LOW-TEMPERATURE SCANNING ACOUSTIC MICROSCOPY IN RANGE OF 85-225K


1Center of Acoustic Microscopy, Institute of Chemical Physics, Russian Academy of Sciences, Moscow, 117977, Kosygin Str. 4, Russia
2Freie Universitat Berlin, Farbereich Physic, Arnimallee 14, D-1000 Berlin 33, Germany

INTRODUCTION

Although acoustic microscopy is well-known to be an effective non-destructive control of local elastic and structural properties in the bulk of both opaque and transparent materials, the applicability of commercial scanning acoustic microscopes (SAM) is limited to temperatures near ambient, because SAM calls for the use of an immersion liquid. On the other hand, since the discovery of high-Tc superconductivity, there is a rapidly growing interest in non-destructive low-temperature examination of ceramics, crystals and devices made out of these materials. It is interesting to investigate other materials also in low-temperature region.

INVESTIGATIONS

We extended the applicability of SAM to temperatures as low as 85K using liquid propane as adequate immersion liquid. An adequate low-temperature chamber - Fig.1 (Chernoizatonskii, Abilov et al.) as well as a special lens-adapter had to be developed in order to overcome the difficulties arising from the large temperature gradient between the lens and its scanning unit. The images of the grating (Fig.2) were obtained at different and it could be demonstrated that the setup (ELSAM plus the cryostat) operates properly in the range of 85-225K. Furthermore a SrTiO$_3$ single crystal (used a well-known substrate for high-Tc films) was investigated in this range. No unusual structure was observed in sample at temperatures higher than 108K. However a subsurface structure appeared at about 108K and became more pronounced at lower temperatures. The subsurface structure looks like scratches which sometimes are parallel to each other. This structure is associated with the formation of domains due to a structural transition near 106K. After heating structure disappeared. We also observed the acoustic image in Bi-HTSC single crystals in the temperature range of 85-225K. The observed structure, which is indicative for a domain wall, cannot be observed if focusing on the surface with a delay time usually applied in SAM for obtaining both surface and subsurface images. We determined surface acoustic wave
(SAW) velocity on the (a,b) plane of Bi$_2$Ca$_2$Sr$_2$Cu$_3$O$_x$ crystal at 100K from V(Z) curve - Fig.3.

In such crystals we also studied phonon focusing effect, which was predicted and calculated for acoustic image case by Chernozatonskii et al. (1988,1991) and at first was observed by Every et al.(1990) in transmission variant of laser induced acoustic pulse and by Levin et al (1991) in reflect variant of SAM. Due to this effect, subsurface structures may be observed not only focusing on the respective subsurface region but also focusing on the surface of the sample and changing the delay time of the receiver window in appropriate manner. In real space this means that an acoustic beam focused in "point" on the surface of a layered specimen, for example on (001) plane of Bi$_2$Sr$_2$Ca$_2$Cu$_3$O$_x$ crystal - Fig.4 were we see fast transversal mode computer image of point source, will propagate in the interior of the sample in a predominantly unfocused manner as shown in Fig.5. In this Figure we see the artificial cross on the opposite surface of the Bi-oxide crystal (300 m thick) after choosing gate position corresponds to "there-here" propagation of transversal acoustic waves (Z=0, T=100K). As indicated by the arrow in our imagings, a subsurface crack becomes visible not only by subsurface focusing. We mention that the observed microcracks at T=100-120K was not visible at room temperature. It originates from internal stress developing upon cooling the sample.

Although we have confined ourselves to a few examples only, we may state that a low-temperature acoustic microscope provides valuable information about crystal perfection in particular HTSC compounds which otherwise are hard to get.