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First Application of C_c Corrected Imaging for High-Resolution and Energy-Filtered TEM

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Chromatic aberration has been the limiting factor for TEM experiments where the energy spread of the beam and the coefficient of chromatic aberration of the objective lens (C_c) determine the optical properties of the instrument. This is the case for a wide scope of TEM application such as in-situ experiments, energy filtered TEM, Lorentz TEM, tomography and biological samples. A first prototype of an electron optical system correcting spherical as well as chromatic aberration has been designed [1] and fabricated within the TEAM project. Tests of this prototype have successfully demonstrated correction of C_c for the first time for a TEM with acceleration voltages between 80 and 300 kV. C_c has been corrected by three orders of magnitude. The information limit at 80 kV is enhanced by C_c-correction from 1.8 Å to 1.0 Å.

A major benefit of C_c-correction is that it relaxes the constraint for a narrow energy width to achieve high resolution. Therefore, C_c-correction has a strong impact on energy-filtered TEM (EFTEM) which requires large energy windows between 5 and 50 eV to collect a sufficient number of electrons. C_c-corrected experiments with cross-sectional thin film samples demonstrate a large enhancement of resolution in elemental maps derived from energy-filtered images. Figure 1 shows line-scans calculated from a La map (La-$M_{4,5}$, onset 832eV) across the interface LSAT/$LaCoO_3$ [2] recorded with an uncorrected and a C_c-corrected TEM at 200kV acceleration voltage. The width of the electron energy selection aperture was 50eV for both instruments. The apparent width of the interface can be improved with C_c-correction by a factor of about 5. The gain in resolution by C_c-correction can be exploited for other energy-filtered imaging modes such as “contrast tuning” and “most-probable-loss” imaging. This benefit of C_c-correction can be demonstrated by recording the interface LSAT/$LaCoO_3$ with a wide energy selection aperture of 50eV in the low loss region. High-resolution information is completely lost for the uncorrected state (Figure 2a) while the (001) and (110) lattice planes are recognizable with high contrast if C_c is corrected (Figure 2b).

Beyond the gain in resolution which has been demonstrated for elemental mapping in EFTEM mode and higher spatial resolution for low acceleration voltages we expect further benefits for in-situ TEM, ultra-fast experiments, soft matter imaging, Lorentz TEM and visualizing thick samples. A summary of these benefits of C_c-correction can be found in the literature [3].

References

[1] M. Haider, M. Müller, S. Uhlemann, J. Zach, U. Löbau and R Höschen, *Ultramicroscopy*, 108 (2008) 167
[2] B. Kabius, P. Hartel, M. Haider, H. Müller, S. Uhlemann, U. Loebau, J. Zach and H. Rose, submitted to *Journal of Electron Microscopy*.
[3] B. Kabius and H. Rose, *Advances in Imaging and Electron Physics*, Elsevier, San Diego, 153 (2008).

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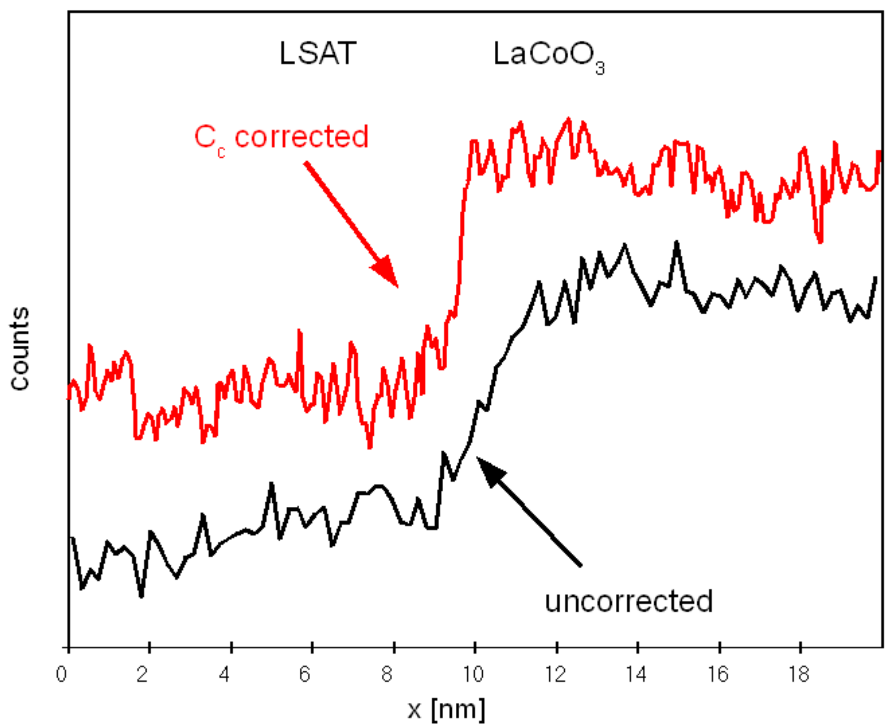

Figure 1: Line-scans derived from elemental maps of La across the interface LSAT/$LaCoO_3$.

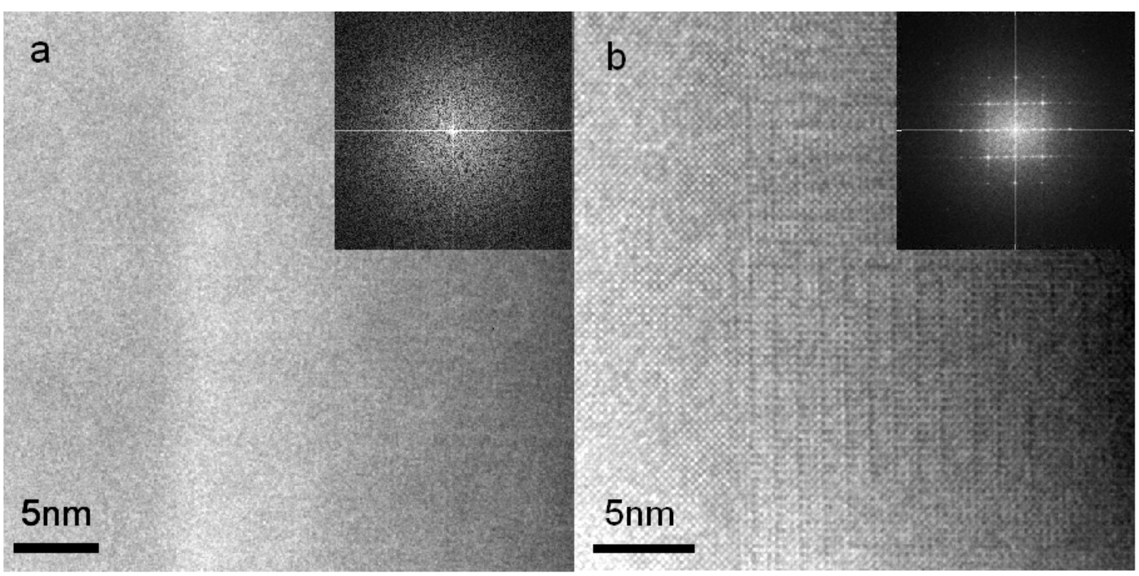

Figure 2: High-resolution energy filtered images in the low-energy loss range: a) uncorrected Tecnai F20 ST b) C_c-corrected FEI Titan 80-300, both operated at 200kV.

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