The temperature coefficient delay time of the Rayleigh waves

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Abstract. The effect of variation of temperature of adsorbing surface and humidity of gas medium on velocity of surface acoustic waves in layered system "adsorbed water - lithium niobate" has been investigated. The dependence of temperature coefficient delay time of the Rayleigh waves in system "adsorbed water - lithium niobate" on degree of moisture content of gas medium was considered.

Acoustoelectronic devices had practical application in modern radio signal processing systems. The main element of acoustoelectronic devices is the SAW delay line. The SAW delay line is a piezoelectric substrate on which surface acoustic waves of Rayleigh type (SAW) propagate. To generate and register of SAWs on a polished surface of a piezoelectric substrate – acoustic line, two (or more) interdigital transducers are formed. Acoustoelectronic devices often work under destabilizing effects ambient gas.

In a humid gas environment, a thin layer of water forms as a result of adsorption on the working surface of the acoustic line of an acoustoelectronic device. The liquid layer on the surface of the acoustic line result in changes in the conditions for the propagation of SAW and consequently, to a change in the signal parameters at the output of the acoustoelectronic device.

The thickness of the adsorption layer depends on the temperature and degree of humidity of the vapor-gas medium. Influence of temperature and humidity of gas medium leads to change of conditions of surface waves propagation. This results in a change in attenuation and surface wave velocity. In addition, the linear dimensions of the acoustic line change. This work is devoted to the study of the complex effect of temperature and humidity of the environment on the temperature coefficient delay time of Rayleigh waves.

The SAW velocity change and linear dimensions of the acoustic line leads to a change in the temperature coefficient delay time (TCD) \( \zeta = \frac{\tau}{\partial \tau / \partial T} \), which in the absence of an adsorption layer of water has the following form:

\[
\zeta = \frac{1}{\tau} \frac{\partial \tau}{\partial T} = \frac{1}{L} \frac{\partial L}{\partial T} - \frac{1}{V} \frac{\partial V}{\partial T} = \alpha - \frac{1}{V} \frac{\partial V}{\partial T}
\]

where \( \tau \) – delay time of surface acoustic waves, \( L \) – length of the acoustic line, \( V \) – velocity of surface acoustic waves. TCD includes the temperature coefficient surface wave velocity change \( \partial V / (V \partial T) \) and the coefficients of linear thermal expansion \( \alpha \) [2].

Change of delay time of acoustic signal in case of variation of substrate (acoustic line) temperature must be investigated for investigation of TCD dependence on vapor-gas medium degree of humidity.
As a result of adsorption, a thin layer of water is formed on the surface of the substrate, which affects the propagation of surface acoustic waves. This effect is manifested in a decrease in the SAW velocity, therefore, in a change in the delay time. The thickness of the adsorption layer increases with a decrease in temperature, and when the temperatures of distilled water and the substrate are equal, condensation begins on the surface of the substrate. At the same time as the temperature decreases, the SAW velocity in the substrate material increases and the linear dimensions of the acoustic line decrease. The complex of these interconnected, temperature dependent parameters results in the nature of the change in SAW velocity and delay time being significantly complicated.

A method based on interference of the balanced antiphase signals was used to detect the change in the SAW velocity: the direct signal supplied from the generator and the signal passed by the SAW delay line.

![Figure 1. Temperature dependence of interference minimum frequency variation.](image)

Temperature dependence of interference minimum frequency change in case of free surface of acoustic line is linear (Fig.1, curve 1). The presence of the adsorption layer complicates the nature of this relationship (curve 2), since when cooling the acoustic line, the change in delay time is influenced by two competing processes. First, the delay time is reduced as a result of the thermal increase in the SAW velocity and the reduction in the length of the acoustic line. Second, the delay time is increased due to a decrease in the SAW velocity caused by an increase in the thickness of the adsorption layer with a decrease in the temperature of the substrate (acoustic line).

In the first step of lowering the substrate temperature, the effect of the process of reducing the delay time (as a result of increasing the velocity) prevails (curve 2). When cooling a substrate thickness of an adsorptive layer increases, respectively, SAW velocity decreases and at some temperature frequency change of an interferential minimum reaches the maximum value. Obviously, in this case, the competing processes are balanced. Further, in the second step of cooling the substrate, the effect of the adsorption layer is increased by so much that the process of increasing the delay time (as a result of decreasing the velocity) is dominated.
Figure 2. Temperature dependence of TCD of Rayleigh waves
1 – in dry gas environment; 2 in a humid gas environment.

On the basis of experimental data of temperature dependence of frequency change of an interferential minimum from a condition of equality it is possible to carry out the assessment of change of TCD of the Rayleigh waves in a layered system an adsorbed water – lithium niobate. On the basis of experimental data of temperature dependence of frequency change of an interferential minimum from a condition of equality $\Delta f / f = \Delta \tau / \tau$ it is possible to carry out the assessment of change of TCD of the Rayleigh waves in a layered system an adsorbed water – lithium niobate. To do this, it is enough to take the temperature derivative of the function describing curve 2 (Fig. 1). From the experimental curve 2 (Fig. 1), it can be seen that with the rise in temperature of the TCD of the Rayleigh waves increases from negative to positive value and tends to the value of the TCD of the Rayleigh waves in the dry gas medium. Temperature of null value of TCD matches temperature of a maximum of a curve of frequency change of an interferential minimum.

Using the known relationship of relative vapor pressure to temperature (e.g., the Claveyron-Clausius equation), one can consider how the humidity of the gas medium affects the TCD of the Rayleigh waves in a layered system. The results of the analysis are shown in Figure 2. With increase of relative humidity TCD system decreases from positive to negative value. At relative humidity $\sim 88\%$ TCD takes zero value (Fig. 2, curve 2).

Thus, it is shown that the temperature coefficient delay time of the Rayleigh waves depends on both the degree of humidity and the temperature of the acoustic line. When humidity increases, TCD varies from positive to negative value. The largest change is observed at relative humidity values close to 100%. Destabilizing effect of ambient temperature and humidity must be taken into account when designing SAW-devices.

References
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