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The Digital Ultrasonic Interferometer For Quality Inspection of Piezoelectric Crystals

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Abstract: Researcher refers to hypersonic measurement technique. A digital hypersonic method for quality inspection of piezoelectric crystals. The method is grounded on automatic metering of a time interval between echo pulses and Supersonic Wave Attenuation (SWA) in an inspected article with information output in a digital form. The hardware and functional features of hypersonic system is presented. The method can be used in factory and scientific laboratories to obtain express-information on quality of ingoing materials for fabricated items.

Key words: Velocity, absorption, amplitude, frequency, Q-factor, duration

INTRODUCTION

Wide application of piezoelectric crystals in resonators, filters and other electromechanical devices where the item made from a piezocrystal is the main working material (Ostrovsky *et al.,* 2003) is well-known. For quality operation of such devices they should have a minimum number of defects, i.e. have high acoustic Q-factor. In this connection, there is a necessity to explore quality of crystals that is related with searching and development of various experimental methods and exploration methods (Ermolov *et al*., 1991; Zemlyakov, 2009). The study is devoted to development of spectroscopic methods on exploration of Q-factor of piezoelectric crystals. In the studies, the Raman light scattering method was used for investigation of Q-factor for quartz and lithium niobate crystals. The method of a diffraction of light on ultrasound (Johnson *et al*., 2003; Whatmore, 1980) and a X-ray method (Roshchupkin *et al*., 2014) were used for investigation of electromechanical parameters of new prospective piezoelectric crystals from langasite and langanite group. The observed methods in the core refer to optical methods of Q-factor exploration for piezoelectric crystals and as to acoustical methods of exploration, their number is restricted.

MATERIALS AND METHODS

The essence of the proposed method consists in that velocity and absorption coefficient of supersonic waves in the investigated medium are related to a time interval between echo pulses, attenuation and length of the investigated sample by the relationships: For supersonic wave propagation velocity:

$$C=\frac{1}{\tau} \quad (1)$$

Where:
l = Length of the investigated sample
τ = Time interval between echo pulses

For an absorption coefficient of supersonic waves:

$$\alpha=\frac{1}{2Kl}\left(\ln\frac{U_0}{U_k}-2Kl\frac{1}{R}\right) \quad (2)$$

Where:
k = Serial number of an echo puls
U_0 = Direct pulse amplitude
U_K = amplitude of k-th echo pulse
R = Reflection factor of a piezoelectric transducer Velocity ν and an absorption coefficient of supersonic waves
α = This is related to Q-factor of a crystal with the relationship

$$Q=\frac{\pi\nu}{\alpha v} \quad (3)$$

where, ν is frequency of a monitoring pulse. As the length of the sample l can be measured by means of the comparator with accuracy 10^{-5} m, the problem of velocity definition and an absorption coefficient of

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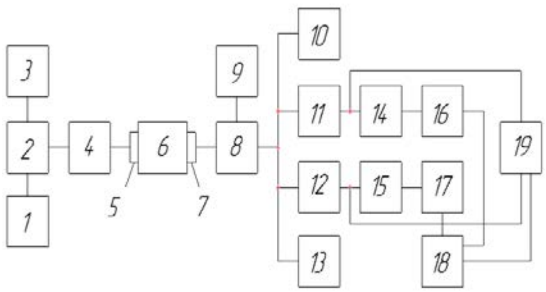

Fig. 1: Functional block diagram of supersonic waves generated by the installation

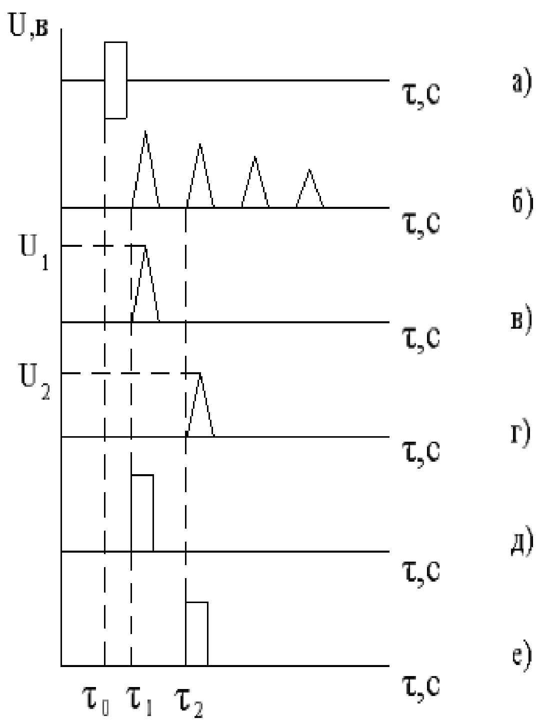

Fig. 2: Voltage current waveforms

supersonic waves is reduced to measurement of time intervals τ and attenuation U. Definition of these parameters imposes hard requirements to the experiment performance technique (Truwell *et al*., 1972; Kundrotas *et al*., 1973).

