Focused ion beam assisted fabrication and application of high speed scanning thermal microscopy selfactuated piezoresistive probe

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Scanning thermal microscopy (SThM) belongs to the technologies enabling high resolution imaging of local thermal surface parameters. In this technology heat transfer between the thermal probe and the investigated surface is monitored in order to determine local sample temperature or probe-sample thermal resistance. In order to perform quantitative measurements the thermal probe must fulfil several requirements, which despite several attempts of various technological groups have not been yet completely met. The thermal mass of the thermal tip should be as low as possible and thermal resistance between the tip and the spring beam as high as possible in order not to retrieve the energy of the investigated structure. Moreover, the thermal probe should be stiff enough to transfer the mechanical load to the spring beam and endure temperature stress. In our design we integrated with the piezoresistive cantilever a focus ion beam (FIB) resistive thermal tip-Fig. 1(a, b, c). The piezoresistive deflection technology made out of the fabricated probe the metrology tool, using which a precise definition of the force interaction between the sample and sample will be enabled[1]. Additionally the application of the designed SThM probe in vacuum systems will be significantly simplified. In our design we integrated an auxiliary metal loop with the mechanical spring beam, in order to control heat transfer from the thermal tip through the silicon cantilever and to excite probe vibration[2]-Table 1. The SThM tip is formed by platinum film deposited on the spring beam and over the silicon support pyramide. It should be underlined, that the silicon pyramide defines the probe geometry, which in our solution is of the same quality as the standard atomic force microscopy (AFM) probe. Moreover, the SThM tip is placed at the end of the spring beam so that the proper and reliable contact between the probe and thermally investigated sample is ensured. The inner part of the tip is focused ion beam (FIB) milled, in order to reduce the mass of the tip, decrease the thermal time constant and increase the thermal resistance between the thermal apex and the mechanical spring beam. Fabrication process of the described SThM probe is based on a double side micromachining concept[3]. The applied fabrication procedure enables us to fabricate cantilevers of the thickness smaller than 5 microns with piezoresistor depth smaller than 100 nm. In this way structures with excellent mechanical parameters (spring constant of tens of N/m, resonance frequency bigger than 50 kHz), optimized electrical characteristics of tip deflection detectors and minimized thermal resistance of the spring beam are obtained-Fig. 2,3. The described probe was integrated with a scanning set-up capable to perform routinely 10x10µm frame with rate of one fps, pixel size (256 pixels 256 pixels)[4]. In this work we will introduce the probe fabrication process, mechanical and thermal calibration procedures and present the results of topography and thermal investigations conducted using the presented probe.

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[3] I.W. Rangelow et al., Microelectronic Engineering, **84**, 1260, (2007).
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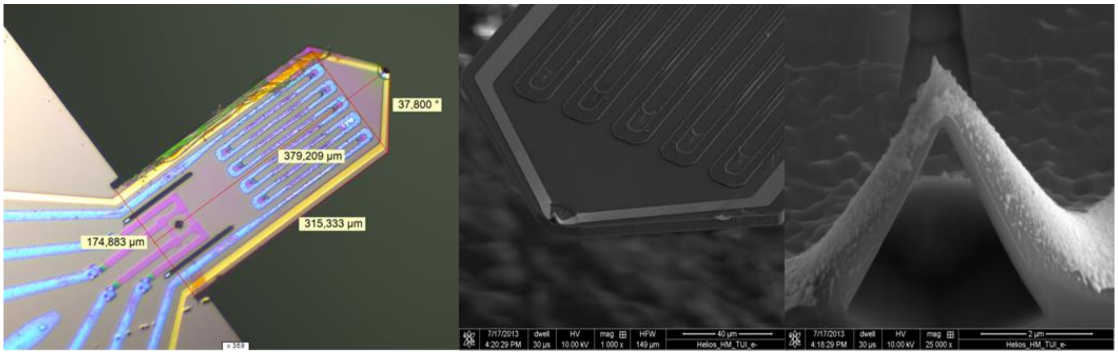

a) b) c)

Fig. 1. Focused ion beam assisted fabrication and application of high speed scanning thermal microscopy selfactuated piezoresistive probe a), thermal tip with deflection actuator b), thermal tip milled using FIB technology

Table 1 Basic parameters of the fabricated SThM probe

R_1 [Ω]	R_2 [Ω]	R_H [Ω]	R_{Pt} [kΩ]	f_R [Hz]	Q [-]	k [N/m]	S_V [µV/nm]	S_A [nm/mW]
2,762	2,760	23,8	2,931	55762	380	23,54	6,3	36,1

R_1, R_2 – piezoresitors in the deflection detector, R_H – heater resistance - actuator, R_{Pt} – thermal heater resistance , f_R – resonance frequency, k – spring constant , S_V – deflection sensitivity of the piezoresitive detector, S_A – thermal actuation sensitivity (at 1/2 f_R)

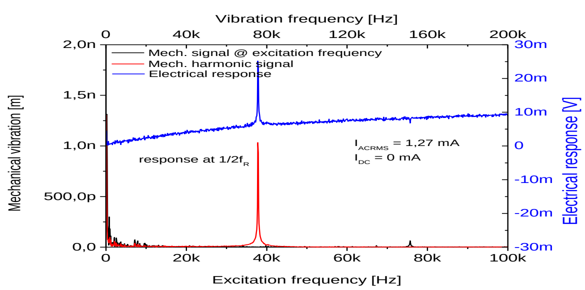

Fig. 2. Calibration of the piezoresistive detection of the SThM tip deflection

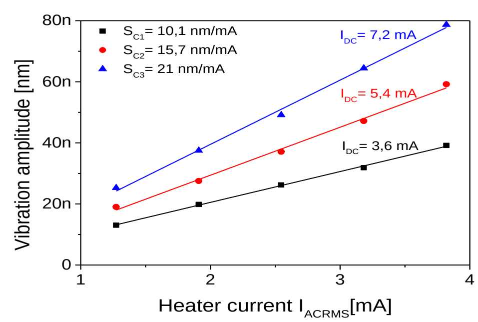

Fig. 4. Calibration of deflection actuation sensitivity of the SThM probe