Shear-mode magnetic force microscopy with a quartz tuning fork

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Some of the cantilever’s weak points can be overcome by using a quartz tuning fork as a force sensor to perform magnetic force microscopy (MFM). Namely, (i) the tuning fork is not pulled by the attractive van der Waals force not only in shear-mode but in tapping-mode operation also due to its high spring constant, thus a tip can approach closer to the sample surface than the conventional cantilever tip, and (ii) is self-dithering and self-sensing, therefore scanning head is simple and small.

There have been some reports on the tuning-fork-based MFM,[1, 2] but none has operated in shear-mode yet. One merit of this mode is that it is less sensitive to the electric noise because the tip vibrates parallel with the equi-potential surface. The grounded tip and sample are not necessary in the shear-mode operation.

We have used the tuning fork having a resonance frequency f of 33 kHz, a quality factor Q of 3000 in air and a spring constant of 2600 N/m. A commercial magnetic cantilever tip is attached to one prong of the tuning fork to realize the shear-mode operation. We have obtained high-resolution MFM images with a spatial resolution of less than 100 nm and a frequency resolution of 1 mHz in ambient condition, which are achieved by a simple phase-shift detection method.

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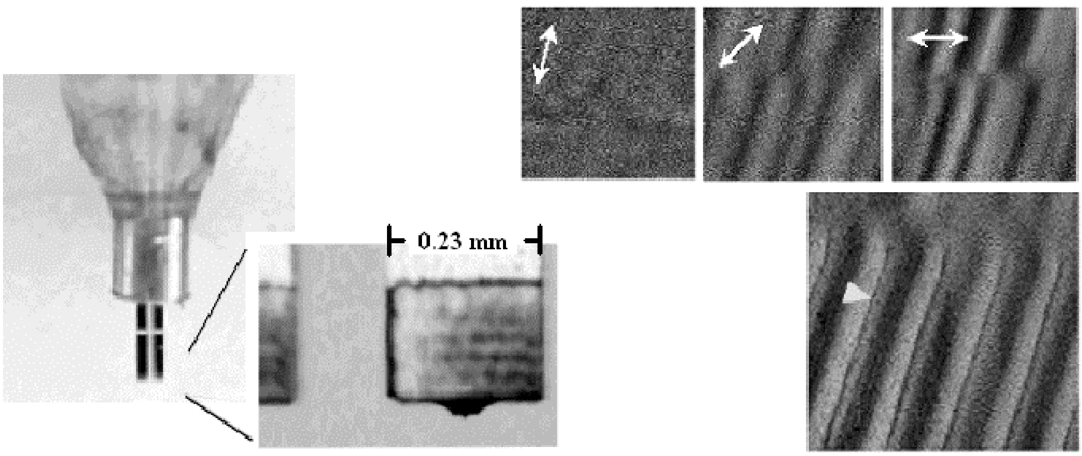

Figure 1. Optical microscope images of the tuning fork where a commercial MFM cantilever tip is glued to the bottom end of one prong.(left) Right top three shear-mode MFM images show the lateral variation of the magnetic force gradient. Arrows represent the dithering directions of the tip. And, the FWHM of the sharp line at the right bottom image is about 100 nm. Image dimensions here are 6 x 6 .

[1] H. Edwards, L. Taylor, W. Duncan, and A. J. Melmed, J. Appl. Phys. **82**, 980 (1997).
[2] M. Todorovic, and S. Schultz, J. Appl. Phys. **83**, 6229 (1998).