HIGH ANGEL ANNULAR DARK-FIELD (HAADF) MICROSCOPY

HAADF images are formed by collecting high-angle scattered electrons with an annular dark-field detector in dedicated scanning transmission electron microscopy (STEM) instruments. The contrast of HAADF images is (a) strongly dependent on the average atomic number of the scatterer encountered by the incident probe; (b) not strongly affected by dynamical diffraction effects; (c)not strongly affected by defocus; and (d) not strongly affected by sample thickness variations. Spatial resolution is limited by the size of the focussed incident probe.

Possible Applications

- Characterization of supported catalysts[1]
- Quantitative elemental mapping[2]
- Compositional imaging of semiconductor interfaces,[3] quantum well,[3,4] and X-ray multilayer[5] structures
- Investigation of compositional modulations in superconductors,[3,6] and minerals,[7] etc.
- Imaging surface features on bulk samples[4]
- Observing dislocations,[8] precipitates,[2,8] and grain boundary segregations[2]

Specimen Requirements

Specimen must be thin (<40nm) for most high resolution imaging applications. Samples can be prepared by chemical thinning, ion beam thinning, crushing, etc.

Limitations

HAADF imaging is only quasi-spectroscopic. The image resolution is not as high as that of HREM images. Thick specimens cause beam broadening and degradation of the spatial resolution. HAADF images have a much poorer signal-to-noise ratio compared to HREM images.

Suitable Microscopes

This technique is available on the following instruments:

- JEOL ARM200F
- Nion UltraSTEM
- JEOL JEM 2010F

References

1. M.M.J. Treacy, and S.B. Rice, J. Microsc. 156, 211 (1989); J. Liu and J.M. Cowley, Ultramicroscopy 34, 199 (1990).
2. S.J. Pennycook, S.D. Berger, and R.J. Culbertson, J. Microsc. 144, 229 (1986).
3. S.J. Pennycook, Ultramicroscopy 30, 58 (1989); S.J. Pennycook and D.E. Jesson, UItramicroscopy 37, 14 (1991).
4. J. Liu and J.M. Cowley, Ultramicroscopy 37, 50 (1991); J. Liu, Proc. XII Int. Conf. Elec. Microsc. 1, 33 (1990).
5. J. Liu, Y. Cheng, J.M. Cowley, and M.B. Stearns, Ultramicroscopy (1991); J. Liu et al., MRS Proc. 238 (1992).
6. S.J. Pennycook and L.A. Boatner, Nature 336, 565 (1988).
7. S. Wang, J. Liu, P.K. Buseck, and J.M. Cowley, Proc. XII Int. Conf. Elec Microsc. 4, 398 (1990).
8. J. Liu and J.M. Cowley, Proc. 50th Annual EMSA Meeting (1992).