These requirements are met by the automated hypersonic system developed by us which having high sensitivity and accuracy allows at minimum operator intervention in experiment process to obtain the information in a digital form. Figure 1 represents the functional block diagram of the hypersonic installation and Fig. 2 shows the voltage current waveforms characterizing time and peak relationships for acoustic signals.

RESULTS AND DISCUSSION

A high-frequency signal (Fig. 1) being pulse modulated with use of the square waveform oscillator 1 (G5-15) from the high-frequency alternator 2 (G4-107) which frequency is controlled by a frequency meter 3 (Ch3-34), then amplified by the amplifier 4 (U3-33) and arrives the piezoelectric transducer 5 (Fig. 2a). The excited acoustical waves pass through the investigated sample 6, then are accepted by the receiving transducer 7, amplified и detected by the superheterodyne receiver 8, checked by the oscilloscope 9 and represent exponentially decayed pulses (Fig. 2b). These pulses bear all information on the object, namely, the time delay between echo pulses gives the information on velocity and amplitude bears information on absorption of supersonic waves. Other units of the block diagram are used to obtain this information in a digital form. Let us assume that we have separated the first two pulses for measurement of time and peak relationships between pulses of a train (Fig. 2b). The segmentation scheme separates these pulses between two channels and sends them to gate circuits 11 and 12 which are used for sampling and gating of the selected echo pulses and are assembled with application of field-effect transistors. Each gate is controlled by its own delay device 10 and 13 representing two series-connected flip-flop circuits and operating in the waiting mode. The first flip-flop circuit is actuated from a common clock pulse and detains actuation of the second flip-flop circuit for a time necessary for triggering of the gate. The second flip-flop circuit controls the gate directly setting to it an actuation time equal to width of an investigated part of the acoustic spectrum. Then these gated signals by their channels are applied to the time intervals measurement circuit 19 (Ch3-34) and to the amplitude measurement circuit consisting of peak detectors 14 and 15 and Analogue-to-Digital Converters (ADC) 16 and 17. The peak detector is used for contersion of pulsing voltage of a signal to the sconstant one. A shunt common-drain amplifier is used for ADC connection to it at its output.

To measure a signal transmission time, a leading edge of the first normalized strobe pulse (Fig. 2e) triggers the time interval block of a frequency meter 19 and a leading edge of the second strobe pulse (Fig. 2f) in the second channel also gives a stop “command” to the time interval block of the frequency meter 19. The time interval block defines the moment of entering for each pulse, converts them to a pulse with duration τ applies it to data selection system 18 (F5039) where they are registered.

For measurement of supersonic wave attenuation the first strobe pulse (Fig. 2c) enters the peak detector

14 bypassing the amplifier-limiter, then it is converted to constant voltage, stabilized by ADC 16 and then is applied to data selection system 18. The second chosen reflected strobe pulse (Fig. 2d) through the second channel enters the peak detector 15, then it is converted, stabilized by amplitude in ADC 17 and also enters the data selection system 18. Thus, data on duration τ and amplitudes U of the acoustic signals enter the selection system 18. Output of selection system 18 represents the exact sequence of digits in a binary decimal code: the first digit is a duration τ the second one is amplitude U_0 , the third digit is amplitude U_1, the fourth one is amplitude U_2 etc., for echo pulses. Output of this information to digital printer is provided. A velocity, an absorption coefficient of supersonic waves and Q-factor in the investigated medium are computed by the measured values τ and U at the given temperature and frequency under Eq. 1-3. Tests of all hypersonic system have shown its reliability and convenience in carrying out experiments.

The measurement error for a velocity makes an order of 0.03÷0.05% and for an absorption coefficient of supersonic waves makes 5÷7% disregarding losses on conversions. Range of operating frequencies is 5-50 MHz and higher.

Findings: The offered hypersonic exploration method is the effective tool to solve technological problems of quality inspection for piezoelectric crystals and may be used in factory and scientific laboratories for reception of express information on quality of products.

CONCLUSION

The created digital hypersonic system with its high sensitivity and accuracy allows at minimum operator intervention into the process of an experiment to measure a time interval between echo pulses and attenuation of supersonic waves in the investigated medium with information output in a digital form. Based on gained results about a time of propagation and attenuation of supersonic waves, a velocity, an absorption coefficient of supersonic waves and Q-factor of investigated crystals may be calculated.

The system allows not only quality of piezoelectric crystals to judge, but also in wide area of frequencies and temperatures to carry out explorations of acoustical properties of condensed media.

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