NON-DESTRUCTIVE SAW VELOCITY DETERMINATION IN LANGASITE

S.A.Sakharov[1], A.N.Zabelin[1], O.A.Buzanov[1], A.V.Medvedev[1],
V.V.Alenkov[1], S.N.Kondratiev[2], S.A.Zhgoon[3]

[1]OOO "Fomos Technology"
[2]Temex SAW
[3]Moscow Power Engineering Institute

1. ABSTRACT

Langasite is one of the most promising material for application in communication systems in the nearest future. One of the demands is the homogeneity of acoustic parameters of substrates, and particularly of the SAW velocity.

Presented methods allow to essentially simplify the analysis of the langasite substrates heterogeneity by means of non-destructive method. The software has been created for data acquisition and processing. The results of the langasite substrate acoustic homogeneity investigation are presented. Described methods may be successfully used for inspection of the SAW velocity in other materials such as quartz, lithium niobate and lithium tantalate.

2. INTRODUCTION

Lanthanum gallium silicate (langasite) generates a steadily growing interest of surface acoustic wave (SAW) device manufacturers oriented on the design of IF filters operating in the range of 70 – 450 MHz. The main requirement of the filter designers to the substrate materials is the homogeneity of acoustic properties both over the substrate surface and between separate substrates. The acoustic homogeneity is directly related to the repeatability of SAW propagation velocity in the substrate.

Many different methods were developed for evaluation of SAW propagation velocity in substrates. All of them have advantages and disadvantages. These methods were mainly developed for the control of lithium niobate substrates having a high electromechanical coupling coefficient. The application of these methods to langasite substrates present certain difficulties due to a weak level of acoustic wave excitation in langasite substrate.

This paper describes the procedure of SAW velocities measurement in langasite substrates enabling fast and accurate substrate testing by means of a nondestructive method. The practical results of SAW velocities measurement in langasite, lithium niobate and quartz are also presented. The possibility of investigation of SAW velocity dependence vs temperature and orientation is shown.

3. REQUIREMENTS TO SAW VELOCITY MEASUREMENT ACCURACY

Langasite filters belong to the class of medium relative pass band filters. For example, the 71 MHz filter (of GSM Standard) has the pass band of 250 kHz. The center frequency tolerance is ± 25 kHz, including the tolerance ± 5 kHz for frequency vs temperature deviations over the temperature range from -20^oC to $+70^oC$ and ± 5 kHz is a technological tolerance. Consequently for this filter class the center frequency deviation along the substrate should not exceed ± 10 kHz that corresponds after recalculation to the velocity change within 2736 ± 0,4 m/s. Thus, the measurement accuracy of SAW velocity should be ± 0,2 m/s. Different methods of SAW velocity homogeneity control over the substrate surface are used now.

The most common method consists of deposition of test structures such as resonators or stop band filters with subsequent measurement of their frequencies and their recalculation into velocity values. The main disadvantage of this method is connected with the fact that during the test structure frequency measurement it is impossible to separate the influence of non-homogeneity of the material and technological errors of test patterns preparation. It is necessary to note that this method is destructive and requires spending certain material costs and processing time. Methods described in [1,2] are complicated and cannot be used for mass production.

The method proposed in this paper is based on the simplicity of practical measurement realization together with high accuracy. The parameter being measured is the SAW propagation time delay between two interdigital transducers located at a fixed distance.

4. MEASUREMENT SETUP DESCRIPTION

The measurement setup consists of an acoustic system and a vector network analyzer HP-3577A. The sensor element is prepared on the surface of a dielectric substrate (e.g. glass) that is provided with two identical IDTs. The piezoelectric substrate under control is placed over the transducer system. The input IDT converts the applied electrical signal by means of inverse piezoelectric effect into SAW, which propagates along the substrate to be received by the output IDT.

The output IDT makes the inverse conversion. The vector network analyzer HP-3577A is used for SAW excitation and measurement of frequency characteristic of the acoustic system.

