New developments in the field of electrostatic phase plates in transmission electron microscopy

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Achieving phase contrast of weak-phase objects in transmission electron microscopy has recently been approached by various types of phase plates as an alternative to through-focus image series. Phase plates positioned in the back focal plane of the objective lens aim to achieve a relative phase shift of the scattered electrons with respect to the transmitted beam. Two different categories of phase plates exist: thin-film phase plates (Zernike- and Hilbert-phase plate [1,2]) and electrostatic phase plates like the Boersch-phase plate [3] with the possibility to adjust the phase shift by varying the applied electrostatic potential.

The main disadvantage of the Boersch-phase plate follows from its design which consists of a microlens which is attached to supporting bars. Especially the ring-shaped microlens around the unscattered electrons completely obstructs a band of small spatial frequencies which leads to artifacts in the image like the disappearance of relatively large structures. Zach has suggested a new design for an electrostatic phase plate with the aim to achieve minimum obstruction of the scattered electrons in the back focal plane [4]. The Zach-phase plate (ZaPP) consists of a single screened conductor that is placed in the vicinity of the beam of transmitted electrons. A field is formed at the tip between central conductor and the metal screening layers which are separated by an insulating layer as shown in Fig. 1.

We successfully fabricated several prototypes of Zach-phase plates and present first experimental results. As test sample we investigated a thin carbon film with platinum nanoparticles. In Fig. 2 conventional TEM (CTEM) images with different defocus values (Figs. 2a,b) are compared with a ZaPP image (Fig. 2c). The same sample region is imaged and analyzed by line scans (Figs. 2d-f). An improvement of contrast of the particles with respect to the background can be achieved between the in-focus CTEM image and the ZaPP image.

To summarize, we investigated a promising new electrostatic phase-plate concept which minimizes the obstruction of a complete spatial frequency band. Prototypes are tested and there are further efforts to understand all effects quantitatively.

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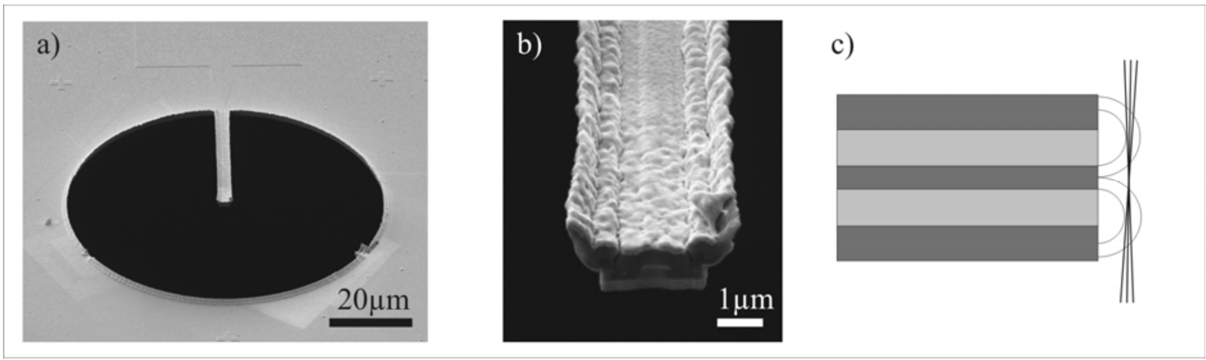

Figure 1: a) First prototype of Zach-phase plate. b) Magnified view of the tip. c) Schematic cross-section of Zach-phase plate with an electrostatic field at the tip where unscattered electrons pass.

