Advantages of Cs-correctors for Spectrometry in STEM


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Recent theoretical calculations and practical experiments have proven that high-angle annular dark-field (HA-ADF) imaging is significantly improved due to the incident probe refined by a spherical aberration corrector (Cs-corrector) in scanning transmission electron microscopes (STEMs) [1]. The Oak Ridge group has achieved the sub-Å image resolution using a 300 keV Cs-corrected STEM [2]. For microanalysis via electron energy-loss spectrometry (EELS) and/or X-ray energy dispersive spectrometry (XEDS), the major benefit due to the Cs corrector is also improvement of spatial resolution in analysis. For the EELS analysis, it is possible to achieve atomic-level spatial resolution even in conventional STEM instruments and further improvements have been demonstrated by the Cs-corrected STEM [3]. Figure 1 shows a HA-ADF STEM image of Si<110> (a) and an EELS spectrum around Si K edge (at 1839 eV) (b) obtained with the beam current of 50 pA in a 200 keV JEM-2200FS STEM/TEM at Lehigh University, which is equipped with a CEOS STEM Cs-corrector. It is possible to measure higher core-loss spectrum within a reasonable acquisition time (10 s in this case) while maintaining the atomic resolution (1.36 Å).

In the STEM-XEDS approach, much higher beam currents are required to generate sufficient X-ray signals. Because of enlargement of the probe due to the higher beam current, the atomic-column spatial resolution is not achievable in conventional STEMs. Recently, a VG HB 603 (300 keV) dedicated STEM at Lehigh is upgraded by installing a Nion Cs corrector. Figure 2 shows simulated intensity distributions of the incident probes at 1 nA in conventional and Cs-corrected configurations of the HB 603. By the Cs-corrector, the incident probe can be reduced by a factor of 2.5 (from 1.5 nm to 0.6 nm) even with the same beam current. The theoretical calculation for XEDS shows that the sub-nm spatial resolution is achievable with the 1 nA probe (Fig. 3(a)). Conversely, the beam current can be increased considerably in the same beam size by the Cs-corrector, and hence the analytical sensitivity can also be improved. Fig. 3(b) shows an expected improvement in analytical sensitivity by using Cs-corrected STEMs. It is considered that all these recent developments related to analytical STEMs may permit atomic-level analytical resolution in X-ray mapping.
References
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1.5 nm (FWTM) 0.6 nm (FWTM)

Fig. 1. a HA-ADF STEM image of Si <110> (a) and an EELS spectrum around the Si K edge measured in the JEM-2200FS Cs-corrected STEM/TEM at Lehigh University.

Fig. 2. Simulated images and profiles of the incident probes in conventional (left) and Cs-corrected (right) configurations of the VG HB 603 dedicated STEM.

Fig. 3 (a) Simulated spatial resolution of XEDS analysis of a Cu-5wt%Mn thin specimen in the conventional (dashed line) and the C_	ext{s}-corrected HB 603 (solid line). (b) X-ray signal quality as a function of thickness for Cu-0.12% Mn, measured in the conventional HB 603 (circles) and calculated for the C_	ext{s}-corrected HB 603.