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High Resolution Imaging Using the Oxford Aberration Corrected TEM.

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Aberration correction in the TEM leads to improvements in resolution and to a reduction in image delocalisation. For the case of the JEM-2200FS double corrected 200kV FEG(S)TEM installed in Oxford (Fig 1), aberrations in both the pre- and post-fields of the objective lens [1] can be independently corrected to third order. For TEM imaging the interpretable resolution is extended from 0.19nm in the uncorrected state to < 0.12nm (Fig 2) and is only limited by the temporal coherence (ΔE=0.7 – 1eV, dependent on emission current) and the combined Chromatic aberration of the objective lens and corrector ($C_{c,\ \mathrm{Total}}$ = 1.3mm). The effects due to spatial coherence are also improved by the correction of the spherical aberration such that for field emission sources this is not limiting.

In practice, aberration correction is achieved through the acquisition of a Zemlin tableau of images recorded at several tilt azimuths with constant tilt magnitude (typically 18-40mrad) of a thin amorphous foil. This dataset is then used to measure the tilt induced defocus and 2-fold astigmatism from calculated power spectra. From a series of these values the required coefficients of the wave aberration function can be calculated and used in the adjustment of the corrector currents with the Spherical aberration set to either zero (for pure amplitude contrast), or to a small negative value (for optimum phase contrast) and with all other aberration coefficients set to zero. Initially the incident beam direction in the objective lens is aligned to the conventional voltage centre, but as a consequence of the correction of the objective lens axial coma the local specimen orientation can subsequently be accurately adjusted using the beam tilt coils.

As an alternative to direct electron optical correction, focal series reconstruction enables the numerical retrieval of the specimen exit wave function through post acquisition compensation of the aberrations, achieving similar benefits [2] in terms of resolution enhancement. However, in tandem these two techniques provide additional advantages through the localised compensation of higher order aberrations, improved signal to noise and the availability of a complex wave function compared with the conventional image intensity. As an example, Fig. 3 shows both an aberration corrected image of a Pt nanoparticle supported on partially graphitised carbon (a) together with the reconstructed phase of the specimen exit plane wavefucntion (b). It should be noted that the latter reveals substantially more structural detail with surface steps, adatoms and localized rearrangements clearly visible.

References

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FIG. 1. JEOL JEM-2200FS double aberration corrected 200kV FEG(S)TEM installed in Oxford

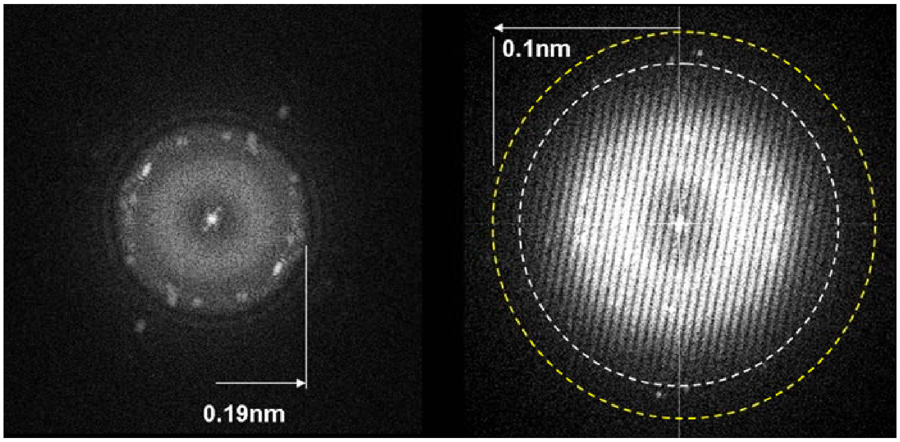

FIG. 2. Optical diffractograms showing the extension of the interpretable resolution from 0.19nm to < 0.12nm (marked by the inner circle, right) after aberration correction.

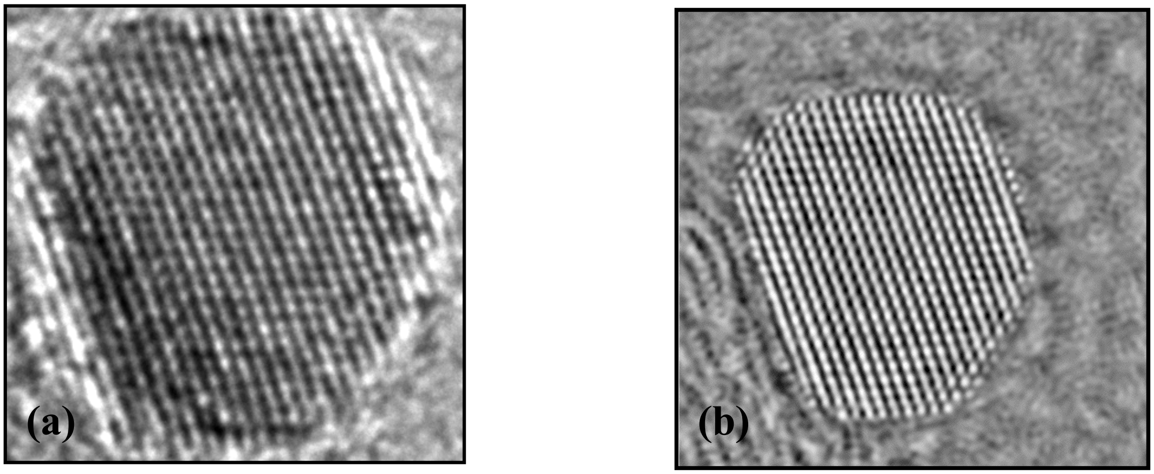

FIG. 3. (a) Aberration corrected image of a Pt nanoparticle taken from a focal series of 20 images (Δf = -93nm, C_s=-20μm) (b) Phase of the reconstructed exit wave function.

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