STEM Tilt Series for Tomography in Scanning Electron Microscope

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Electron tomography is usually achieved by either bright field transmission electron microscopy (BF-TEM) or annular dark-field scanning transmission electron microscopy (ADF-STEM), both of which are usually performed in a TEM setup with high electron beam energy. With slightly different configuration, the ADF-STEM imaging is also available on a standard SEM setup. This opens up the possibility to perform electron tomography also in SEM by performing tilt series of ADF-STEM imaging. However, standard SEM instrumentation is not designed for tomography: the limited tilt range of the stage and detector geometry commonly prohibits imaging with large tilt. To overcome such limitations researchers have constructed customized stage and detector systems, demonstrating the feasibility of ADF-STEM tomography in SEM [1]. In this contribution we report the realization of ADF-STEM tilt series and tomography in a normal SEM setup using a specially designed sample holder but with the standard sample stage and STEM detector.

The configuration of the ADF-STEM imaging is illustrated in Fig.1(a): the sample holder is basically a long arm with the 3 mm grid sample mounted on the edge. This arm is then placed into the gap between the objective lens and the STEM detector (shown in Fig.2(b)). The sample holder is mounted on a standard stage with only one tilt direction, and the holder is rotated to the orientation such that the arm is along the tilt axis. Tilt angle up to 60° can be readily achieved by this configuration. The region of interest is kept unchanged under different tilt angle by either adjusting the sample to eucentric height, or automatically compensating the shift due to tilt by stage x-y axis. As the stage can only achieve 60° tilt in one direction, the tilt to negative direction is achieved by compu-centrically rotate the sample by 180° degree combined with 180° scan rotation to emulate a negative tilt. During image acquisition multiple channels of the STEM detectors are acquired simultaneously to obtain signal from different scattering angles with just one scan, which helps to reduce doses on the sample. Example images from the tilt series on CeO2 nanoparticles are shown in Fig.2. The images are obtained with 30 kV, 150 pA electron beam. The signal from outer segments of the detector (ADF+HAADF) shows reduced diffraction contrast due to crystalline orientation, which will be used for tomography reconstruction.

Reference
[1] V. Morandi *et al*, AIP Conference Proceedings **1667**, 020013 (2015)

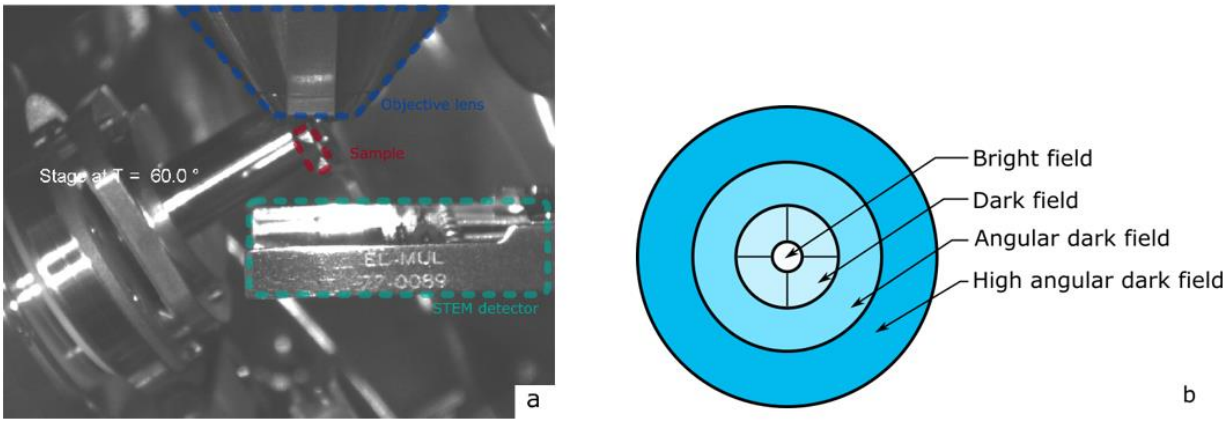

Figure 1: The image (a) shows the 60° tilt configuration of the sample with respect to the objective lens and STEM detector for the tilt series imaged using the infrared camera of the SEM chamber. Different segments of STEM detector are illustrated in image (b).