If a δ-pulse of electrical voltage is applied to the input IDT, then surface perturbations will propagate from it and their structure reflects the structure of the input IDT. Due to the fact that the input IDT is homogenous, the perturbations excited by it are periodical. Their spatial period is equal to the double distance between the axes of neighboring fingers. The duration of the signal θ is equal to the active transducer length divided by SAW velocity value.

Then, the frequency characteristic of the input IDT which is the Fourier transform of the impulse response will take the form of sin(x)/x.

5. CALCULATION METHOD

The impulse and the frequency responses of the output IDT are the same. The impulse response of the acoustical system which is formed by the convolution of impulse characteristics of the input and of the output IDTs is a sinusoidal signal with the duration 2θ and a triangular envelope. The frequency response of the acoustical system is the product of frequency characteristics of the input and output IDTs and has the form of $[\sin(x)/x]^2$.

The complex frequency characteristic of the acoustic system H(f) is related to its impulse characteristic h(t) by Fourier transform. Hence, if H(f) is known, it is possible to find the impulse characteristic of the acoustical system h(t). Hence, by knowing the distance that the SAW travels during this time, it is possible to find its velocity.

Thus the calculation of the SAW velocity based on the frequency characteristic H(f) can be realized in the following algorithm.

Calculation of the impulse characteristic h(t). The actual frequency response H(f) can be represented only within a limited frequency range (Fig.1). This range is defined both by the possibilities of the measuring equipment available and by the form of the frequency characteristic itself.

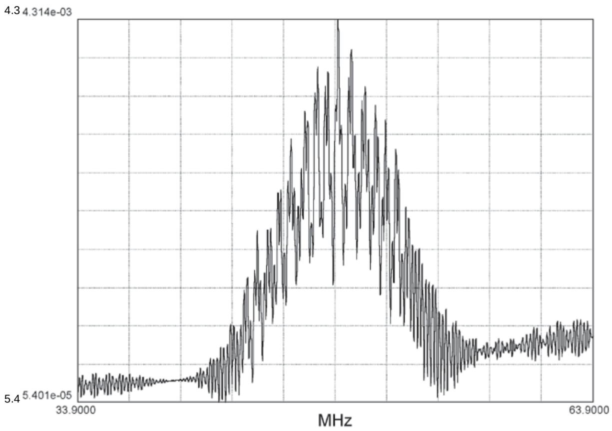


Fig. 1. Amplitude characteristic of a delay line on Langasite yslt/50^{o}/25^{o}.

The use of the common quadrature formulas for h(t) calculation is not practical because for obtaining a result with acceptable accuracy it is necessary to take a very small integration step. Therefore Filon quadrature formulas were used for calculation that implies less stringent requirements to the integration step compared to the common quadrature formulas.

Figure 2 shows the impulse characteristic of the acoustical system h(t) calculated by using its amplitude characteristic |H (f)| represented in Fig. 1.

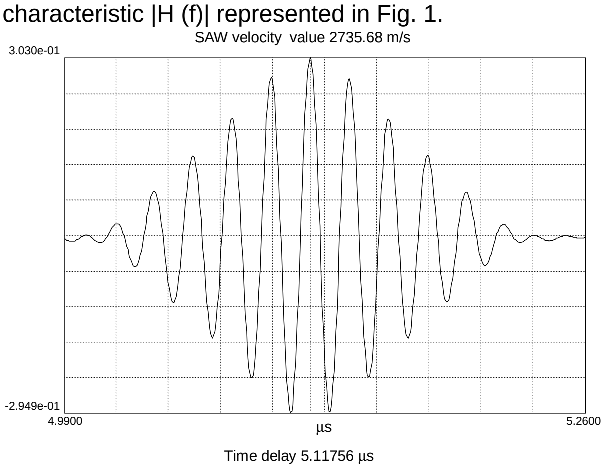


Fig. 2. Impulse characteristic of a delay line on Langasite yxlt/50^{o}25^{o}.

Determination of the signal time delay. The position of the maximum of the impulse characteristic h(t) (Fig. 2) is determined in a specified time interval.

SAW velocity calculation

The value of SAW velocity is determined by using the known geometrical dimensions of the acoustical system and the evaluated time delay.

