Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office using the **Electronic Report Submission Application:**

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Reports supporting requests for additional beam time

Reports can now be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF

Experiment title:

Visualization of wave fronts of surface acoustic waves propagating in semiconductor layers within hybrid SAW devices

Experiment number: MI-344

Beamline: ID19

Date of experiment: from: 02-Dec-99 to: 06-Dec-99

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Shifts: 12

Local contact(s): Dr. Juergen HAERTWIG

Received at ESRF:

Names and affiliations of applicants (* indicates experimentalists):

Prof. Dr. Johann PEISL
Dr. Till Hartmut METZGER
Dr. Wolfgang SAUER
Sektion Physik, LMU Munchen,Geschwister Scholl Pl. 1, 80539 Munchen, Germany

Prof. Emil ZOLOTOYABKO,
Doron SHILO,
Department of Materials Engineering, Technion-Israel Institute of Technology, Haifa 32000, Israel

Report:

It was demonstrated very recently [1], that the stroboscopic x-ray topography on synchrotron beam lines can be successfully used to visualize short individual wave fronts of high frequency surface acoustic waves (SAW) propagating in piezoelectric crystals. Experiments with 290 MHz $LiNbO_3$ [1-3] and 580 MHz GaAs-based [4] SAW devices showed that the visible wave front distortions bring important information on SAW propagation and its interaction with lattice defects. The latter topic is of great importance to modern microelectronics and optoelectronics. Bearing this in mind, we tried, in current experiment, to visualize the acoustic wave fronts, propagating in weakly piezoelectric and non-piezoelectric semiconductor materials which were mechanically attached or bonded to the piezoelectric $LiNbO_3$ SAW devices.

X-ray topography measurements were performed in a stroboscopic mode i.e. by synchronizing the acoustic wave periodicity with periodic x-ray illumination of investigated crystals. The storage ring was operated in a 16-bunch mode with a bunch repetition frequency of ν_r = 5.68 MHz. This frequency was used in order to drive SAW devices in a phase-locked mode via computerized frequency synthesizers, which provided multiple output frequencies $\nu = N \nu_r$ and rigid phase relation between input and output signals. The resonant frequencies of SAW devices were in a range of 0.29 - 0.58 GHz, which corresponds to SAW wavelengths in $LiNbO_3$, ranging between 6 - 12 μm. Diffraction images under SAW excitation were detected by using the reflecting Berg-Barret geometry with a monochromatized radiation (12, 24 or 40 keV) and high-resolution Kodak films exposed for 400-1000 sec. It was found that the measurement geometry with the SAW propagation direction aligned perpendicular to the scattering plane of x-rays provides the best imaging conditions, at least for acoustic waves propagating within the $LiNbO_3$ crystals.

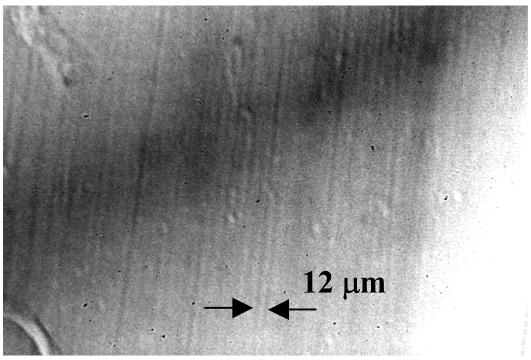
Two sets of samples, 500 μm $Si/LiNbO_3$ and 0.5 μm $GaAs/LiNbO_3$, were used in these measurements. In all cases the SAWs were generated by means of interdigital transducers fabricated on the polished surface of $LiNbO_3$ wafers by lift-off photolithography. Acoustic waves were transmitted from the $LiNbO_3$ devices to the semiconductor crystals due to mechanical coupling between materials.

Two types of $Si/LiNbO_3$ attachments were prepared in Technion (Haifa) for this experiment: "side-to-side" attachment and "face-to-face" attachment (see Ref. [5]). The first assembly ("side-to-side") consisted of the 500 μm thick Si specimen clampped between two $LiNbO_3$ plates which also were 500 μm thick. Special greese was used to provide an acoustic contact between these pieces. The second assembly ("face-to-face") consisted of the Si piece mounted on two $LiNbO_3$ plates in such a way that the Si polished surface contacted the polished surfaces of $LiNbO_3$ outside the interdigital electrode strips. For the second assembly, the different contact materials (greese, several epoxy resine as well as a Wood alloy) were examined. In case of viscosous contact materials, the Si pieces have been supported by small springs which forces could be regulated in some limits. The hybride $GaAs/LiNbO_3$ structures were prepared in LMU (Munich) by means of technology described in Ref. [6]. In these samples the bonded 0.5 μm thick GaAs layer has been situated between interdigital electrode strips on top of the 500 μm $LiNbO_3$ substrate.

In case of $GaAs/LiNbO_3$ samples, the x-ray diffraction images were taken from the (004)GaAs atomic planes. Despite the numerous attempts, these images did not exhibit individual SAW wave fronts. On the contrary, very clear wave fronts were found in topographs taken from the (060) atomic planes of $LiNbO_3$ substrates, composing the assembly. These findings allowed us to conclude that the measurements failed due to not enough thickness of the GaAs layer. In fact, as is shown in Ref. [7], the strong SAW effect on x-ray diffraction is achieved when dynamical diffraction is transformed to kinematic one (due to acoustic deformation of the crystal lattice). Since the thickness of GaAs layer was much less than the extinction length, we were far away from this transition. The thickness of the GaAs layer was also much lower than the SAW wavelength and, correspondingly, than the SAW penetration depth, which also diminished an effectivity of SAW-x-ray interaction.

In case of $Si/LiNbO_3$ samples the diffraction topographs were taken from the (004)Si and (008)Si atomic planes. For the "face-to-face" assembly it was done through a special window in the sample holder. As a rule, the x-ray diffraction images of Si samples were very smooth with no static defects and with no signs of dynamic deformations induced by SAW. However, in part of the images, we found non-homogeneous contrasts in the contact area, caused by some deformation fileds there. Non-homogeinety increases for harder contact materials. The best results have been received if low-temperature Wood alloy was used as contact material. In this case we observed a weak quasi-periodic contrast (see Figure) giving us an image of 12 μm SAW propagating in non-piezoelectric Si crystal. These studies should be continued to optimize the SAW transmission from the $LiNbO_3$ transducer to the non-piezoelectric areas in order to enhance the visible contrast of individual wave fronts.

Figure. Stroboscopic x-ray topograph taken from the (008)Si reflection under 290 MHz SAW excitation. Spatial contrast variations (nearly vertical dark lines) are due to dynamic deformation introduced into Si crystal by 12 μm SAW.



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