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SCANNING ACOUSTIC FORCE MICROSCOPY ON INTERDIGITAL TRANSDUCERS[1]

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The distributions of surface oscillation and surface charges were probed within an interdigital transducer (IDT). The IDT was driven at a frequency of 39.5 MHz. The measurements with sub-μm spatial resolution were performed with a scanning acoustic force microscope. It utilizes the nonlinear interaction of the sample with the tip of a scanning force microscope. In the case of surface oscillation detection, this nonlinearity leads to a shift of the mean position of the cantilever due to varying oscillation amplitudes. The surface charges are mapped through the additional cantilever deflection caused by the attraction of the plates of the capacitor formed by the cantilever and the sample. Spatial distributions of the amplitude of surface oscillations and of surface charges at the end of a 39.5 MHz splitfinger IDT are presented. The obtained experimental results may lead to a deeper understanding in modelling of IDTs in the future.

1. Principle

A common way of exciting surface acoustic waves (SAWs) is the interdigital transducer (IDT). The separation of the metallic finger electrodes is determining the wavelength. Due to the coming up of high frequency devices operating at frequencies above the 1 GHz threshold, structural scales in the sub-μm range are demanded for fundamental wave operation. The conventional wave probing techniques, on the other hand, are limited in their lateral resolutions to some μm. Scanning probe microscopies are a key technique when aiming to undergo these limits. Sub-μm resolution in surface oscillation and surface charge distributions within IDTs are in reach. Therefore, modelling of surface acoustic wave devices can be verified through the local measurement of mechanical and electrical parameters.

The first probing of SAWs by a scanning force microscope was performed in 1991 [1]. The detection principle relies on the nonlinear dependence of the interacting force

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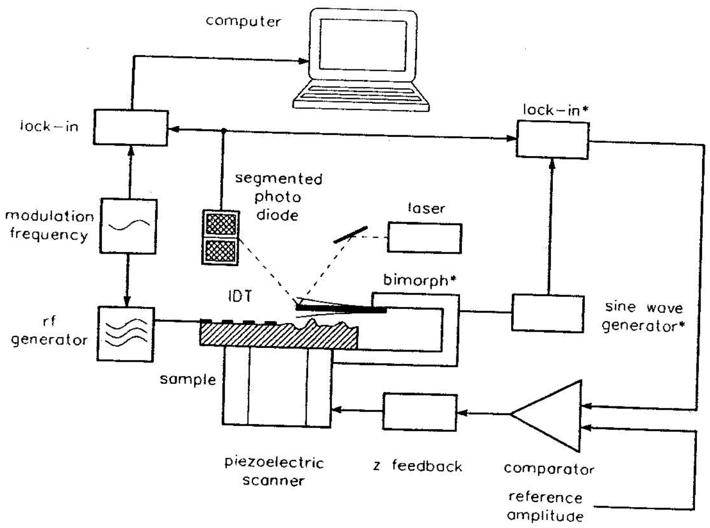

Figure 1. Experimental setup of the SAFM

on the tip-to-sample spacing. Therefore, a varying oscillation amplitude leads to a shift of the mean position of the microscope's cantilever [2]. The cantilever itself cannot follow the fast surface oscillations at typical SAW frequencies [3]. If one modulates the amplitude of the SAW by a kHz-frequency the height difference between oscillating and undisturbed surface can be measured by lock-in technique. This principle is utilized in the scanning acoustic force microscope (SAFM) [4]. Hereby two different operational modes can be applied. In contact mode, the tip, being located at the very end of the cantilever is in contact with the surface. The deflection of a laser beam, focussed on the back side of the cantilever is registered by a position sensitive detector. A feedback loop keeps the force between probe and sample constant by readjusting the sample height. In contact mode surface deformations become visible. In non-contact mode, the tip is positioned 5-10 nm above the surface. The cantilever is vibrated near its resonance frequency. A changing interacting force now leads to a detuning of the mechanical resonator. Here, the force gradient, i.e., the oscillation amplitude, is kept constant by adjusting the spacing, too. Besides the surface deformations, surface charges become visible because the conducting tip formes together with the conducting parts of the sample a local capacitor. When being charged, Coulomb forces become active [5].

2. Experimental Setup

The experimental setup is sketched in figure 1. The SAFM, which is based on a commercial scanning force microscope (autoprobe cp), was operated in the contact and non-contact mode. The parts denoted by (*) are used in non-contact mode only. The cantilever and the sample geometry are presented in figure 2. The measurements were

