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High Resolution Imaging with an Aberration Corrected JEOL 2200FS-AC STEM/TEM

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A new JEOL 2200FS 200kV field emission STEM/TEM with a hexapole C_s-corrector (CEOS GmbH) for the probe-forming lens and an in-column Omega-type energy filter has recently been installed at the Advanced Microscopy Laboratory (AML) at Oak Ridge National Laboratory (ORNL). The microscope is intended primarily for high-resolution imaging of catalyst systems that are of interest to the U.S. Department of Energy for increased energy efficiency and energy security. In this paper we report on the high-resolution imaging characteristics of our microscope for both conventional high-resolution TEM and STEM imaging.

The TEM Scherzer point resolution for our objective lens polepiece (C_s = 0.5 mm) is 0.19 nm, but more significantly the information limit has been demonstrated to be better than 0.09 nm, as shown in Fig. 1. This figure shows a Young's fringe experiment carried out on an amorphous Ge specimen which was estimated to be 10 nm thick. The thickness of the sample damps out the Thon rings to some extent, but the information transfer to sub 0.1 nm resolution is clearly evident. The electron wave at the specimen exit surface with resolution out to the information limit of a microscope may be reconstructed via computational processing of a focal [1] or tilt series of images. The extension of the TEM information limit to the sub-0.1 nm range in our microscope can be attributed primarily to the improved objective lens and high tension power supply stabilities provided by JEOL Co. to satisfy our instrument specifications. A contrast transfer function (CTF) calculated using the parameters for our microscope is shown in Fig. 2, computed at the alpha-null defocus condition used for FSR processing [2]. The CTF closely matches the demonstrated Young's fringe pattern, indicating the ability of the microscope to achieve ultimate performance in TEM mode.

Characterization of catalyst systems will be a primary focus of the aberration-corrected JEOL 2200FS and therefore high-resolution STEM high-angle annular dark field (HA-ADF) imaging will be applied to understand the atomic-scale arrangement of supported catalyst clusters. By correcting for the primary resolution-limiting aberration of a round electromagnetic lens - the third-order spherical aberration - smaller electron probes with greater probe current can be formed, with resulting improvements in both the point-to-point resolution for HA-ADF imaging and the signal-to-noise ratio. Both benefits are important for the study of the atomic arrangement of catalyst clusters. Figure 3 shows initial HA-ADF imaging images of very small Pt clusters on a 1.1 nm thick amorphous carbon film. Individual Pt atoms are clearly visible with a high signal-to-noise, as is shown in Fig. 4 [3].

References

[1] A. Thust, W.M.J. Coene, M. Op de Beeck & D. Van Dyck, *Ultramicrosc.* **64** (1996) 211-230.
[2] M.A. O'Keefe, *Microsc. and Microanal.* **7** (Suppl 2) (2002) 916

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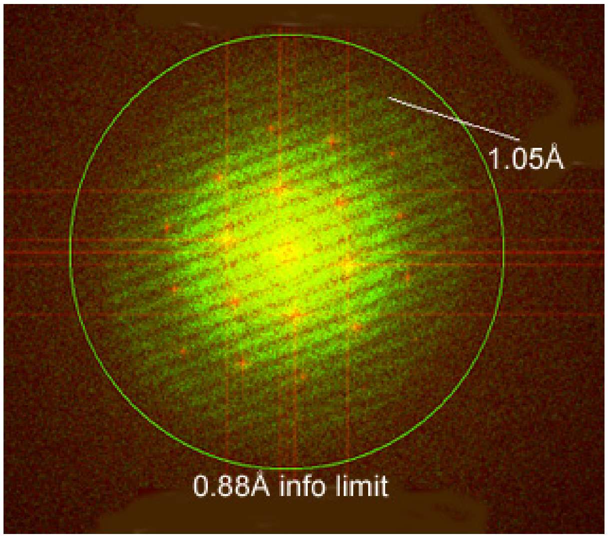

FIG. 1. Young's fringes experiment on amorphous Ge film demonstrating 0.09 nm information limit for the ORNL JEOL 2200FS-AC in TEM mode. Spot pattern is a superimposed power spectrum from a 110 Si single crystal taken at the same magnification

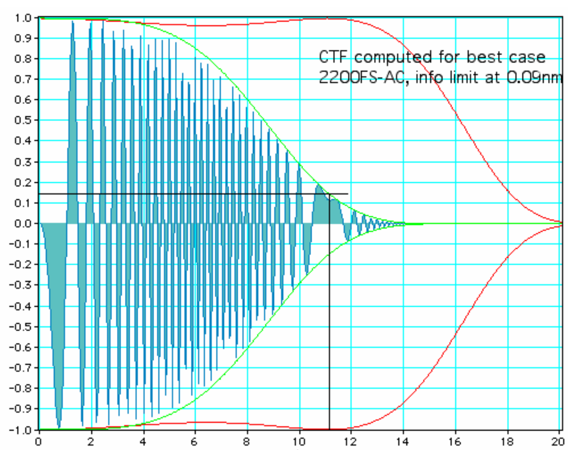

FIG 2. Phase contrast transfer calculation at the alpha null defocus with the parameters of our JEOL 2200FS-AC. Red curve is spatial coherence samping function, while green curve is the temporal coherence damping function.

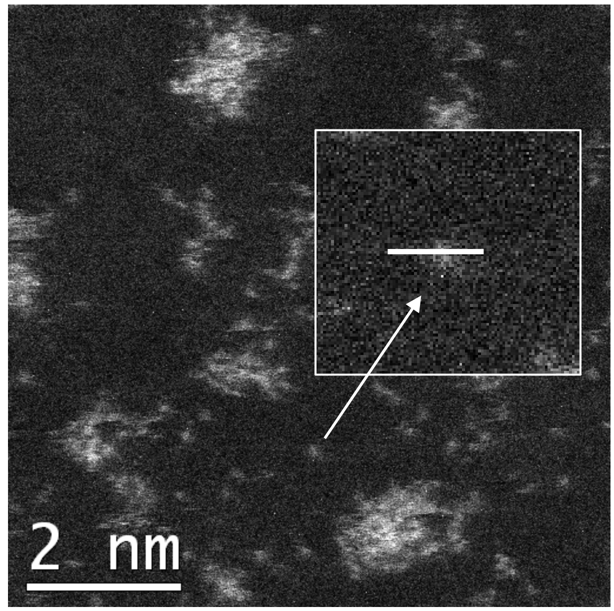

FIG. 3. HA-ADF STEM image of Pt clusters on a 0.11 nm thick amorphous carbon support film. Note the excellent signal-to-noise ratio for imaging individual atoms.

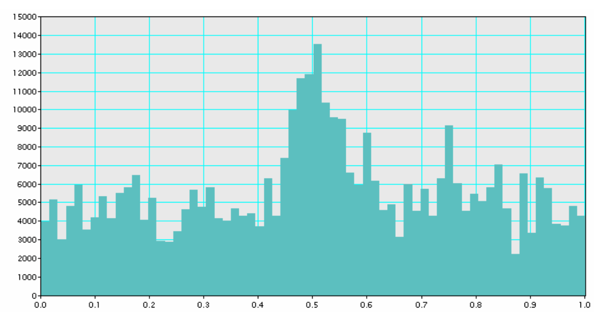

FIG 4 Line trace over an individual atom (inset) in Fig. 3. (FWHM = ~0.1 nm.)

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