SMART approaches to analytical, Cs-corrected STEM

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The latest generation of spherical aberration (Cs) corrected scanning transmission electron microscopes (STEM) allows electron energy-loss spectroscopy (EELS) data to be acquired and mapped at true atomic resolution [1]. Due to the high currents available by Cs-correction in angstrom sized probes, energy-dispersive X-ray spectroscopy (EDXS) also becomes feasible at atomic length scales. While modern microscopes push the techniques to highest resolution, the practical limitations are, however, increasingly set by the specimen under investigation. Both beam damage in radiation sensitive materials, contamination in all but the cleanest samples, and localized charging effects in insulating materials hamper data acquisition and restrict the maximum exposure time for signal detection and thus the signal-to-noise ratio of the data.

In our work, we use a set of flexible routines to customize data acquisition to the needs of the specimen. In particular, we use the ability to position/scan the probe independently from the spectrum acquisition. This allows the integration of signal from similar areas of interest with one single detector read-out, and thus reduces read-out noise while still enabling low-dose applications as the total electron dose is spread over a larger sample area [2,3].

Three typical applications for this technique are: multi-particle analysis in a matrix, where image contrast is converted into a binary mask of rapidly scanned positions during one spectrum acquisition; extended line scans across – not necessarily flat – interfaces, where each ‘point’ of the line profile is extended as a perpendicular scan along a defined path following the interface; and core-shell particle analysis, where the beam is scanned along the shell of the particles.

While the major aim of the technique is to enable spectroscopy on beam sensitive materials, rapid scanning also proves beneficial in case of micro-charging and contamination, as demonstrated in Figure 1. On a heavily contaminating test specimen, a rapidly scanned ‘extended’ line scan is compared to a standard scan, both delivering the same total electron dose. In both cases, contamination is rapidly grown, but local contamination is kept at an acceptable, rather homogenous level for the extended scan, whereas the standard line scan suffers from ever increasing contamination.

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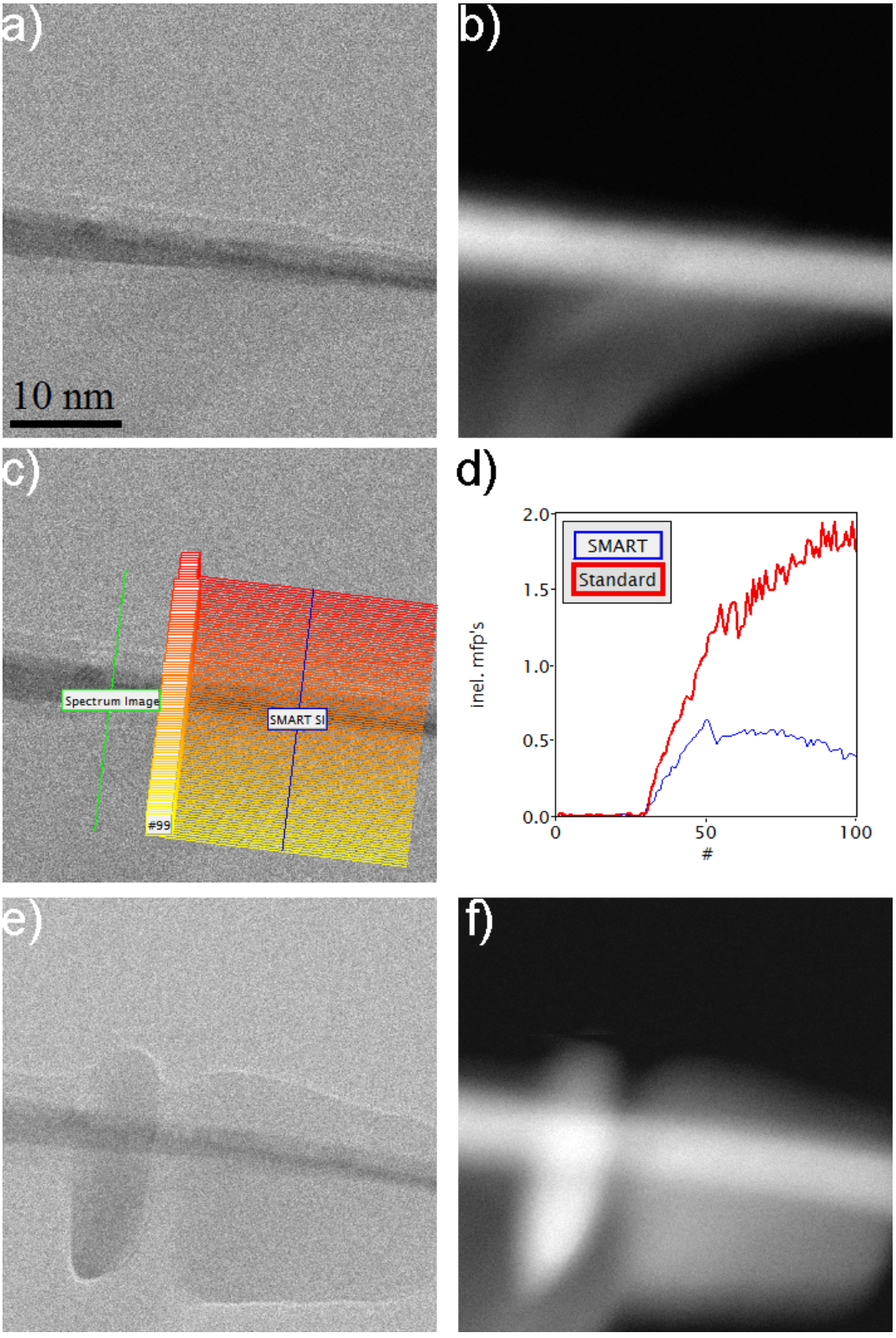

Figure 1. STEM images of heavily contaminating sample as demonstration of different approaches to EELS line scans on layered samples. STEM BF / HAADF images before (a/b) and after (e/f) EELS line scans (100 data points, 0.1 sec pixel dwell time) as indicated in c. For SMART SI, the beam is rapidly scanned along the indicated lines during EELS acquisition. Relative thickness measurements (d) derived from the acquired EELS line scans show difference in accumulated contamination.

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