

Model 3000

Annular Dark Field (ADF) Detector

High-Angle Annular Dark-Field
STEM imaging



EXCELLENCE...MAGNIFIED

Model 3000 Annular Dark Field (ADF) Detector

- *High resolution STEM imaging.*
- *Yields Z-contrast information.*
- *Simultaneous high angle annular dark field imaging and electron energy loss spectroscopy (EELS).*
- *Single electron detection capability.*
- *High quantum efficiency.*
- *For TEMs with active STEM coils.*
- *Fully retractable from the beam path.*
- *Highly accurate and repeatable positioning.*



The Model 3000 is capable of single electron detection.

Highly efficient detection

The Fischione Model 3000 Annular Dark Field (ADF) Detector incorporates a single crystal yttrium aluminum perovskite (YAP) scintillator optically coupled to a photomultiplier tube. Its unique design requires very few optical junctions and yields high quantum efficiency.

In addition, the detector accommodates simultaneous high angle annular dark field imaging and electron energy loss spectroscopy (EELS).

Applications

- Quantitative mapping of elemental chemistries
- Imaging of semiconductors, multi-layered structures, interfaces, and quantum wells
- Grain boundaries, dislocations, and precipitate investigations
- Catalyst characterization
- Analysis of superconductors and geological materials

Specimen preparation

A key characteristic for high-resolution STEM imaging is the quality of the specimen. For the best results from either ADF or high-resolution electron microscopy (HREM) imaging, the specimen should be thinner than 40nm. Thicker materials may limit spatial resolution by broadening the incident electron probe as it passes through the transparent region. Nevertheless, a few nm spatial resolution is still possible in micron-thick samples.

Specimens are prepared using traditional TEM specimen preparation techniques such as electropolishing, ion beam milling, or focused ion beam (FIB). However, the presence of thick amorphous layers on the entrance surface of the sample can severely degrade the quality of lattice images. Furthermore, the specimen must be free from any type of organic contamination, which precludes effective imaging and analysis.

Fischione features a complete product line for the conventional preparation of high-quality TEM specimens, including the Model 1020 Plasma Cleaner that yields atomically clean specimens.

High Angle Annular Dark Field STEM imaging

Images are formed by collecting electrons that have been forward scattered through high angles, typically a few degrees or more, using high angle annular dark field (HAADF) scanning transmission electron microscopy (STEM). Unlike normal dark-field imaging where the signal comes from elastic (Bragg) scattering of electrons typically to smaller angles, the HAADF STEM signal is the result of inelastic scattering of electrons typically to larger angles.

For high angles, elastic and inelastic interactions between the incident electrons and the columns of atoms within the specimen produce image contrast. Since inelastic scattering depends on the number of electrons in an atom, the strength of scattering varies with atomic number.

The Model 3000 ADF Detector was specifically developed to capture these highly scattered electrons. Spatial resolution is determined by the size of the focused incident electron probe. With electron beam sizes of less than 3 Angstroms, imaging at atomic resolution is possible.

The signal is typically collected, amplified, and converted to gray levels. Certain atoms within the electron transparent region of the specimen will appear brighter than others. As a result, it is possible to distinguish between atomic columns made up of different elements. In a HAADF image, brighter spots represent the heavier atomic columns while the less intense spots indicate the lighter atomic columns.

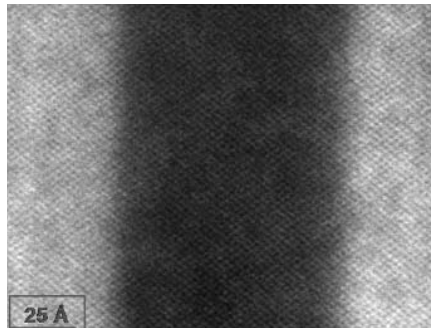
Image interpretation

HAADF is more strongly dependent on specimen thickness than backscattered electron imaging. Specimens possessing significant variations in thickness may show high intensity in the thicker areas. In these cases, the HAADF signal does not necessarily indicate a high atomic number.

In addition, de-channeling of the electron beam can also produce contrast variations from local strain fields, vacancies, dislocations, and changes in crystal tilt. In many cases, these effects can be distinguished from atomic number contrast by comparing a medium-angle ADF (MAADF) image (30 mrad inner angle) with a high-angle ADF image (greater than 50 mrad inner angle). Strain contrast is greater in the MAADF image and lesser in the HAADF image while mass-density contrast is similar in both images.

STEM image resolution depends on the size and shape of the electron beam and the current in the spot. In principle, these two parameters are directly related. Smaller spot sizes possess lower beam currents. An important characteristic in determining the spot size is the stability of the electron probe. Combining a small spot size with a high stability beam yields better STEM image resolution. Modern microscopes possess stable spots down to a few Angstroms, with high beam current density, allowing atomic resolution STEM imaging.

