Application of a Gripper in FIB Microstructuring

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Motivation

A gripper [1] as new tool implemented in a FIB/SEM Dual Beam instrument offers numerous new opportunities to manipulate objects on a the scale of a few micrometers or even some 100 nm.

Two examples for the application of the gripper are presented:

- Improvement of the fabrication process of an electrostatic microlens which can be used as a (Boersch) phase plate in a transmission electron microscope [2].
- TEM lamella preparation without any FIB-induced metal depositions.

Technical Specification [1]

- Total length gripper 30 mm
- Tip length 5 mm
- Height 5 mm
- Gripping area $(4 \pm 1\ \mu m)^2$
- Resolution < 15 nm
- Force > 200 µN
- Span range > 20 µm
- Temperature range 273 K to 353 K
- Lowest pressure for operation 10 e^{-7} mbar

Motion and Positioning

- Gripper fixed at sample stage following movement of stage in z- and tilt-axis.
- Independent motion of the gripper in three axes: up-down (perpendicular to stage), radial (parallel to stage) and in-out (along its longitudinal axis).
- Amplitude of each motion step controlled by 6 different step sizes.

Positioning in 4 perspectives and views:

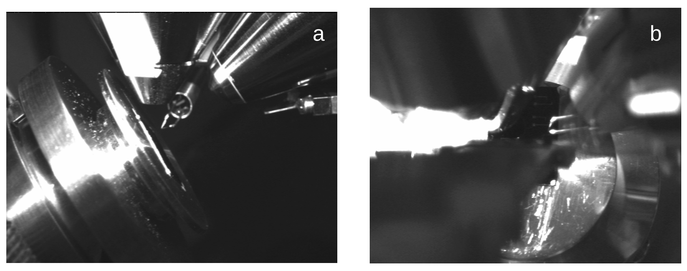


Figure 1: Coarse positioning: a) TV camera 1: up-down and radial axis, b) TV camera 2: in-out axis.

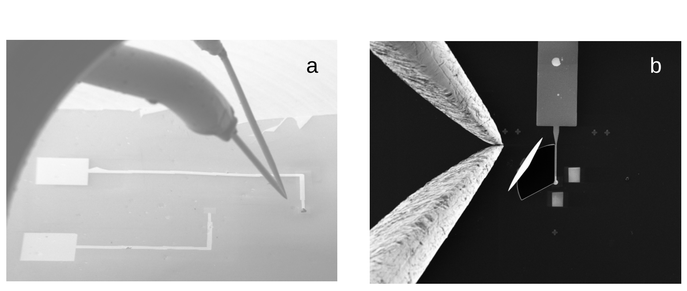


Figure 2: Fine positioning: a) SEM image, b) FIB image.

1. Fabrication of Electrostatic Microlens as (Boersch) Phase Plate in TEM

Boersch phase plate (Fig. 3)

- 5-layered structure surrounded by a grounding layer apart from the interior of the central hole.
- a voltage can be applied at the electrode layer 3 (Fig.3 b) to induce an electrostatic field in the central hole.

