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Phase Contrast Aberration Corrected Electron Microscope for Phase Plate Imaging

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The PACEM (Phase Contrast Aberration Corrected Electron Microscope, ZEISS) has been installed last year at the Department of Structural Biology in the Max-Planck-Institute for Biophysics in Frankfurt (Fig. 1 A and 2 A). This Transmission Electron Microscope (TEM) is dedicated to high-contrast imaging of biological specimens, cryo-samples and other weak phase objects that, by their nature, generate low image contrast in conventional electron microscopy. In conventional TEMs image contrast is achieved by defocusing the objective lens thereby introducing contrast reversal, vanishing contrast transfer, impairment of resolution and other artefacts. The analysis of such images can be complicated and the artefacts often lead to misinterpretations. In the PACEM contrast is achieved by the insertion of a phase plate into a conjugate back focal plane of the objective lens [1,2]. This allows to image phase objects with maximal contrast transfer and without contrast reversal. In addition, the C_S-corrector (CEOS GmbH) yields increased spatial resolution and allows to extend the objective pole piece gap, thereby giving enough space for cryo-work and tomography.

In this paper we describe the electron optical design of the PACEM and present results showing the functionality of the instrument. The PACEM is equipped with a Schottky Emitter FEG and an electrostatic omega type monochromator designed by CEOS. Combined with the corrected Omega filter this allows zero-loss filtering and high-resolution spectroscopic investigations (EELS, ESI). A specially designed electron-optical unit, the Diffraction Magnification Unit (DMU), allows to position the phase plate at a location distant from the specimen and to minimize possible artefacts caused by the finite dimensions of the phase plate at the same time [3]. The DMU is arranged below the C_S-corrector. The resulting magnification of the diffraction plane by a factor of five significantly reduces artefacts caused by the innermost structures of the phase plate and yields a higher tolerance in the positioning accuracy of the phase plate.

The combination of FEG with monochromator, C_S-corrector and DMU yields a spatial resolution of 2.0 Å as shown by the visible platinum lattice lines (Fig. 1 B) and by the Young fringes obtained from image pairs of platinum particles recorded at high magnification (Fig. 1 C and D). Our experiments demonstrate an excellent cryo-performance with an ice contamination well below 0.5 nm/h (Fig. 2 A and B). First cryo-tomograms of thick vitrified samples were recorded. Results demonstrating the contrast enhancement with a Boersch phase plate are presented in [4].

References

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[5] We kindly acknowledge the financial support of the DFG.

