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EXPERIMENTAL INVESTIGATION OF ELECTROACOUSTIC EFFECT FOR STRONTIUM TITANATE NEAR STRUCTURAL PHASE TRANSITION

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The results of experimental investigation of peculiarities of elecrtoacoustic effect for strontium titanate single crystal near structural phase transition at $T_c = 103K$ are presented. The measurements of 30 MHz-longitudinal wave velocity as a function of external electric field are carried out at different temperatures. A gradual deviation from square-law electric field dependence of ultrasound velocity, which take place in electrostrictive crystals, and its transformation to linear dependence (typical for piezoelectrics) are observed near $T_c = 103K$ .The analysis of observed phenomena are carried out.

The strontium titanate $SrTiO_3$ is one of classical system, exibiting a second-order, displacive, structural phase transition. This transition is decribed by the theory of phonon-mode softening. $SrTiO_3$ is crystal with perovskite centre symmetrical structure of m3m class at room temperature and is investigated already for a long time [1-3]. The transformation in $SrTiO_3$ lattice from cubic to tetragonal occurs at $T_c \approx 103K$. Near and below T_c, the order parameter is the rotational angle of the TiO_6 octahedra about the tetragonal c axis [4]. The tetragonal distortion, which has been determined by neutron diffraction, is very small ($c/a \approx 1.0009$ at 10 K, where) [5].

By analysis of birefringence and x-ray data it was proposed that $SrTiO_3$ is actually never perfectly cubic above T_c but retains c/a ratio 1.00008 even at room temperature [6]. The following investigation of the electromechanical properties for $SrTiO_3$ confirms this observation. In addition to expected electrostrictive response a small piezoelectric effect was obsurved at temperatures above T_c, indicating that the $SrTiO_3$ lattice is not cubic of m3m class above temperature of the phase transition [7]. In addition recently anisotropy of linear coefficient of thermal expansion has been revealed in $SrTiO_3$ above T_c, at 105-120 K [8]. These facts are evidence that peculiarities of structural phase transition in $SrTiO_3$ have been investigated unsufficiently and the additional experimental researches are required.

We have investigated experimentally electroacoustic effect (EAE) in strontium titanate single crystal in temperature range 102.3-110 K. Electroacoustic effect consists in interaction of constant electric field with acoustic wave (AW) in solids, as a results change of AW velocity occurs. In general case relative change of AW velocity in solids by application of electric field is determined by expression:

$$\Delta v / v = (1/2\rho v^2)[e^* E + f^* E^2], \qquad (1)$$

where ρ-density of crystal, v-AW velocity, Δv-change of AW velocity by application of electric field E, e^*- effective piezoelectric coefficient, determined by components of 3-th and 5-th order tensor, f^*- effective coefficient of electrostriction, determined by combination of 4-th and 6-th order tensor components [9].

EAE in piezoelectric crystals, in which centre of symmetry is absent, is determined basically by e^* coefficient and AW velocity change linearly depends from electric field. There is square-law dependence of relative change of AW velocity on electric field in centre symmetrical crystals. This dependence is determined by second term in the right part of expression (1). Contributions of piezoelectric and electrostriction mechanisms can be comparable in piezoelectric materials having high values of dielectric constant (for example, in piezoelectric ceramics).

The sample in form rectangular parallelepiped was cut from strontium titanate single crystal, which has been grown by Verneuil method. Faces of sample have been oriented along [100], [011], $[0\bar{1}1]$ directions with accuracy less one degree. Constant electric field in [011] direction was put with

