Harmonic Active Atomic Force Microscope Cantilevers for Improved Material Contrast

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Funding: European Union's Seventh Framework Programme FP7/2007- 2013, grant agreement no. 318804 (SNM), ZIM-Project KF2114205NT2

Introduction

Atomic Force Microscope (AFM) cantilevers have the ability to map topography and material properties simultaneously. The periodic impact of the tip onto the sample surface causes the material dependent excitation of higher harmonics in the Fourier spectrum. Combined with the cantilever dynamics, the harmonics in the vicinity of higher eigenmodes are less attenuated and can easily be detected by measurement devices. To improve the Signal-to-Noise Ratio (SNR), the cantilever eigenmodes can be matched with the harmonics that appear in integer multiples of the fundamental resonance used for scanning the topography. In the past, Sahin et al. [1] have created regular harmonic cantilevers during their fabrication process. However, they only matched a single eigenmode with a nearby harmonic at a time, and the yield was very low due to the fabrication process. In this work, harmonic cantilevers are created in a custom post-fabrication step, using cantilevers with integrated actuation and piezo-resistive sensing [2].

Fabrication

The harmonic active cantilevers are fabricated by removing mass at predefined locations and using a Focused Ion Beam (FIB) tool. The shape and location of such mass removal is either determined beforehand through an FEM simulation or in-situ by monitoring the evolving cantilever signals at its resonances. In the simulation, the cut shape is swept in a parameterized fashion. Its proper size is determined based on the pre-cut and desired post-cut ratios. The result is shown in Figure 1, with Figure 1(a) being the digital mask as resulted of the FEM simulation. It is used to automatically create the holes in the cantilever by the FIB, as seen in the cantilever image of Figure 1(b) obtained by the scanning electron beam inside the FIB chamber.

Result

Figure 2 indicates the measured resonances before and after the fabrication, as explained in the previous section. The original ratios of the second and third eigenmode to the first eigenmode are 6.219 and 16.885, respectively. The matched ratios after fabrication are 6.003 and 16.009. This allows for maximum SNR and contrast to different materials. Also, this technique can be used to lower the resonances of the higher eigenmodes such that it allows easier access with bandwidth limited actuation and sensor electronics.

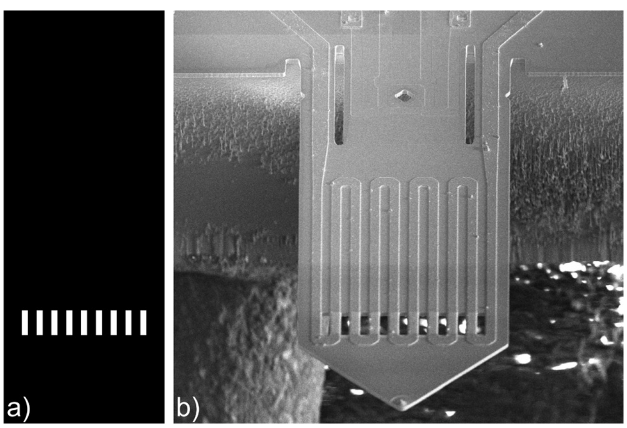

Fig. 1: (a) FEM based digital cantilever mask, (b) cantilever after FIB modification

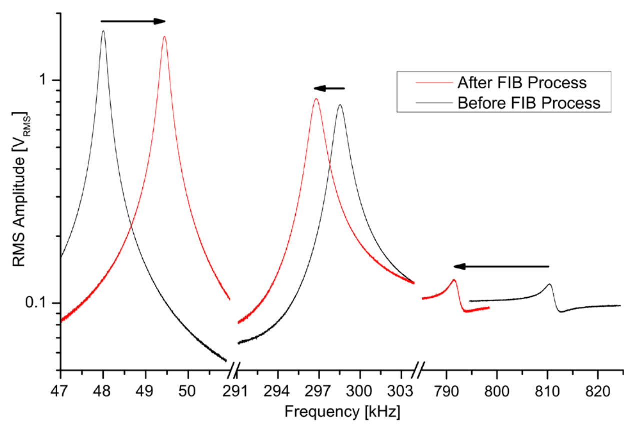

Fig. 2: Resonance shift before (black curve) and after (red curve) the FIB modification. Arrows indicate the change

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[2] R. Pedrak, T. Ivanov, K. Ivanova, T. Gotszalk, N. Abedinov, I. W. Rangelow, K. Edinger, E. Tomerov, T. Schenkel, and P. Hudek, Journal of Vacuum Science & Technology B: Microelectronics and Nanometer Structures, vol. 21, no. 6, p. 3102, 2003.

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