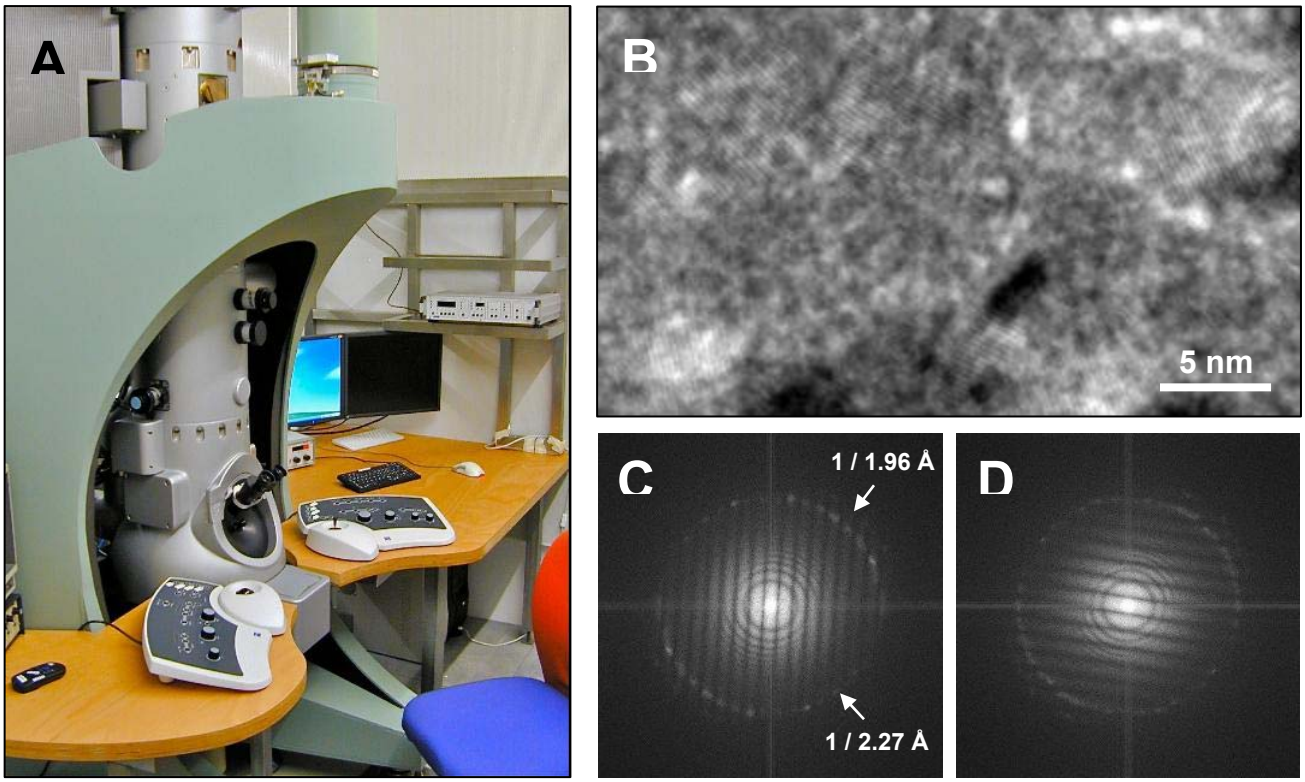

FIG. 1. A) PACEM installed at the Max-Planck-Institute for Biophysics in Frankfurt, Germany. B) Image of platinum particles recorded at high magnification showing Pt lattice lines. C) and D) Young fringes reaching out beyond the 2.0 Å reflections of platinum.

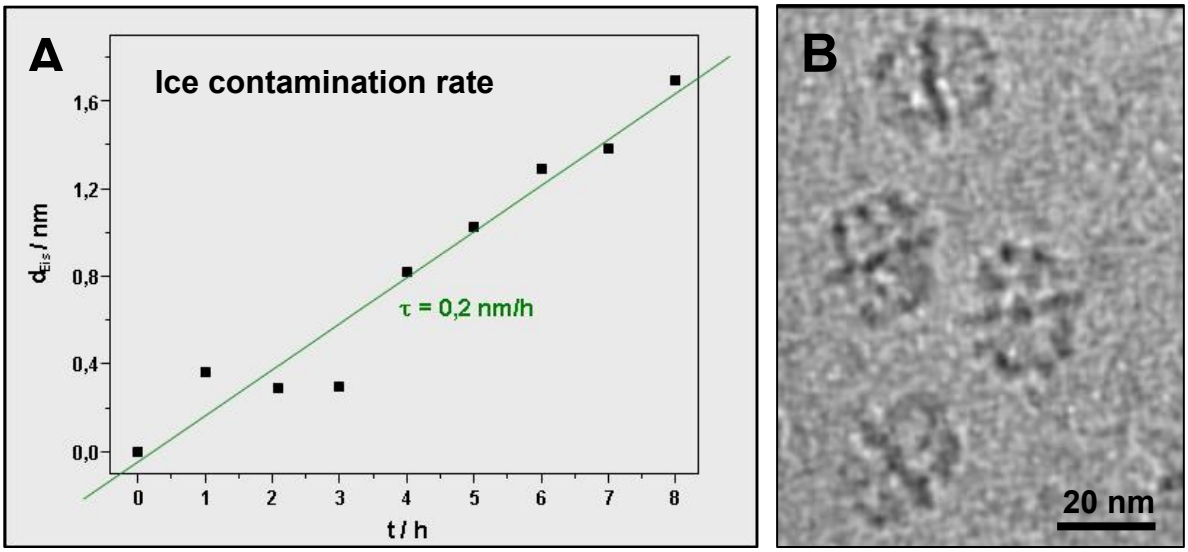

FIG. 2. A) Ice contamination measurement over 8 hours showing an ice contamination rate of 0,2 nm/h. B) Cryo-EM of the protein Fatty Acid Syntase (FAS).

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