Surface Phonons in Ferroic Materials

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INTRODUCTION

Ferroelastics are the mechanical analogues of ferroelectrics, with spontaneous strain replacing spontaneous polarization and uniaxial stress replacing the electric field. They exhibit mechanical domain structure, stress-strain hysteresis and the so-called soft acoustic mode due to the strong temperature dependence of the phonon velocity coupled to the spontaneous deformation. The bulk elastic properties of ferroelastics have been extensively studied for the last 25 years both by ultrasonic and classical Brillouin spectroscopy [1-9]. Literature does not provide information concerning the surface phonons in these materials, mostly because the surface Brillouin spectroscopy was used to study the surface acoustic waves (SAW) in the opaque materials like semiconductors and metals in which the light penetration depth is relatively small, which makes the experiment much easier to perform [10-12].

We present here the results of Brillouin scattering on the surface phonons propagating in three different ferroelastic crystals: gadolinium molybdate (GMO), lithium-caesium sulphate (LCS) and acid rubidium-lithium sulphate (RLHS) in the temperature ranges covering their phase transitions: GMO-432 K, LCS-202 K, RLHS-132 K. GMO undergoes a phase transition of the first order. The other two LCS and RLHS undergo second order phase transitions.

The aim these studies was to answer the question on the way the phase transitions accompanied by strong anomalies of the elastic properties of the crystal were manifested on the surface.

EXPERIMENT

A general scheme of the spectrometer has been described in details in our paper [13]. A stabilized single-mode diode-pumped, solid state laser (Coherent 532) operating at λ = 532 nm (200 mW) was used as a source of incident light, see Fig.1. The scattered light was analyzed with a piezoelectrically scanned (2 x 3) pass tandem Fabry–Perot interferometer (Sandercock system [14]).

RESULTS AND DISCUSSION

Investigation of each surface was begun with identification of the currently observed phonons. Apart from surface phonons we observed bulk ones, both longitudinal and transversal, see Fig.2. In order to unambiguously identify the surface phonon the Brillouin spectra were recorded for different angles of the light beam incidence.

On the basis of the Brillouin scattering spectra recorded for different crystallographic planes of our crystals covered with aluminum film, we could determine the velocities of the surface phonons in these planes.

The temperature dependencies of particular surface waves measured in experiment are shown in Figures 3-5. The dependencies reveal anomalies at the phase transition temperature. In the phase transition region, a few percent velocity anomalies of all the surface phonons were noted. These changes are essentially different from the anomalies of the velocity of longitudinal and transversal bulk phonons in these crystals.

In the case of Brillouin scattering experiment we penetrate the surface layer of a thickness smaller then the wavelength of light λ used, in our case the typical penetration depth was about 300 nm. It is obvious that the crystal surface cannot be treated as the last layer of the semi-infinite crystal. In the real crystal several factors have to be taken to account which influence the near surface layer structure and properties. These are: chemical and mechanical reconstruction or the process known as rumpling when some of the atoms are shifted above the ideal plane of the surface.

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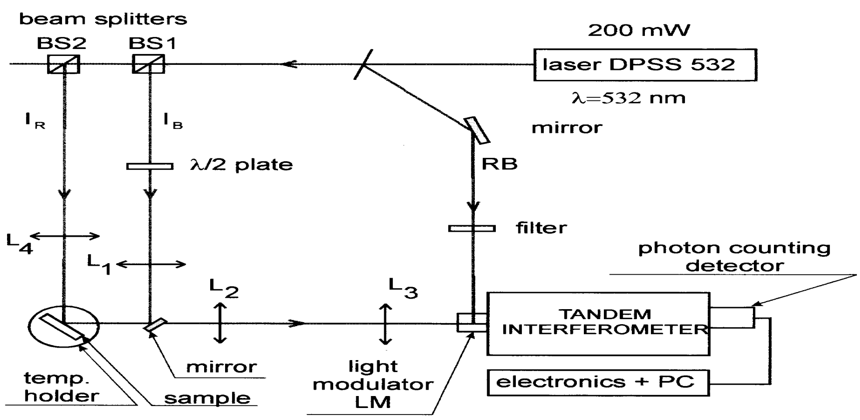

Fig.1. Experimental setup

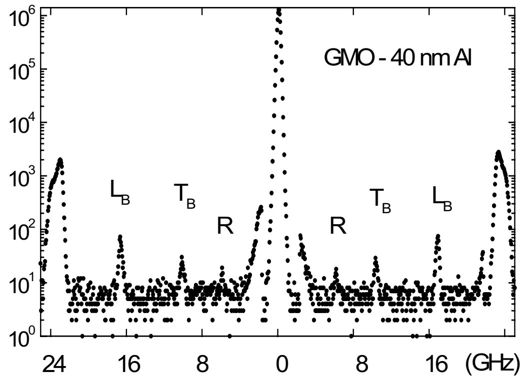

Fig.2. Brillouin spectra of GMO crystal covered with 40 nm Al film

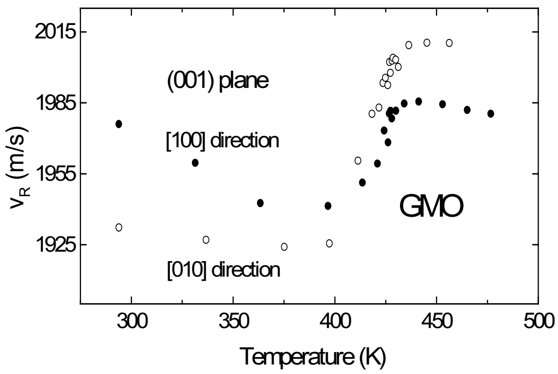

Fig.3. Temperature dependencies of surface phonon velocities of GMO crystal

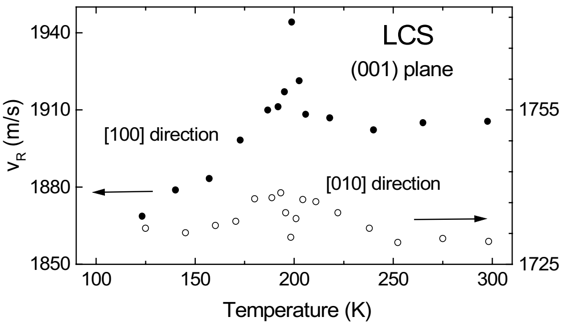

Fig.4. Temperature dependencies of surface phonon velocities of LCS crystal

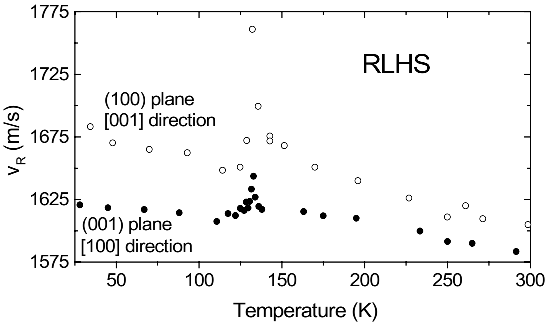

Fig.5. Temperature dependencies of surface phonon velocities of RLHS crystal

Acknowledgements
This work has been partially supported by the grant No. 2P03B 048 17 from the State Committee for Scientific Research.

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