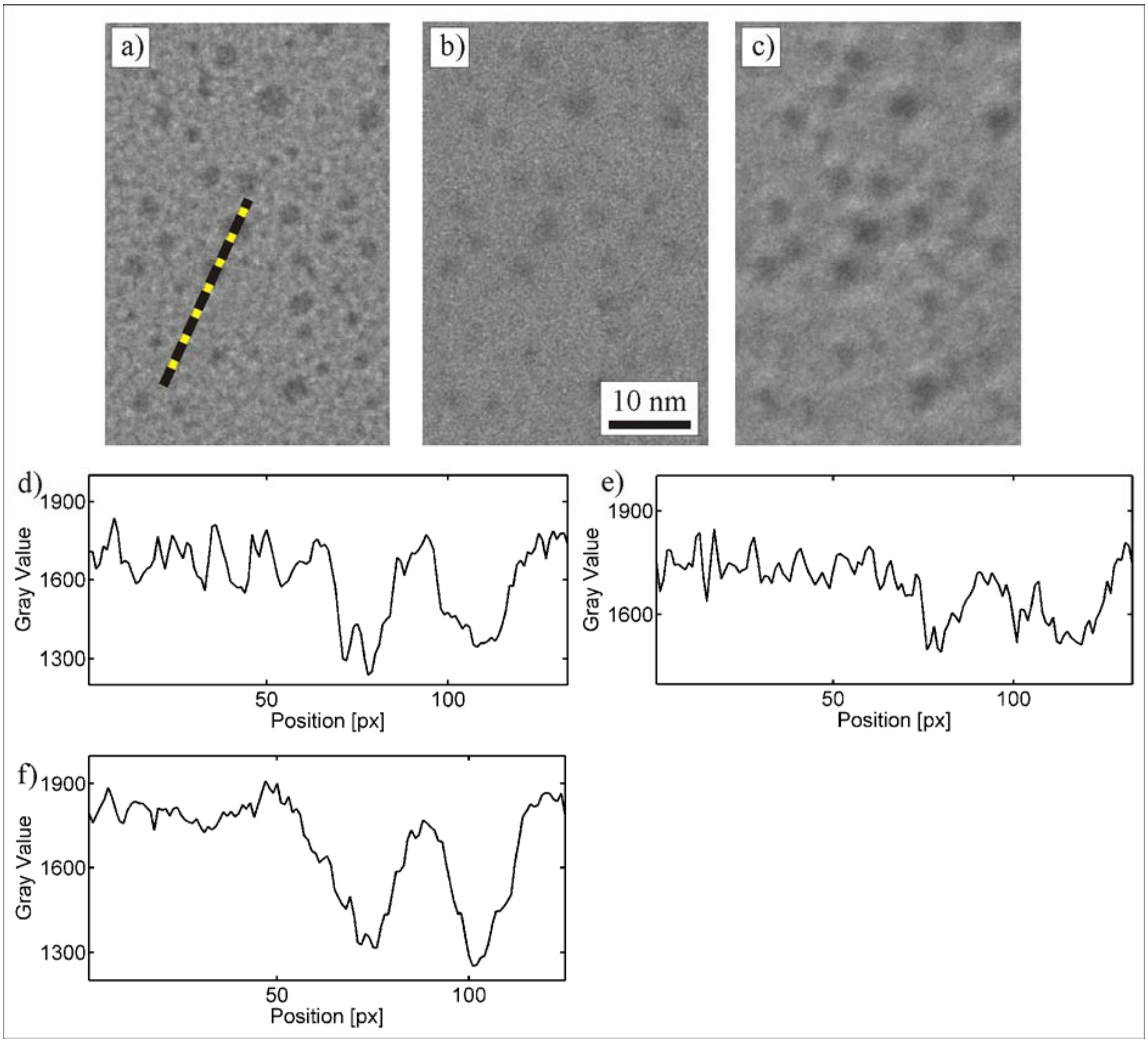

Figure 2: a) Defocused CTEM image of Pt particles on amorphous carbon film, b) in-focus CTEM image c) ZaPP image, 0.4V applied. d) Linescan above two particles in a) [doted line]. e) Linescan above same region in b). f) Linescan above same region in c). Relative contrast of particles above background signal is improved.

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