

# High-resolution STEM Image Acquisition Method for Tilted Specimen Using a New Type of Aberration Corrector

Wataru Koibuchi<sup>1</sup>, Mr. Ryusuke Sagawa<sup>1</sup>

<sup>1</sup>JEOL, Akishima, JAPAN

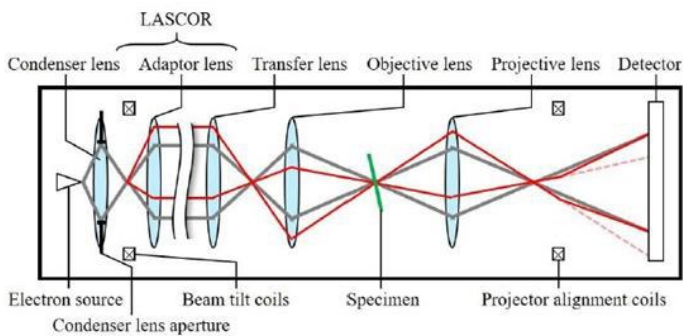
When acquiring scanning transmission electron microscope (STEM) images, it is necessary to align the crystalline zone axis of a specimen tilt with a goniometer and a holder. Since the backlash and drift cannot be avoided in such operations, it is necessary to wait for the drift to settle after aligning crystalline zone axis for a high-quality image acquisition. Therefore, it is desirable to operate a goniometer or a holder mechanically as less as possible. Meanwhile, advances in aberration correction technology have been remarkable and three-hexapole type STEM corrector, Large Aperture STEM Corrector (LASCOR), was recently developed by CEOS GmbH [1, 2]. It is capable of correcting aberrations up to sixth-order three-lobe aberration which had been a limiting factor in the ASCOR corrector. With the LASCOR, the Ronchigram flat area has now been extended to 80 mrad in semi-angle at an acceleration voltage of 200 kV. Thanks to this large flat area, one can align crystalline zone axis using only optical elements (beam tilt and projector shift) of a microscope without any mechanical operation. In this study, we demonstrate a high-resolution STEM image acquisition using this technique.

The procedure is described here how to acquire STEM images of a specimen with a misaligned crystalline zone axis by the proposed method. Firstly, a condenser lens aperture is inserted at the center of the optical axis, and the electron beam is tilted by the beam tilt coils in Fig. 1. This beam tilt appears as the shift of a condenser lens aperture and it can be aligned to the crystal zone axis. The beam is detilted to the center of the detector plane by the projector alignment coils. In this setup, high-resolution STEM images are acquired.

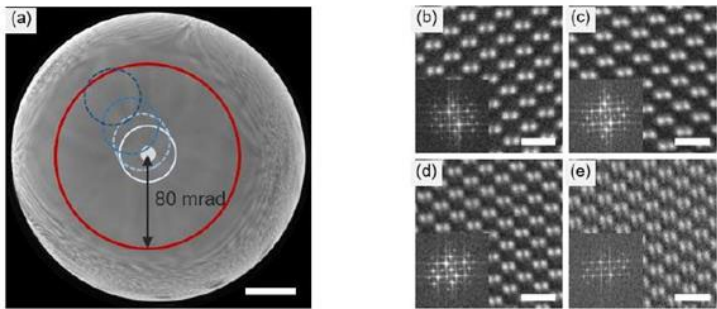
Fig. 2(a) shows an experimentally recorded Ronchigram image with dashed circles indicating the amount of beam tilts used. As the flat area is as large as approximately 80 mrad in semi-angle, the electron beam can be tilted with little influence of geometrical aberrations. Fig. 2(b) ~ (e) show high-resolution STEM images of Si[110] single crystal obtained under different beam tilt conditions corresponding to the dashed circles in Fig. 2(a). It is demonstrated that even for a specimen tilt of over 60 mrad, atomic resolution imaging is achieved by aligning the zone axis using only the optical elements. However, under the tilted conditions, STEM images were blurred in the direction of the tilts, which can also be confirmed in each FFT image. It is assumed that the blurring is due to the effects of the combination of chromatic aberration and beam tilt. Further improvement of image quality can be expected by the use of a monochromator or a chromatic aberration corrector. Although a

specimen tilt causes defocus at the edges of an image and image shrinkage in the direction of the tilt, they can be corrected by changing the defocus during the scan and by a simple image processing, respectively. The correction parameters can be directly calculated by the azimuthal and tilt angles of the beam. The technique introduced here will facilitate an automated acquisition of STEM images and is expected to have applications in the field of semiconductor where it is particularly important to acquire a large number of STEM images quickly.

Graphic:



**Fig. 1.** Schematic ray path in a STEM for specimen with a misaligned crystalline zone axis. The normal ray path is shown in gray and the ray path for a tilted specimen is shown in red.



**Fig. 2.** (a) Ronchigram image with flat area extended to approximately 80 mrad acquired with the LASCOR. White dot indicates the optical axis and dashed circles represent the beam tilts used corresponding to (b), (c), (d), and (e). Scale bar = 50 mrad. (b, c, d and e) ADF-STEM and their FFT images of a Si[110] specimen recorded using a condenser lens aperture with convergence semi-angle of 26.1 mrad under 4 tilt conditions. (b) Without tilt and (c), (d) and (e) with 13.0, 32.0 and 65.2 mrad tilts, respectively. Scale bars = 0.5 nm.

Keywords:

STEM, Cs-corrector, Automation, Semiconductor, Zone-axis

**Reference:**

1. H Müller et al., Microscopy and Microanalysis, 12 (2006) p. 442.
2. S Uhlemann et al., Microscopy and Microanalysis, 28 (2022) p. 2630.