Reproducibility of Drift-Tolerant Focused Ion Beam Lithography Method

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Focused Ion Beam (FIB)-technology has since its inception been used for minor manual modification of devices. Today the technology is employed in fully automatic systems for device fabrication. Advances in milling strategies have allowed this method to be applied on conventional dual-beam systems as a primary method of prototyping microelectromechanical devices,[1] for instance micro four-point probes (M4PPs).

M4PP characterisation of a sample's electrical properties has proven valuable for both material research and production quality control. It has previously been demonstrated that L-shaped cantilevers can provide non-destructive contact of fragile nanostructured surfaces[2] – as opposed to traditional straight cantilever electrodes. However, downscaling by an order of magnitude is necessary to compete with commercially available M4PP with an electrode pitch of 1.5 µm.

In this work we demonstrate L-shaped cantilever M4PPs with an electrode pitch of 1.5 µm and 0.5 µm. These are realised through fast prototype FIB-fabrication from generic suspended polysilicon template chips. This method employs a drift-tolerant feature-conformal milling strategy (Figure 1), which allows for drift up to ~20 nm/min without compromising structural integrity. The strategy combines a large current for reduced milling time and a low current for high resolution milling.

Prototype M4PPs were made using two standard commercial dual-beam systems[a] without employing active drift correction, and with a continuous milling time of up to 1 hour. Features and voids with an aspect ratio of 5:1 and 3:1, respectively, have been made reproducibly on both systems (Figure 2). It is found that the local geometry may cause variations to the realised dimensions, although these are considerably less than the nominal ion beam width (cf. Figure 3).

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[a] FEI Quanta 200 3D, FEI Helios

[1] B. Malm, D.H. Petersen, A. Lei, T.J. Booth, L.V. Homann, and P. Bøggild, Microelectronic Engineering **88**, 2671 (2011).

[2] D.H. Petersen, F. Wang, M.B. Olesen, R. Wierzbicki, M.S. Schmidt, P.F. Nielsen, P. Boggild, O. Hansen, and K. Molhave, in *Solid-State Sensors, Actuators and Microsystems Conference (TRANSDUCERS), 2011 16th International* (IEEE, 2011), pp. 1060-1063.

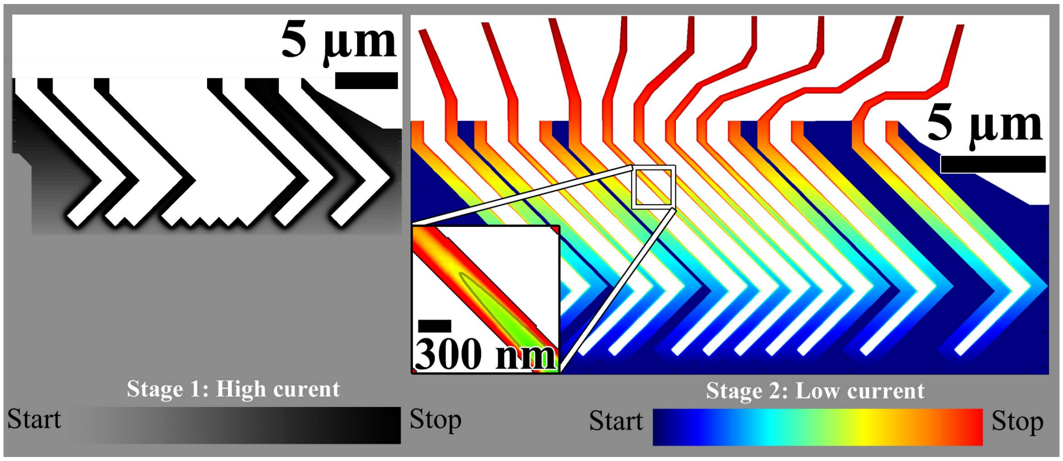

Figure 1: Conformal milling strategy. The pattern is initially written with a high current (1 nA, left), followed by the detailed shape where a lower current is used for higher precision (0.3 nA, right). Both stages employ a conformal milling strategy in order to maximise milling accuracy.

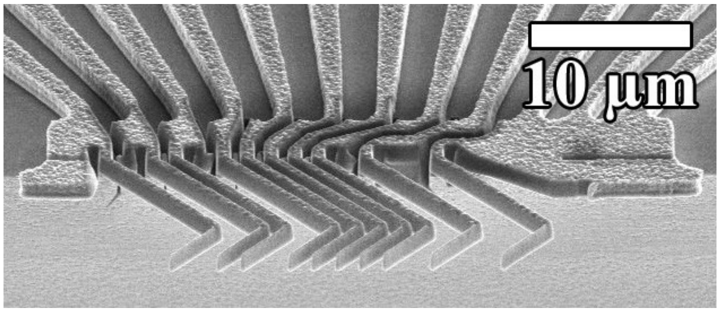

Figure 2: L-shaped M4PP prototype. Electron image taken immediately after FIB-milling. The polysilicon template membrane has a thickness of 1.25 µm. The outer sub-cantilevers have a mean aspect ratio of 5.4:1, while the void between the inner sub-cantilevers have a mean aspect ratio of 2.9:1.

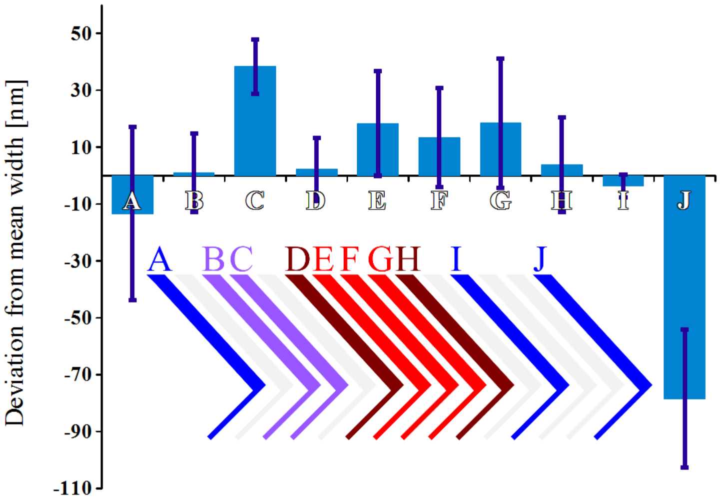

Figure 3: Reproducibility of feature width. The mean cantilever width is 614 nm, with embedded cantilevers (E, F, G) deviating by +16 nm, and isolated (A, I, J) cantilevers by -32 nm.