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Atomic-Resolution STEM Imaging of Materials using a Segmented Annular All Field Detector

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Scanning transmission electron microscopy (STEM) has become a commonly used, versatile tool for analyzing atomic-scale structures in many materials science and device engineering fields. In STEM, a finely focused electron probe is scanned across the specimen and transmitted and/or scattered electrons from a localized material volume are detected by the post specimen detector(s) as a function of raster position. By controlling the detector geometry, STEM image formation mechanisms and contrast characteristics can be controlled, producing such imaging modes as bright-field (BF), low-angle annular dark-field (LAADF), high-angle annular dark-field (HAADF) and the recent annular bright-field (ABF) STEM imaging. In addition to these common detector geometries, other image formation mechanisms possible using segmented detectors have been considered [1], and some initial segmented detectors have already been developed [2,3]. Several advantages of utilizing these area detectors for STEM have been proposed, including contrast enhancement [4], aberration correction [5], crystal orientation imaging [6], and magnetic structure imaging [7].

Recently, we have developed new area detector which we refer to as the "Segmented Annular All Field (SAAF)" detector and which is capable of atomic-resolution STEM imaging [8]. This new area detector can obtain 16 simultaneous atomic-resolution STEM images which are sensitive to the spatial distribution of scattered electrons on the detector plane. Fig. 1 shows a schematic illustration of the SAAF detector. In this detector geometry, we can obtain annular bright-field and dark-field images by combining the individual STEM images. Fig. 2 shows $SrTiO_3$ [001] STEM images simultaneously obtained by the SAAF detector. The combined images and a simultaneous HAADF image obtained by a separated annular detector are also shown, clearly demonstrating that we can simultaneously obtain atomic-resolution STEM images from the different detector segments. Note that the combined STEM images are consistent with the expectations for annular detectors spanning the same annular range. Further post-processing of the individual images from the SAAF detector is also possible. These results indicate that this detector can be used for novel imaging techniques such as ABF imaging and differential phase contrast imaging on the atomic scale. Some application results of the SAAF detector for materials characterization will be presented.

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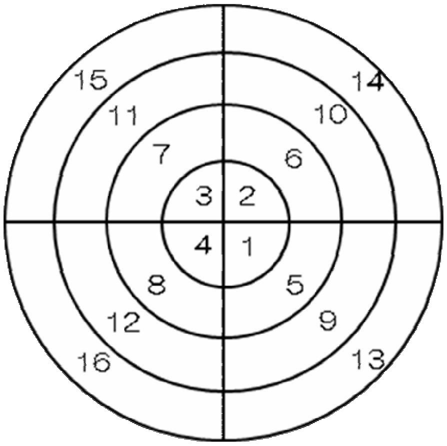

FIG. 1. Schematic illustration of the SAAF detector.

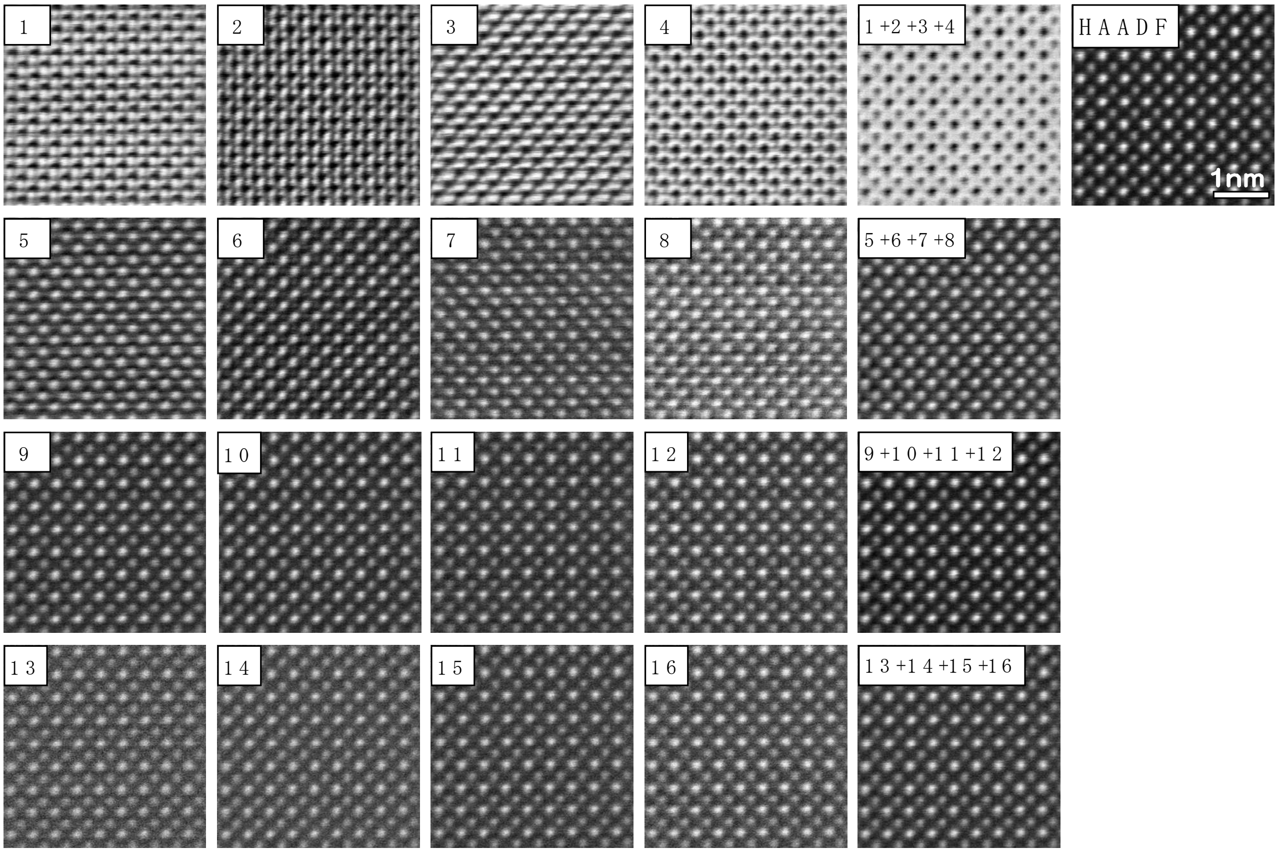

FIG. 2. Sixteen atomic-resolution STEM images simultaneously obtained by the SAAF detector. The sample is a $SrTiO_3$ [001] single crystal. The angle range covered by the whole detector area is 0 - 128 mrad. All the images were filtered using the Radial Difference Filter released by HREM Research Inc.