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Second mode (190 kHz) of the vibration of the turning fork application in shear-force measurements.

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Abstract

In this work the tuning fork technique of control of probe to sample distance, based on commercially available "quartz clock" tuning forks, was investigated. At the experiments on Shear Force Head SNC080 (NTMDT Co.) an extra resonance frequency of quartz fork was found (about six times higher the main resonance frequency). And measurements of calibrating grating show that using high frequency results in more high-quality scan images in comparison with images obtained at standard frequency.

Introduction

The probe in a near-field scanning optical microscope should be kept close to the sample surface. In practice, the probe to sample distance is kept below 10 nm. The most common technique to control this distance in a fiber based instrument, is the shearforce distance control mechanism. In this technique, the fiber is fixed to a vibrating element with a short part of the fiber (0.5 - 5 mm) extending from the vibrating element. This part is vibrated at resonance and parallel to the sample surface. Upon approaching the sample, a decrease in the amplitude of the oscillation is observed, generally attributed to a damping of the oscillation by the surface.

Detection of the oscillation amplitude of the fiber probe has been implemented using different methods such as diffraction and interferometric techniques. But all of these techniques have some sort of disadvantages. An alternative method is to use piezo-electric materials, which generate a piezoelectric voltage proportional to the amplitude of the oscillation. The most common way to implement this idea is to use a crystalline quartz tuning forks for detecting the probe's amplitude. In this case, the end of the fiber is attached to one arm of the fork and the tuning fork is oscillated at resonance (usually about 33 kHz). When approaching the sample surface, a decrease of the oscillation amplitude of the tuning fork is observed.

As usual researchers use a tuning forks of a commercially available type fabricated for “quartz” clocks because of its low cost and high availability. We are studied such kind of forks. The resonance frequency of this most common type of forks is 32768 Hz (=2^{15} Hz) and the resonance curve of free tuning fork is shown in Fig.1a. This is a “main” resonance frequency and exactly this frequency is widely used in shearforce applications.

Fig. 1a. Resonance curve of free tuning fork at “main” resonance frequency.

Fig. 1b. Scan image of calibrating grating obtained at “main” frequency.

But mechanical construction of tuning fork suggests that it may have some extra resonance frequencies. It is natural to assume that extra resonance frequencies are higher then main. Using high frequency oscillation modes should dramatically improve some parameters of microscope. For example higher frequency means shorter relaxation time. And this provides ability to speedup scan velocity and rise a certain increase of sensitivity. Also the analogous electronic components of feedback gain works more perfectly at higher frequencies. This leads to decrease of signal to noise ratio (level of RMS signal) and improve feedback gain stability. It is shown below all that facts have experimental evidence.

Experiment

We used a commercially available model SNC080 (NTMDT Co.) of shear force scanning near field microscope (SNOM) to study the quality of measurements with use of “quartz clock” tuning forks at different oscillation frequencies.

First we adjust our microscope to work on “main” resonance frequency of tuning fork (about 33 kHz). The resonance curve and the resulting topography scan image of calibrating grating are shown in Fig.1a-1b. Then we sweep working frequency from 32kHz up to 220 kHz and found another distinct resonance at about 190 kHz. And then we rearranged our setup to that higher frequency. Rearrangement includes change of working frequency and level of excitation voltage. Obtained results are shown in Fig.2a-2b. The RMS level signal at 190 kHz was from 5 to 10 times smaller than at 33 kHz.

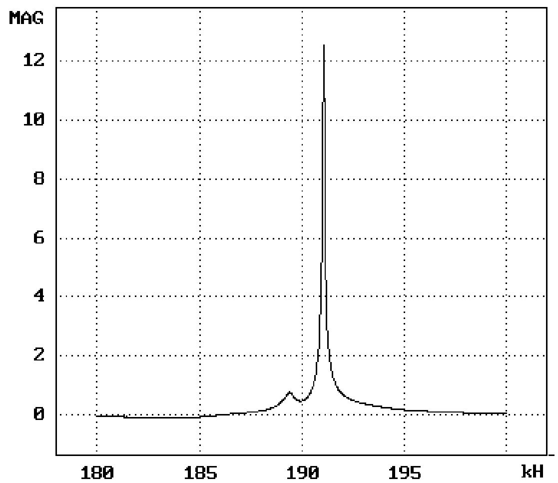

Fig. 2a. Resonance curve of free tuning fork at high resonance frequency.

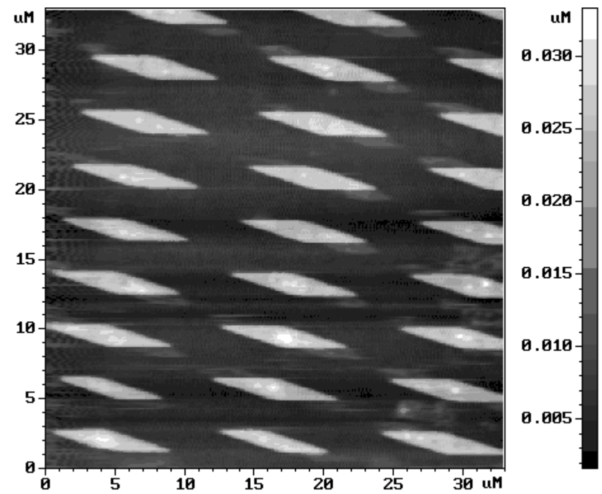

Fig. 2b. Scan image of calibrating grating obtained at high frequency.

Conclusion

According to scan image quality we draw a conclusion that using ordinary "quartz clock" forks but at higher frequency results in better resolution, better signal to noise ratio and increase of scanning velocity due to decrease of time of system relaxation. In our setup in frequency range from 30 kHz up to 250 kHz there is at least one high frequency oscillation mode in the vicinity of 190 kHz that may be used in measurements. So this fact provides a simple way to improve quality of currently used SNOMs just by spreading working frequency of electronic parts.