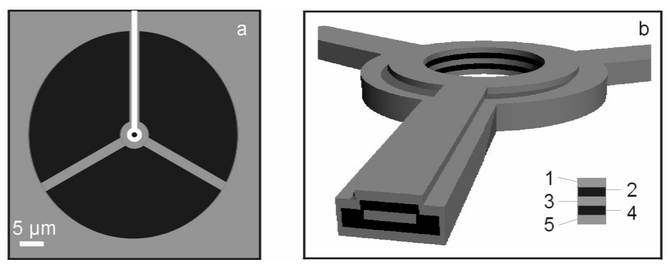
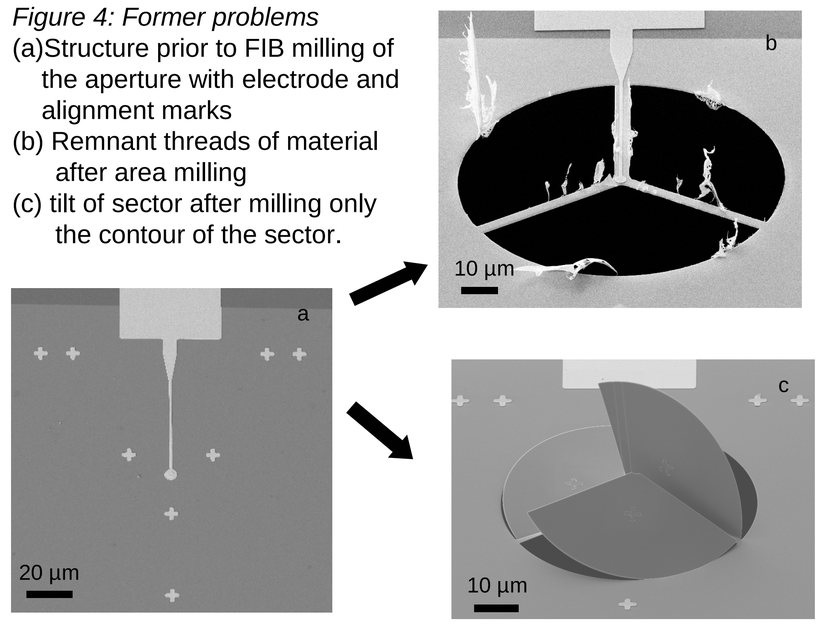


*Fig. 3: (*a) Phase plate at an intermediate fabrication step after:
- Au deposition on bottom-side of Si_3N_4 membrane.
- Structuring of the electrode with connecting leads (white, see also Fig. 4a) by electron beam lithography.
- FIB milling of the aperture consisting of three sectors (black regions in Fig. 3a).

(b) Scheme of the completed phase plate after
- Deposition of insulating and shielding metal layers.
- Milling of central hole.

Elaborate and time-consuming fabrication step:
FIB milling of the aperture (three sectors).

Figure 4: Former problems
(a)Structure prior to FIB milling of the aperture with electrode and alignment marks
(b) Remnant threads of material after area milling
(c) tilt of sector after milling only the contour of the sector.



Improved method:

- FIB milling of the contour until sector tilts along the FIB-axis (Fig. 5b).
- Rotation of specimen towards gripper.
- Precise approach of gripper in steps with a small size.
- Grabbing and removal of sector (Fig.5c)

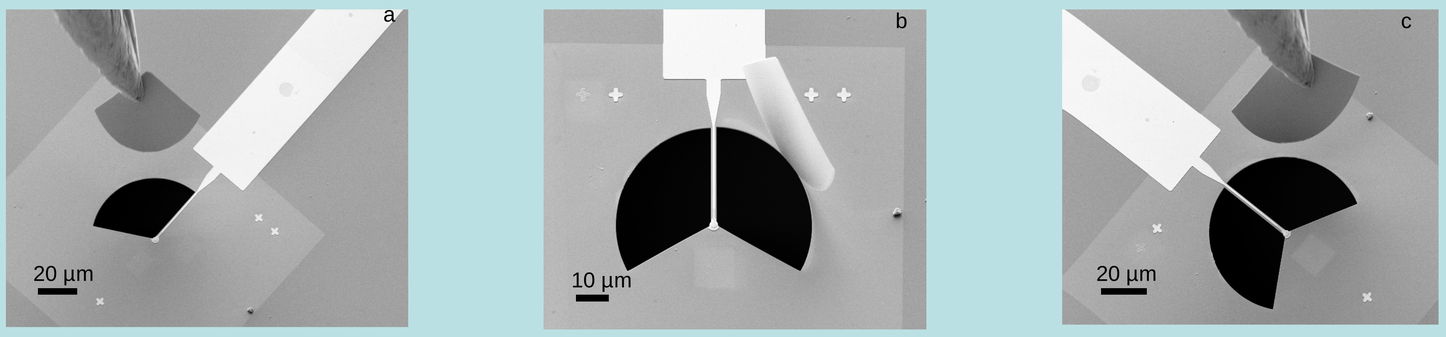


Figure 5: Removal of sectors by the gripper

Advantage:
- Failure-free
- Faster

2. TEM Sample Preparation

Advantages of TEM lamella preparation in a combined FIB/SEM instrument:

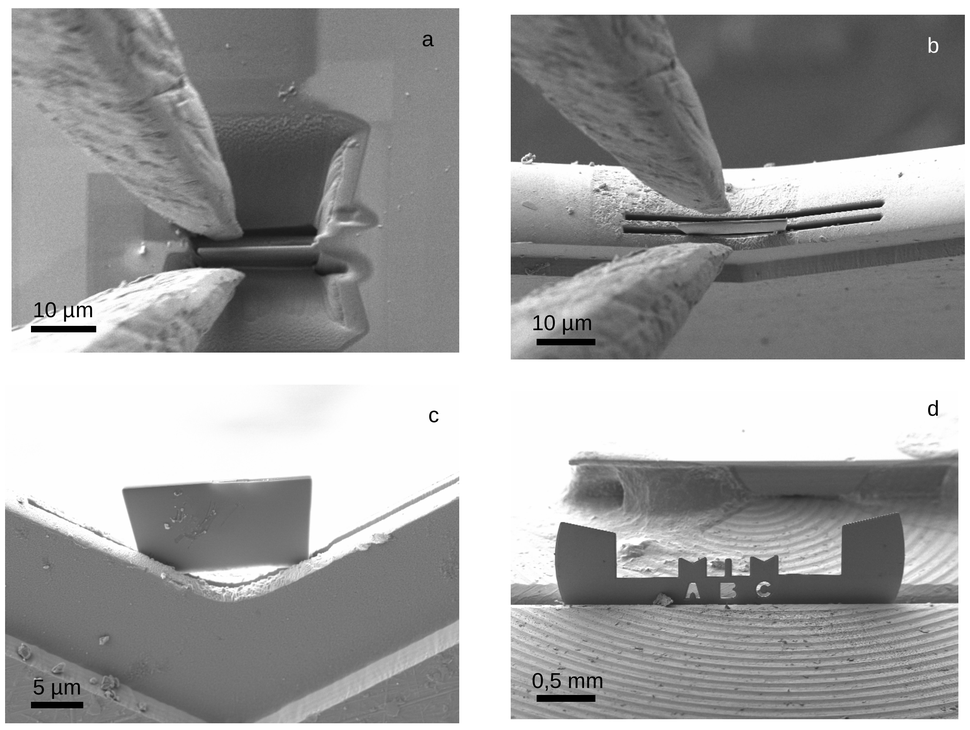
- Preparation at area of interest.
- Control of preparation process (e.g. thickness) with SEM.
- Uniform thinning over large areas.

Standard procedure requires transfer of the lamella from the bulk sample with a micromanipulator tip attached to the lamella with a Pt deposition.

Improved method without Pt deposition:

- Gripping and extraction of the lamella (Fig. 6a).
- Insertion of lamella in a TEM grid with a narrow slit (Figs. 6b,c).

→ Avoids time-consuming bonding processes by FIB-induced metal deposition.



References

[1] Kleindiek Nanotechnik, *www.kleindiek.com*

[2] K. Schultheiß et al., *Rev. Sci. Instrum.* 77, 033701 (2006)

Acknowledgements

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Conclusions

Grabbing of micro- and nano-scaled objects facilitates and accelerates micro-structuring processes and leads to

- Improved structural quality, reduction of sources for failure and faster fabrication of electrostatic (Boersch) phase plates.
- Faster and easier preparation of TEM lamellae.