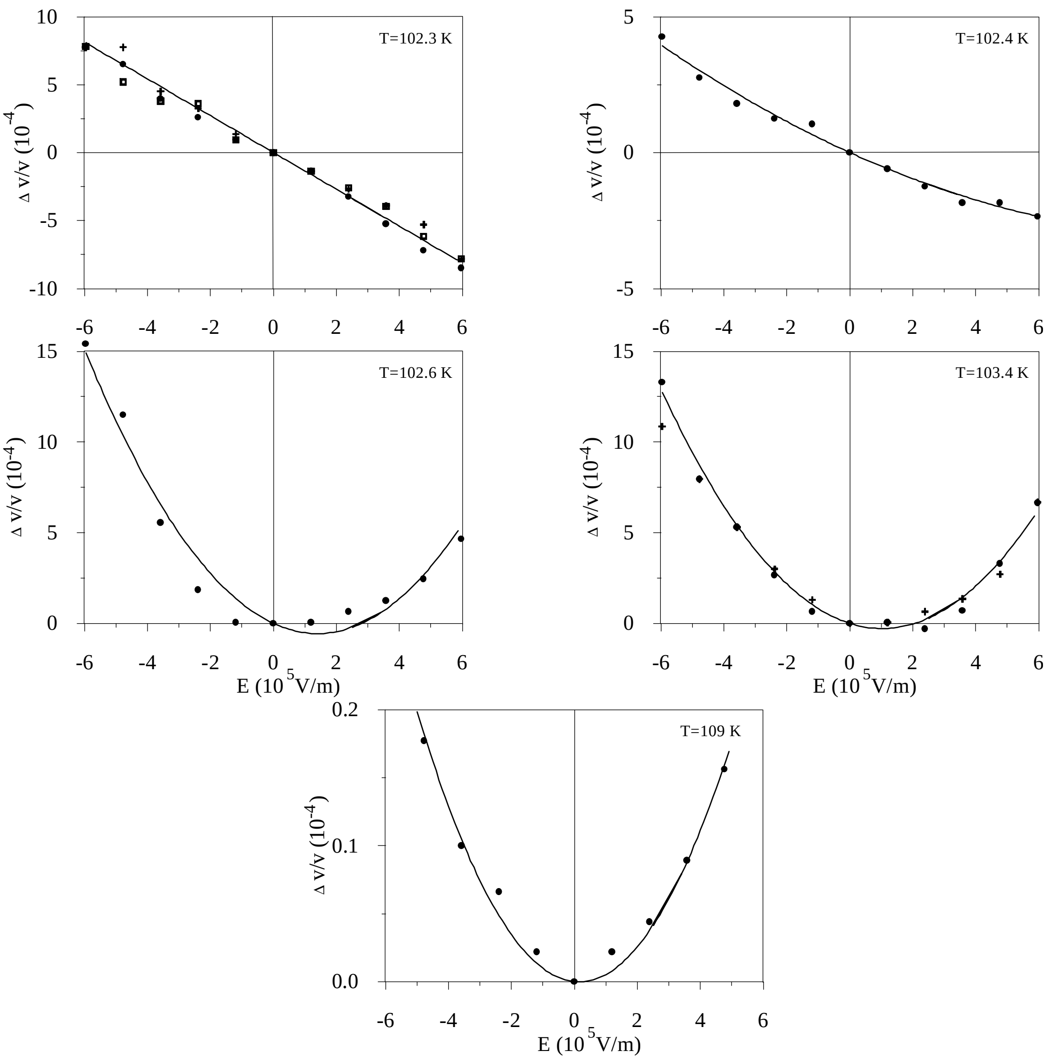

Fig.1. Dependence of relative change velocity of AW on electric field at different temperatures. Lines show approximation of experimental data by expression (1).

the metal (Cu, Ag, Cr) contacts. Magnitude of EAE effect is not depend of kind of metal. Longitudinal 30 MHz-waves is propagated along [100] direction. Measuring of AW velocity have been carried out in pulse regime be method of fixed delay: reversal dependence of relative change velocity on electric field have been registrated. By slow cooling from 300 to 110 K square-low dependence of AW velocity on electric field was observed. Starting with 109 K linear on electric field contribution to change AW velocity was observed parallel with square one. Value of this contribution was increased with temperature decreased. Contribution of electrostriction term, which is square on electric field, was decreased significantly.

By further decreasing of temperature attenuation of AW was increased sharply, and measurement was stopped. Velocity of temperature change was 1 degree/hour in temperature interval 102.3-110 K. It is should be noted that no hysteresis phenomena were observed on measurement of dependence of AW velocity on electric field.

Approximation of experimental dependence of relative change AW velocity by square parabola (1) have been carried out. Approximation curves was shown on fig.1. As a result of approximation numerical values and temperature dependence of effective piezoelectric coefficient e^* and effective coefficient of electrostriction f^* are determined (fig. 2). Their sharp increasing on absolute value in interval 109-12.3K is observed (fig. 2). However at 102.4-102.3 K essential linearization of dependence of relative change velocity on electic field that resulted to further increasing of effective coefficient e^* and essential decreasing of relative contribution in change of

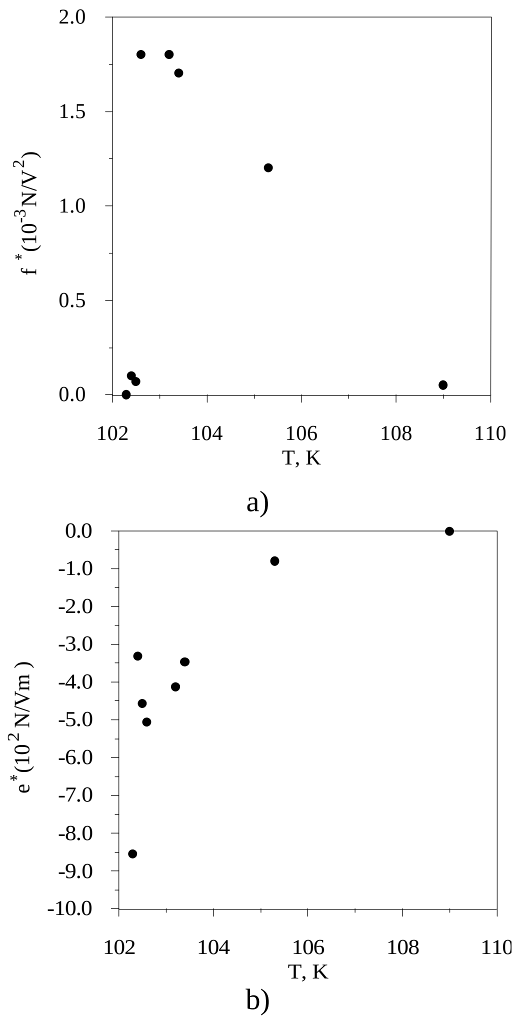

Fig.2. Temperature dependence of effective electrostrictive coefficient f^* (a) and effective piezoelectric coefficient e^* (b).

AW velocity of effective electrostriction coefficient f^*. It is pointed out indirectly that piezoelectric effect is present in studied strontium titanate crystal in temperature 102.4-102.3 K and crystal lattice has not centre of symmetry. The values of measured effective coefficient e^* for strontium titanate essentially exceed values of analogous coefficient for such piezoelectric crystal as quartz and lithium niobate.

Observed in present work arising of piezoelectric contribution to electroacoustic coefficient near phase transition may be explained by distorsion of lattice symmetry.

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