that can be realized. It processes it from 1MHz to the Plano-Convex shape in the frequency range of Bi-Convex and 50MHz or more in the frequency range of 50MHz.

Conclusions

The following results were obtained.

1. It has been understood to obtain the temperature characteristic of ST-cut about LBO SAW. It has been understood that the SAW chip shape is devised, and within the wide range of the temperature, there is a possibility that high steady LBO SAW filter can be realized.
2. The frequency temperature characteristic of the SAW device obtained by the method of spatial excitation of not adding mass to the LST-cut quartz surpasses the frequency temperature characteristic of the AT-cut quartz that the inflection point with a small frequency change is in the normal temperature on the high temperature side.
3. High-Q oscillator near material Q of the quartz can be realized by the lens processing method of the quartz that applies the optical contact.

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