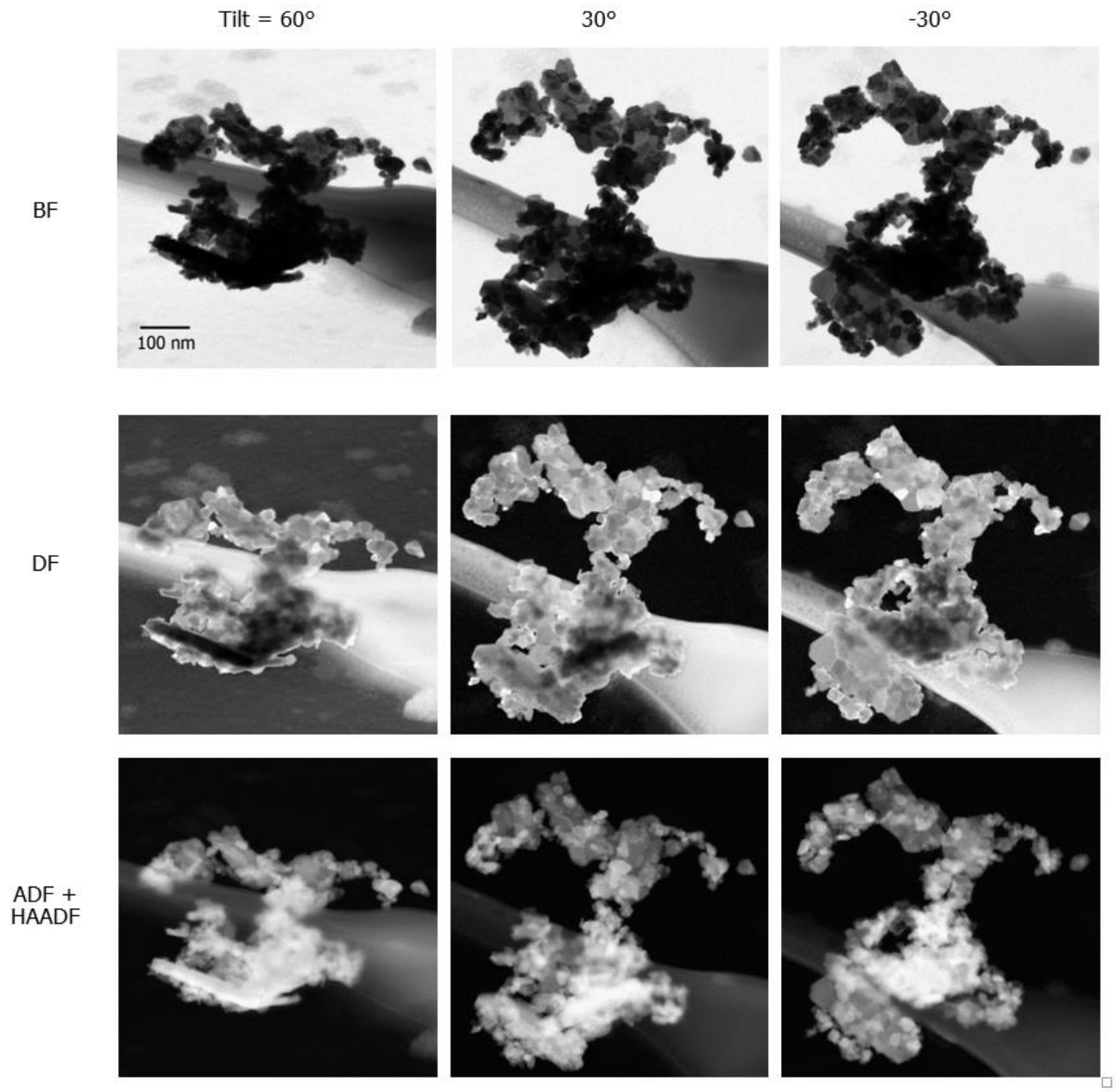

Figure 2: CeO_2 nanoparticles imaged under different tilt angles using different segments of the STEM detector.