Focused ion beam fabrication of planar probes for high resolution shear force microscopy

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The atomic force microscopy (AFM) enables high resolution investigations of various surface parameters. To the AFM technologies belongs also the so called shear force microscopy (ShFM), in which dynamic interactions are measured when a cantilever vibrates parallel to the investigated sample. Because the ShFM cantilever integrates a planarally protruding nanotip its fabrication process is simplified. The weakness of the described technology relies on the limited height aspect ratio of the scanning tip, which makes it difficult for the probe to penetrate deeper surface structures. In this work we present a method of the ShFM cantilever tip sharpening using focused ion beam (FIB) technology. The thermally actuated piezoresistive ShFM silicon probe was fabricated based on a double-side micromachining concept which allow to fabricate line-shape tip - Fig. 1.[1,2] The milling process was performed in two planes using a FIB specimen stub angled by 45° (30 kV, 21 nA to 1.5 nA). Fig. 2 and Fig. 3 present the piezoresistive ShFM probe before and after FIB milling.[3] The tip sharpening process is associated with measurement of beam resonance frequency shift which reflects how the probe mass is removed (we recorded the shift of the resonance frequency of 109 Hz corresponding with the tip mass change of 2 ng). In order to determine the tip geometry the blind tip reconstruction method was applied. In this technology, the shape of an AFM probe is estimated on the basis of a morphological analysis of an AFM image of a rough surface.[4] The presented results were obtained by the regularized blind tip reconstruction (RBTR) proposed in[5]. In this procedure, the estimation of a tip apex is more accurate in the presence of noise. The advantage of the proposed method is that the application of the modified RBTR procedure makes it possible to monitor the tip geometry with the shear force microscope before and after surface scanning. In this way the reliable metrological analysis of the surface properties is enabled. The Budget Sensors TipCheck calibration sample were scanned twice (scan area 1×1 μm with 512×512 resolution) by the same ShFM probe before and after the FIB sharpening-Fig. 3a and Fig. 3b. The effective RBTR reconstructed shape of the ShFM probes are presented in Fig. 3c and Fig. 3d respectively. The corresponding SEM image of the sharpened probe is presented in Fig. 4.

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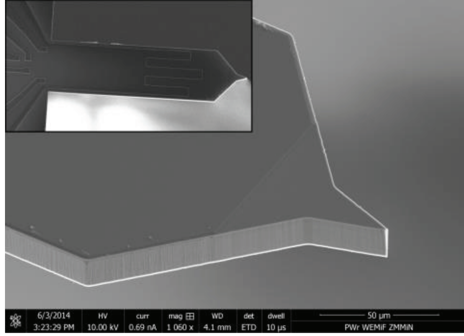

Fig. 1 Scanning electron microscopy image of the piezoresistive thermally actuated ShFM probe tip before sharpening

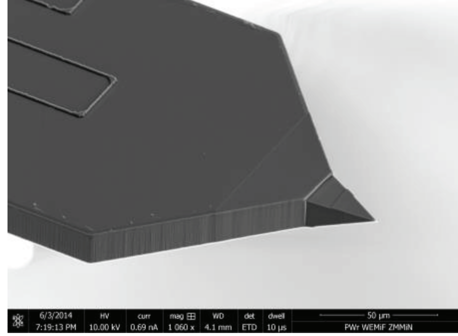

Fig. 2 Scanning electron microscopy image of the piezoresistive thermally actuated ShFM probe tip after tip sharpening

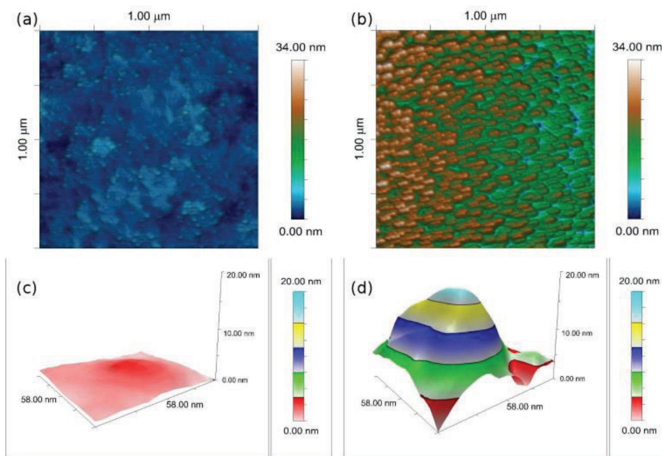

Fig. 3 Probe shape estimated by the regularized blind tip reconstruction algoritm (RBTR)[1]. AFM images of TipCheck calibration standards obtained by unsharpened (a) and sharpened (b) tips. Tip shapes (c) and (d) reconstructed on the basis of AFM images (a) and (b) respectively

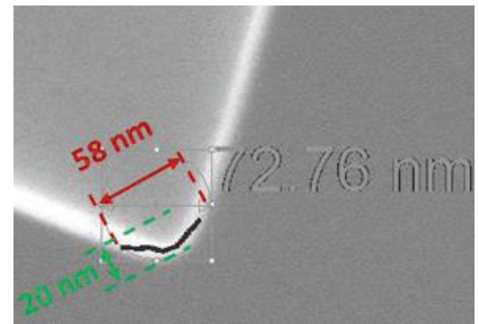

Fig. 4 Scanning electron microscopy image of the FIB sharpened ShFM tip