Resistless fabrication and characterisation of metal nanolevers arrays

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The use of shadow masks (stencils) for nanopatterning overcomes the limitations typically present by patterning methods involving conventional optical lithography and etching, such as diffraction limit and etch selectivity. Nanostencils allow for resistless, low-cost nanopatterning on arbitrary surfaces in a single process step with the prospect of large-scale manufacturing [1]. This paper presents the fabrication of metal cantilevers with sub-micron dimensions using direct evaporation through nanostencils, followed by dry etching to release the metal nanolevers from the substrate [2]. The nanostencils, with structures as small as 250 nm, are excellent tools to study and optimise the process parameters for the fabrication of nanolevers by varying the evaporation conditions. The fabricated cantilevers were characterised using a laser-Doppler interferometer [3].

The smallest slits in the stencil where used to form arrays of nanolevers of 2 – 6 µm long, 450 – 700 nm wide, and 50 – 100 nm thick (see Figure 1 and 2). The resonance frequency as a function of the nanolever thickness was characterised in vacuum. For a 100-nm thick Al cantilever, a resonance frequency of 23 MHz and a quality factor of 628 at 10^{-3} Pa were measured, which corresponds well to theory (see Figure 3). Further studies included deposition of other high-stress metals such as Ni and Cu.

References:

1) G. M. Kim, M. A. F. van den Boogaart, and J. Brugger, Microelectronic Engineering 67-68 (2003), 609-614
2) G. M. Kim, M. A. F. van den Boogaart, S. Kawai, H. Kawakatsu, and J. Brugger, conference proceedings Transducers 2003 Boston, vol 1, .883-886
3) H. Kawakatsu, S. Kawai, D. Saya, M. Nagashio, D. Kobayashi, H. Toshiyoshi, and H. Fujita, Review of Scientific Instruments 73 (2002), 2317-2320

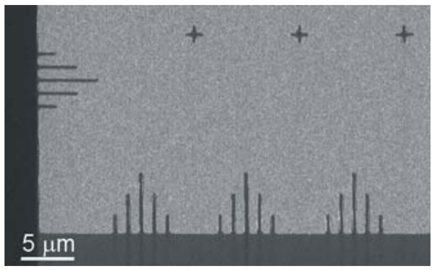


Figure 1: Detail of the silicon nitride nanostencil with arrays of nanolevers.

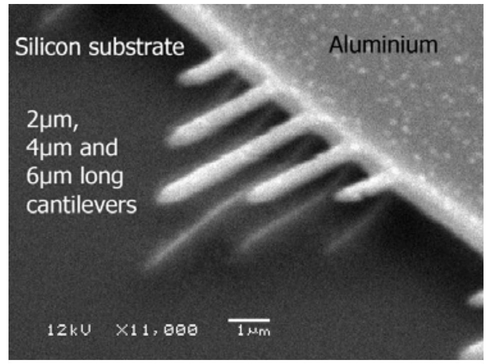
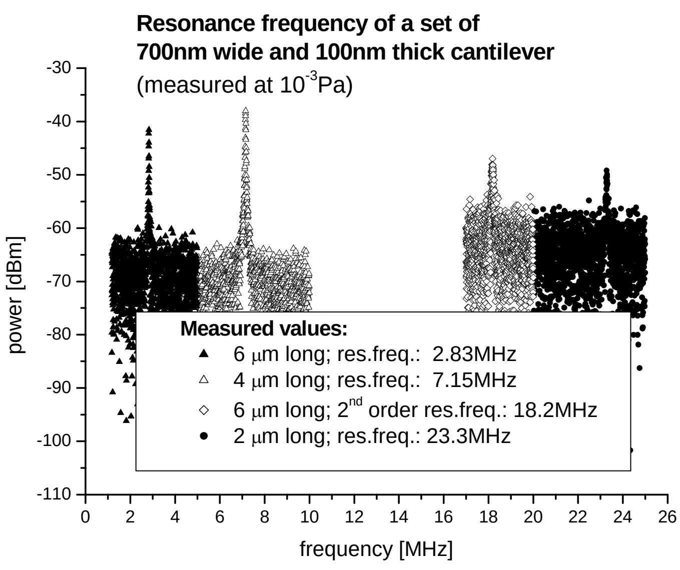


Figure 2: Released 100-nm thick Al nanolevers (2, 4, and 6 µm long) after RIE etching of the Si substrate.



Theoretical value:

$$f_0 = c_0 \frac{t}{l^2} \sqrt{\frac{E}{\rho}}$$

Where t, l, E and ρ are thickness, length, Young's modulus and density of the material. C_0 is the first solution of the equation of motion.

$f_0(6\ \mu m) = 2.28$MHz

$f_0(4\ \mu m) = 5.14$MHz

$f_0(2\ \mu m) = 20.1$MHz

Figure 3: Result of the first order resonance frequency obtained with a laser Doppler interferometer. The measured resonance frequencies are slightly higher than the theoretical values (see right side).