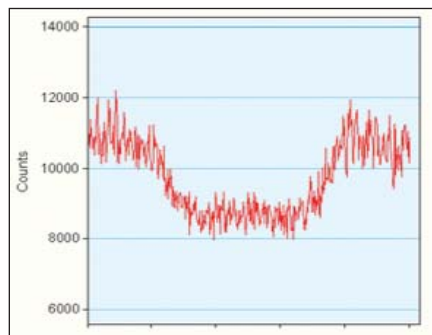
Results



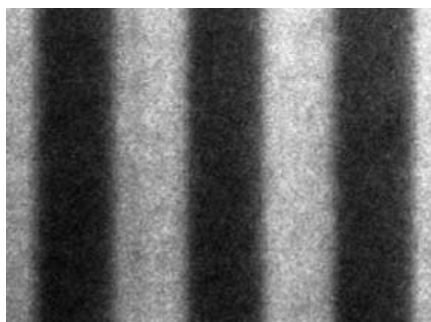
ADF STEM Image of $\text{Si}_{0.81}\text{Ge}_{0.19}$ alloy layers alternating with pure Si layers in a $\langle 110 \rangle$ orientation.

Images courtesy of FEI Company (The Netherlands)

A gradual decay in the atomic number or "Z-contrast" observed between the dark (Si rich) and bright (Ge rich) layers.



Electron energy loss (EELS) data for Ge as a function of position with the expected transitions in chemical composition across the interfaces.



Low magnification image showing a large field of view.

Precise construction

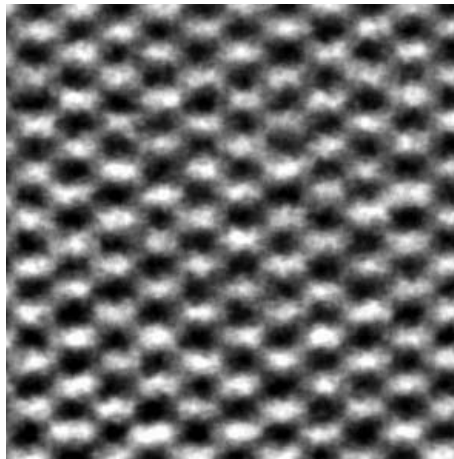
The Model 3000 is pneumatically inserted and fully retracted from the beam path. Precision mechanical parts mean that positioning is accurate and repeatable and operation is extremely reliable. A key component of the reciprocating mechanism is its metal bellows, which ensures the vacuum integrity of the microscope.

The detector is fully self-contained and incorporates effective X and Y adjustments for easy alignment to the optical axis.

If the microscope column contains a port opposite the Model 3000 ADF Detector, other types of detectors or CCD cameras may also be inserted into the beam path.

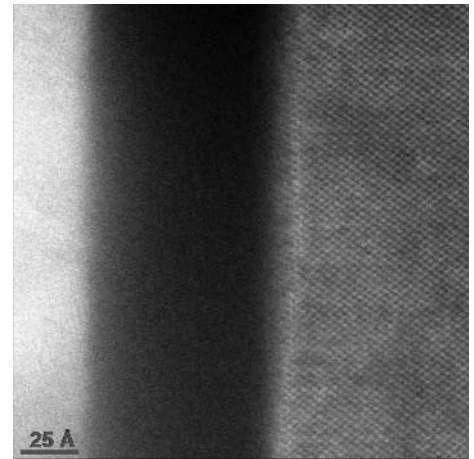
The Model 3000 ADF Detector was developed in collaboration with researchers at Cornell University.

Results



Noise filtered ADF image of Si $\langle 110 \rangle$.

Image courtesy of FEI Company (The Netherlands)



ADF image of the interface of a W plug and Si substrate of a DRAM device. The different layers are clearly resolved with respect to their Z contrast. Amorphous TiN forms a 95Å layer between the bright W (left) and the Si (right). The Si has a $\langle 110 \rangle$ orientation and shows clear lattice fringes.

Image courtesy of FEI Company (The Netherlands)

Model 3000 Annular Dark Field (ADF) Detector

Part number	Description
021-0110-02	Model 3000 ADF STEM Detector; FEI 200kV
021-0111-02	Model 3000 ADF STEM Detector; FEI 300kV
021-0111-10	Model 3000 ADF STEM Detector; FEI 300kV with Collision Protection
021-0146	Model 3000 ADF STEM Detector; Zeiss/LEO 910 and 912
021-0184	Model 3000 ADF STEM Detector; JEOL 2010 — 794 Compatible
021-0217	Model 3000 ADF STEM Detector; Hitachi H-7500
021-0373	Model 3000 ADF STEM Detector; FEI — 794 Compatible
021-0390	Model 3000 ADF STEM Detector; JEOL 2010 — 795 Compatible
021-0399	Model 3000 ADF STEM Detector; JEOL 3000 — 795 Compatible
021-0437	Model 3000 ADF STEM Detector; Zeiss/LEO Libra
021-0440	Model 3000 ADF STEM Detector; JEOL 2100 — 795 Compatible
021-0580	Model 3000 ADF STEM Detector; Zeiss/LEO Libra — Pre-filter



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Cover image: Top; HAADF-STEM lattice image of a LaTiO₃ layer in SrTiO₃. The bottom image is electron transparent and thin enough for ADF lattice imaging over a 0.4-micron field of view. The specimen was prepared by wedge polishing, followed by low angle argon ion milling.

Image courtesy of D.A. Muller, J. Grazul, A. Ohtomo, H. Hwang, Lucent Technologies (U.S.A.)