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Applications of a C_s Corrected HRTEM in Materials Science

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The development of aberration-corrected lenses [1,2] for electron microscopy offers significant improvements for higher spatial resolution in both imaging and nanoanalysis. This will have a considerable impact in materials science applications, particularly those involving nanostructures.. A new TEM with aberration correction of both condenser and objective lenses is being developed for installation at Oxford.[3] This instrument, based on the JEOL 2010 FEF with a Schottky field emission source. With optimised beam energy spread this unique instrument aims to provide HREM information limit and HAADF resolution close to 0.1nm. Additional analytical features include EELS and energy-filtered imaging, EDS and holography. In order to minimise external interference and to maximise thermal and mechanical stability, the microscope column, power supplies and operating console will all be installed in separate, adjacent rooms within a new laboratory, now under construction. Components of the new instrument are now being developed and tested prior to final assembly.

The objective lens C_s corrector has been succesfully developed and tested on a separate JEOL 2010F instrument and we will illustrate here some of the initial results. Tests have confirmed the stability of the corrector over long periods. This corrector system [1] uses extended “Zemlin tableaux” of diffractograms [4] to measure the main aberrations present, i.e. defocus, 2-fold astigmatism, coma, 3-fold astigmatism, and spherical aberration, in addition to 4-fold and star aberration. Fig.1 illustrates tilt tableaux from an amorphous Ge film, without aberration correction and with all main aberrations (i.e. 2-fold and 3-fold astigmatism, coma and spherical aberration) correcteded. These results demonstrate an information limit in the corrected state close to 0.13 nm, consistent with the energy spread in the beam (0.8eV) and chromatic aberration coefficient of 1.2mm at 200keV. The montages of diffractograms are recorded with a range of incident beam tilt semi-angle up to 18mrad, demonstrating the capability of the corrector and the absence of significant aberrations.

There are several benefits arising from the use of a C_s corrected objective lens for image formation. These include an improved “point resolution” limit, coinciding with the instrument’s information limit [1] With an optimised electron beam energy spread, achievable by using a monochromator in the electron gun, this value approaches 0.1 nm. Contrast delocalisation at interfaces and grain boundaries is also greatly reduced [1], as shown in Fig. 2.

Another significant benefit of C_s corrected imaging is illustrated in Fig.3 which shows a small CdSe quantum dot on an amorphous carbon support film. In an uncorrected image at Scherzer defocus the presence of strong Fresnel fringes and “ghost” images would obscure the fine scale structural features, which are further upset by strong phase contrast arising from the carbon film. However, following C_s correction, these effects are almost completely removed while the strong amplitude contrast of the heavier CdSe is enhanced by using a C_s of virtually zero and Gaussian focus. The atomic structure of the dot is thus clarified [5].

Acknowledgement

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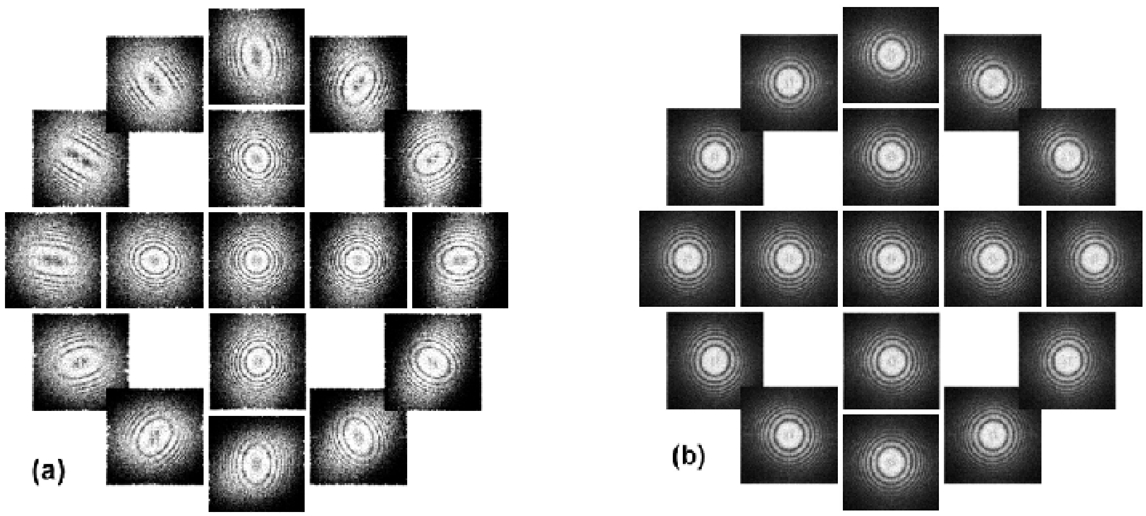

Fig. 1.Tilt tableaux of diffractograms (a) without, and (b) with aberration correction.

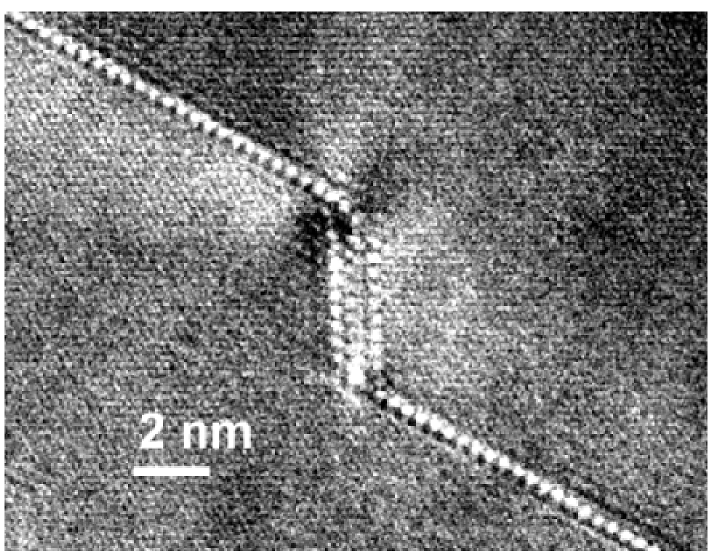

Fig.2. Grain boundary in <111> Au foil showing localised contrast at grain boundary

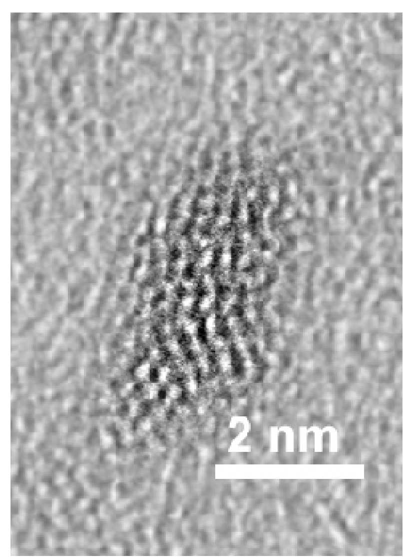

Fig. 3. CdSe quantum dot imaged at Gaussian focus and C_s ~ zero.

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