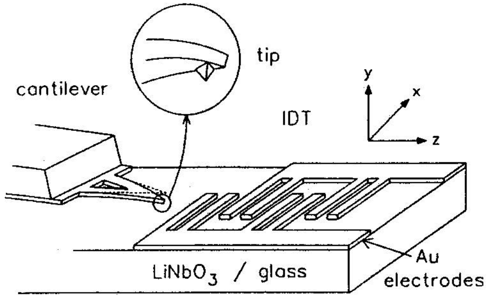

Fig. 2. YZ-$LiNbO_3$ sample geometry and microscope tip

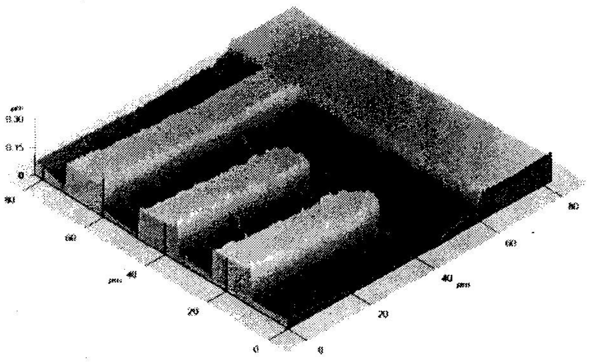

Fig. 3. Topography measured in contact mode

performed at a scan frequency of 0.2 Hz/line on an area of 86x86 μm^2 with a resolution of 256x256 points.

The SAWs were excited with an 39.5 MHz splitfinger IDT on YZ-$LiNbO_3$ (finger width ≈ 11 μm). The applied voltage was 1.41 V rms. The amplitude was modulated with a signal at 50 kHz, i.e., within the bandwidth of the microscope electronics. In dynamic non-contact mode the cantilever oscillates at its resonance frequency of about 360 kHz. The tip follows the low frequency surface modulation, which is time averaged over the fast SAW oscillations.

3. Measurements and Discussion

The contact mode measurements displayed in figures 3 and 4 show the topography and the simultaneously measured amplitude distribution of the surface oscillation close to the collector electrode. Three amplitude maxima are clearly distinguishable in figure 4. They are located parallel to the metallic fingers and are continuing on the

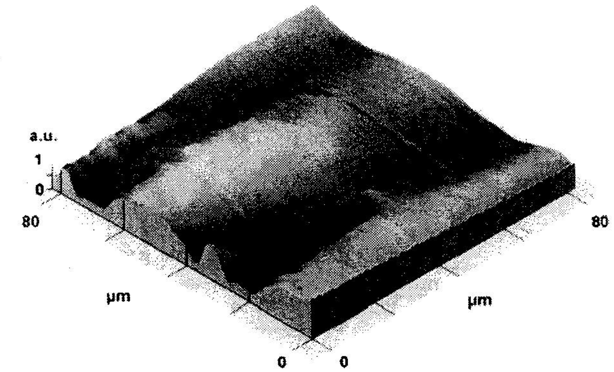

Fig. 4. Surface oscillation distribution measured in contact mode

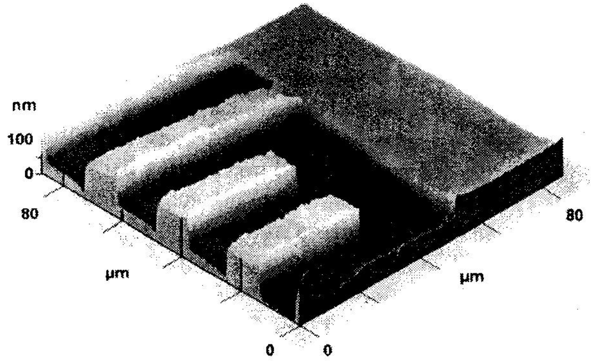

Fig. 5. Topography measured in non-contact mode

collector electrode with a decreasing amplitude. The distortion in the distribution in the upper half of the figure comes from feedback loop oscillations and indicates the edge of the collector electrode (see figure 3). The two minima are both located on IDT fingers with a distance of 44 μm from each other, which corresponds to one half of a SAW wavelength. The measurements in non-contact mode were performed at a similar location on the IDT as in figure 3. Figure 5 shows the topography and figure 6 the amplitude distribution of the surface oscillation with the superimposed distribution of surface charges. Remarkably high charge distribution values are reached at the end of the hot electrodes with a decrease in power towards the collector electrode. This behavior is in good qualitative agreement with model calculations [6]. A maximum in the distribution of surface oscillations can be seen between the end of the middle fingers and the collector electrode. A separation of both contributions can be obtained by subtracting distributions obtained on piezoelectric and dielectric substrates, because on the latter no wave excitation by IDTs occurs [7].

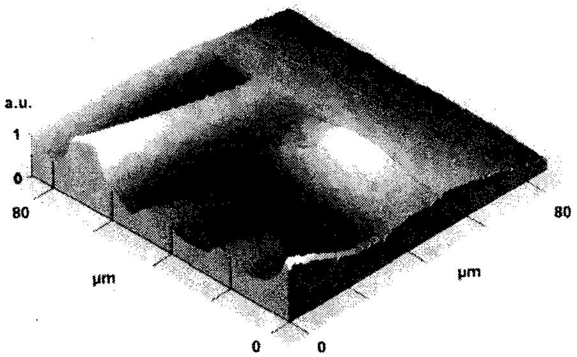

Fig. 6 Surface oscillation and charge distribution measured in non-contact mode

4. Outlook

The measurement of surface oscillation and surface charge distribution within an IDT with high spatial resolution offers a new possibility to check models of surface acoustic wave devices using a more physical approach for the model input parameters.

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