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IT-11-P-1720 Operating principles and practical applications of hole-free phase plate imaging

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Ideal Zernike phase plate (PP) imaging in a TEM could, in principle, provide a quantitative measure of the phase shift induced by the sample directly from the measured image intensity for weak phase objects. In practice, the contrast transfer in PP imaging is far too complicated to allow for reliable quantification of image intensity. Furthermore, most samples are not weak phase objects. On the other hand, PP imaging, even at its current stage of development, allows to decrease the irradiation dose needed for a desired signal to noise ratio (SNR) [1], and to obtain qualitative information about samples that would otherwise require more complicated methods, such as electron holography, or complicated sample preparation. Here we present novel examples and discuss operating principles of the hole-free phase plate (HFPP) implementation [2] of PP imaging.

The HFPP implementation of PP imaging uses a uniform thin film placed in the back focal plane of the objective lens that charges due to primary beam-induced secondary electron emission. The steady-state electrostatic potential resulting from the charges phase shifts the diffracted beams relative to the direct beam resulting in strong phase contrast.

Figure 1 a) shows an example of a mouse kidney sample about 70 nm thick. Generally, biological sample of this kind are stained to obtain sufficient contrast. Instead, HFPP imaging allows to obtain sufficient contrast to study and measure lateral dimensions of the object without the need for staining. Compared to the standard bright field TEM (BFTEM) in Fig 1. b) the HFPP contrast is significantly higher. The good transfer of low spatial frequencies by the HFPP is seen in the power spectra (insets) where the HFPP in a) shows a bright region at low frequencies that is not present in BFTEM shown in b). Figure 2 a) shows an example of hard magnetic material (PrFeB) imaged using a HFPP. When compared to Fresnel imaging in Fig 2 b), new information can be obtained: the edge of the sample is clearly visible in a) while Fresnel fringes make it difficult to detect the sample edge in b). The HFPP image in a) also allow the fringing magnetic field extending into vacuum to be observed [3]. We have shown that phase plate imaging using the hole-free phase plate set up allows to establish low-dose phase contrast from samples that, when observed in Fresnel mode, would require staining. We have also shown that HFPP imaging on magnetic samples provides information that is not possible to obtain in Fresnel mode.

[1] M. Malac et. al. Ultramicroscopy 108 (2008), p. 126.

[2] M. Malac et. al., Ultramicroscopy 118 (2012), p. 77.

[3] S. Pollard et. al. Appl. Phys. Lett. 102 (2013), p.192401.

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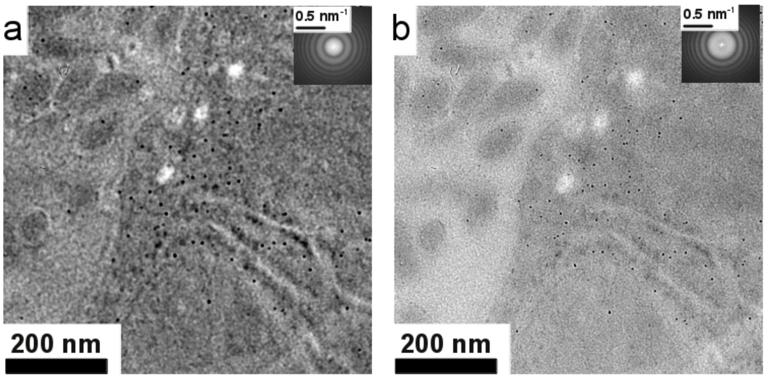

Figure 1 a) HFPP image of unstained mouse kidney tissue and the corresponding power spectrum. b) Bright field TEM image of the same area as a). The scale bar is 200 nm in images and 0.5 1/nm in the power spectra.

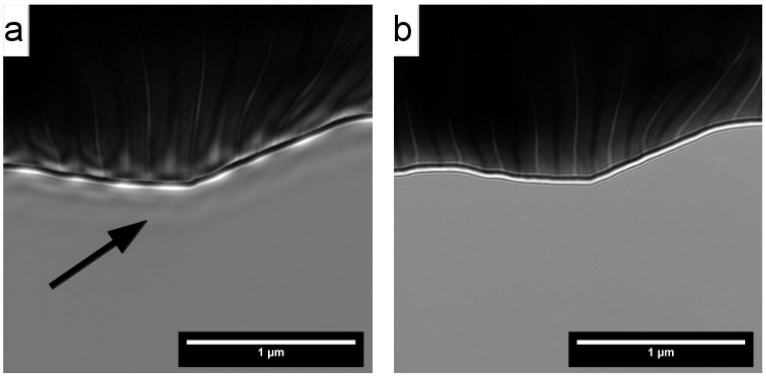

Figure 2 a) HFPP image of a PrFeB hard magnet. b) Same area of the sample imaged using standard Fresnel imaging. The fringing magnetic field in vacuum, marked by an arrow, is visible in a) but not in b). The scale bar is 1 μm.

Fig. 1: .