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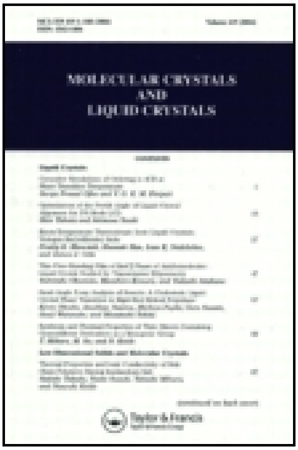

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Development of Scanning Displacement Current Microscope

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Development of Scanning Displacement Current Microscope

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We have developed a scanning displacement current microscope (SDM) which measures the electrical surface properties of samples by displacement current. SDM vibrates its probe perpendicularly to the sample with applying d.c. voltage to the probe. Both displacement current and tunneling current flow periodically in accordance with the vibration of the probe and are separated by using a two-phase lock-in amplifier. In this paper, we observe both displacement current image and the topographic image of a sample with grating profile simultaneously under constant tunneling current operation. We also analyze the resolution of the displacement current image.

Keywords: displacement current; tunneling current; two-phase lock-in amplifier; STM; SCM;

Introduction

Scanning probe microscope (SPM) is widely used for investigation of local surface physics[1-5]. In a variety of SPM family, the scanning capacitance microscope (SCM) is based on the atomic force microscope with an ultrahigh frequency resonant capacitance sensor, and can observe capacitance image between the probe and sample[5]. In SCM, an oscillation voltage is applied to its probe and the change in the capacitance is detected qualitatively as a change of resonant frequency.

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Recently, we have developed a tunneling current and displacement current simultaneous measuring system, where the probe is vibrated perpendicularly to the sample with applying d.c. voltage to the probe. In accordance with the vibration, the displacement current flows periodically due to the change in capacitance between the probe and sample. The periodic tunneling current also flows when the minimum distance between the probe and sample is small enough. Those two currents flow alternately and can be separated quantitatively by using a two-phase lock-in amplifier[6].

In this paper, we present a scanning displacement current microscope (SDM). In SDM, the probe is vibrated perpendicularly and scanned horizontally to the sample with applying d.c. voltage to the probe, and the displacement current image and the topographic image are simultaneously observed by using a two-phase lock-in amplifier under constant tunneling current operation. We show the displacement current image and the topographic image of a sample with grating profile.

Experimental

Figure 1 shows the schematic diagram of SDM. SDM is based on ultra high vacuum scanning tunneling microscope (UNISOKU USM-501). The electrical circuit equipped in the STM system was modified to achieve the vibrational

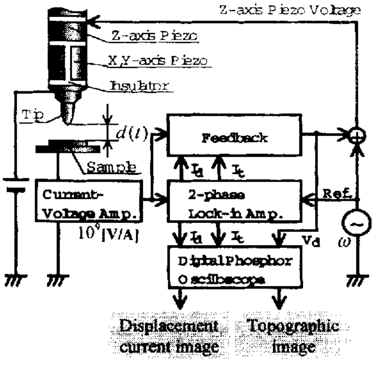

Fig.1 A schematic diagram of SDM

motion of the SDM probe. And we added a system to make images. D.C. voltage is applied between the probe and sample. To vibrate the probe, sinusoidal voltage is added to the z-axis piezo voltage. The sum of tunneling current and displacement current will flow periodically in accordance with the vibration of the probe and they are separated by using a two-phase lock-in amplifier[6].

A sample with grating profile was used. The vibration frequency of the probe was 3420 Hz and its amplitude was 2 nm. The probe radius was 6 μ m and grating interval was 1 μ m.

Results and Discussion

Figure 2 shows both of the displacement current image and topographic image (SDM images) of the sample with grating profile under constant current operation.

Figure 3 shows the cross section of topographic image (relative height). The

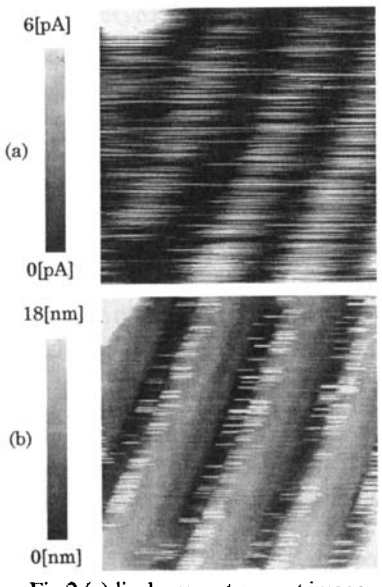

Fig.2 (a)displacement current image
(b)topographic image

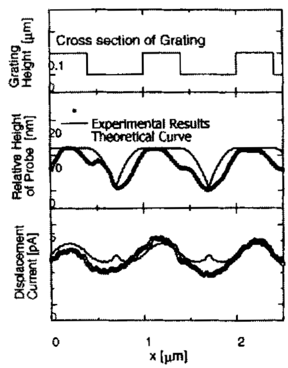

Fig.3 Cross section of the sample, relative height, and displacement current image

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cross section of displacement current image changes, corresponding to the upper and lower parts of the grating. In this experiment, the probe radius (6 μ m) is much larger than the width of the lower part (0.6 μ m). In Fig.3, the probe height decreases only 12 nm at the center of the lower part. It should be noted that the depth of the grating (100 nm) is larger than the change in the probe height (12 nm). As a result, the displacement current when the probe top is placed at the lower part, should be smaller than that at the upper part due to the increase in the mean gap between the probe top and the sample.

In our previous paper, we succeeded in measuring the local depletion width of semiconductors[7,8]. As a consequence, SDM should be useful for observing the doping profile of semiconductor.

Conclusions

We developed a scanning displacement current microscopy (SDM) which measures the electrical surface properties of samples by displacement current. We successfully observed both displacement current image and the topographic image of a sample with grating profile simultaneously under constant tunneling current operation.

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