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STUDY OF SAW PROPAGATION ON QUARTZ BY MEANS OF ACOUSTOELECTRIC METHODS*

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ИЗУЧЕНИЕ РАСПРОСТРАНЕНИЯ АКУСТИЧЕСКИХ ПОВЕРХНОСТНЫХ ВОЛН В КВАРЦЕ С ПОМОЩЬЮ ЭЛЕКТРОАКУСТИЧЕСКИХ МЕТОДОВ

SAW propagation on XY, YZ and XZ planes of quartz were experimentally studied as a function of propagation direction. Measurements of the orientation dependences were carried out by means of methods based on acoustoelectric effects. The existence of high coupling, low beam spreading directions as well as pure mode axes were shown.

With the development of surface acoustic wave (SAW) devices it has become necessary to have a number of material parameters. Four of them are particularly important: The SAW velocity v, the power flow angle ψ, the electromechanical coupling constant $K \approx 2\Delta v/v$, and the far-field diffraction beam spreading angle Φ.

In our paper we have determined the parameter of $\Delta v/v$ by using a layered structure [1]. The structure consisted of a plate of silicon and a sample of quartz studied. After the application of the perturbation theory [2] to our problem an approximate expression was obtained for the value of $\Delta v/v$:

$$\frac{\Delta v}{v} = \frac{1}{2} V_{ae} v^2 \left(\frac{d}{L}\frac{1}{w}\right) \frac{1}{\mu_p} \frac{\left(\varepsilon \frac{\omega_c}{\omega}\right)^2 + (\varepsilon + \varepsilon_p^T)^2}{\varepsilon_0 + \varepsilon_p^T} . \tag{1}$$

Here V_{ae} is the acoustoelectric voltage between the ends of the silicon plate, L is the length of the plate along the SAW propagation and d is the thickness of the plate, μ is the carrier mobility in silicon, ω and ω_c are the circular and the dielectric relaxation frequencies, respectively, w is the average power flow per unit beam width, ε_0 and ε are the dielectric constants of free space and the silicon substrate, respectively, ε_p^T is the effective dielectric permitivity of quartz [2].

It is seen from (1) that $\Delta v/v$ is a linear function of V_{ae}. Therefore, the measurement of V_{ae} can be used to find $\Delta v/v$ for the same propagation direction. Note that in our method it is necessary to know the other parameters entered in (1). Moreover, to obtain the orientation dependence of $\Delta v/v$ the same dependences for v and w should be taken into account.

The power angle Ψ and the far-field beam spreading angle were studied from the ultrasonic field. The experiment consisted of probing the field with an acoustoelectric probe from a CdS crystal [3] and thus obtaining the scans of acoustic profiles at some specified distances from the transducer. The angle Ψ was found from the maxima of the profile. To avoid sidelobes the angle Φ was determined at the 0.1 level from the maxima of the profiles.

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The results of measurements of $\Delta v/v$ and Ψ were found to be in good agreement with the theory [4]. The results obtained for Φ were in agreement with the theoretical curve, calculated in our paper with the help of the parabolic diffraction theory [5].

It was shown that the influence of the anisotropy of quartz on the SAW propagation was very significant. As a result of anisotropy, the power flow angle could be as large as ±15°, and the beam spreading could be much less or more for an isotropic case. The existence of high coupling $\Delta v/v \sim 10^{-3}$, low beam spreading $\Phi < \Phi_{iso}$ directions as well as "pure" mode axes $\psi = 0°$ were experimentally shown. The optimal cut of quartz with a low temperature coefficient of a delay $\sim 1.5 \times 10^{-5}\ \mathrm{K}^{-1}$ was determined. The data for the optimal cut and for other important cuts of quartz are given in Table 1.

Table 1

Cut	Θ	Ψ	Φ/Φ_{iso}	K^2/K^2_{max}	$\partial\Psi/\partial\Theta$	$\frac{1}{\tau}\partial\tau/\partial T$ [K^{-1}]
X	+5° from *Y* axis	−6°	1.36	1	+0.36	-4×10^{-5}
Y	0° from *X* axis	0°	1.65	0.8	+0.65	-2.5×10^{-5}
ST		0°	1.38	0.5	+0.38	0
Y opt.	±27° from *X* axis	±6°	0.51	0.5	−0.49	-1.5×10^{-5}

Here $K^2_{max} = 0.28\,\%$, τ is a delay time, T is a temperature, Θ is an angle between the wave normal and the axis mentioned.

REFERENCES

[1] Gulyaev, Yu. V., Karabanov, A. V., Kmita, A. M., Medved, A. V., Tursunov, Sh. T.: Solid State (Soviet Phys.) *12* (1970), 2595.

[2] Ingrebrigdsen, K. A.: J. Appl. Phys., *40* (1969), 2681. Auld, B. A.: *Proceed. Ultr. Symp. 1970.* San Francisco.

[3] Morozov, A. I., Zemlyanitsin, M. A., Anisimkin, V. I.: *Proc. of the 10th International Conference on Acoustic — Ultrasound.* Prague, September 1972.

[4] Slobodnik, A. J., Jr., Conway, E. D., Delmonico, R. T.: *Microwave Acoustic Handbook*, Air Force Cambridge Research. Laboratories Rep. AFRL-TR-73-0597 (1973), IA.

[5] Crabb, J. C., Maines, J. D., Ogg, N. R.: Electr. Lett. *7* (1971), 253.

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