Estimation of calculation error of SAW velocity. From a posteriori estimate of Filon quadrature formulae errors the calculation of h(t) errors are obtained. Then the error of the delay time determination is calculated, which is defined by h(t) calculation error. And, finally, the SAW velocity determination error is calculated.

6. PRACTICAL MEASUREMENT RESULTS

Using this procedure, SAW velocity measurements were made on langasite, lithium niobate and quartz substrates. The results of SAW velocity measurements are given in Fig. 3, for langasite crystal. The measurements were made in 25 points.

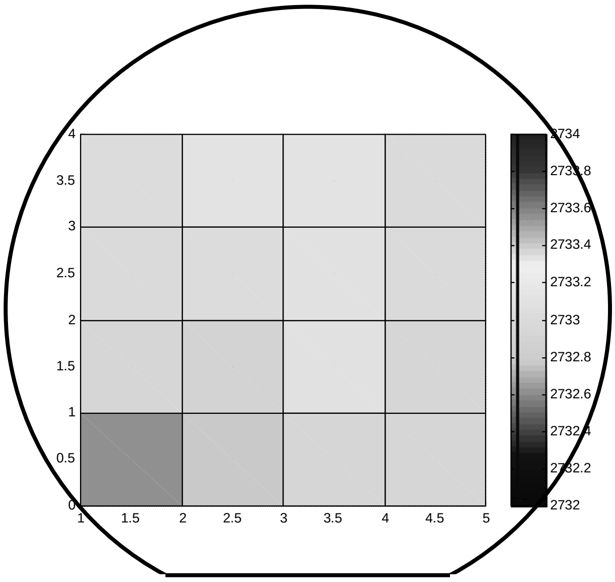


Fig. 3 Langasite (crystal 208-1-93)

1 – Average velocity value 2732,86 m/s

2 – Standard deviation 0.15 m/s (56 ppm).

Fig. 4 and 5 show the dependence of SAW velocity in langasite on temperature and orientation.

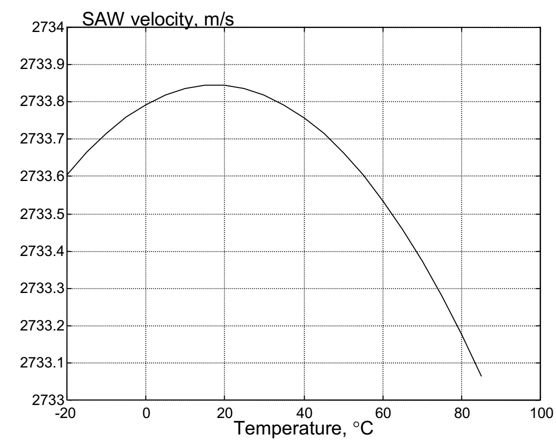
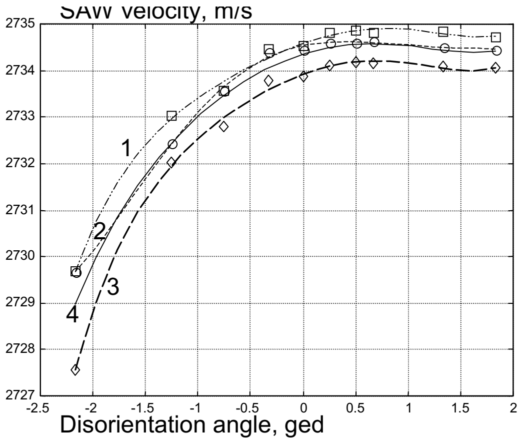


Fig. 4 SAW velocity vs temperature for langasite wafer



1. Wafer No. 1
2. Wafer No. 2
3. Wafer No. 3
4. SAW velocity average for 3 wafers

Fig. 5. SAW velocity vs reference plane orientation (26.6^o)

7. CONCLUSIONS

The results presented in this paper, have shown that the SAW velocity measurement method can be applied as the method of acoustic non-homogeneity inspection of piezoelectric substrates in SAW filter production. The velocity measurements obtained have a good coincidence with the data received by using other methods. The possibility of investigation of SAW velocity dependence on temperature and orientation can be used for study of various acoustic and electric characteristics of piezoelectric crystal substrates.

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