

II. ELECTRON OPTICS

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1. HIGH-RESOLUTION HIGH-CONTRAST ELECTRON OPTICS: FINAL RESULTS WITH THE FIRST PROTOTYPE AUGER ELECTRON MICROSCOPE (AEM-1)

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Introduction

AEM-1 is the first prototype of an Auger electron microscope, an emission-type instrument capable of identifying the species and resolving the positions of individual atoms in complex molecules and on surfaces. First results with the AEM-1 were reported in Quarterly Progress Report No. 114 (page 12), and further results were presented in 1975 at the annual meeting of the Electron Microscopy Society of America.¹ Final results are presented in this report.

Summary of the Earlier Results

The AEM-1 was constructed to study problems of high-quality imaging with very wide-angle lenses, independently of the complicated problems associated with the production and use of Auger electrons in the system. In AEM-1 the simulated Auger electrons are emitted in the back direction, collected throughout a wide cone (6-9° semiangle), reversed in direction by an electrostatic mirror objective, accelerated through up to 20 kV, and transferred optically to the projection system (see Fig. II-1). The earlier results showed conclusively that our mirror objective accelerator system is a practicable approach to developing wide-angle collection and optical processing for Auger electrons.

Final Results with the AEM-1

The following results, not published previously, are final for the AEM-1:

1. The mirror objective accelerator system has been investigated in depth as a compound objective lens (as compared with investigation as a projection lens in the early work) and has been found to be quantitatively and qualitatively within the expected performance range.

2. The system has a magnification of 30 when coupled to the existing projection system, and this can be extended upward, depending upon revised spacing for the projection elements.

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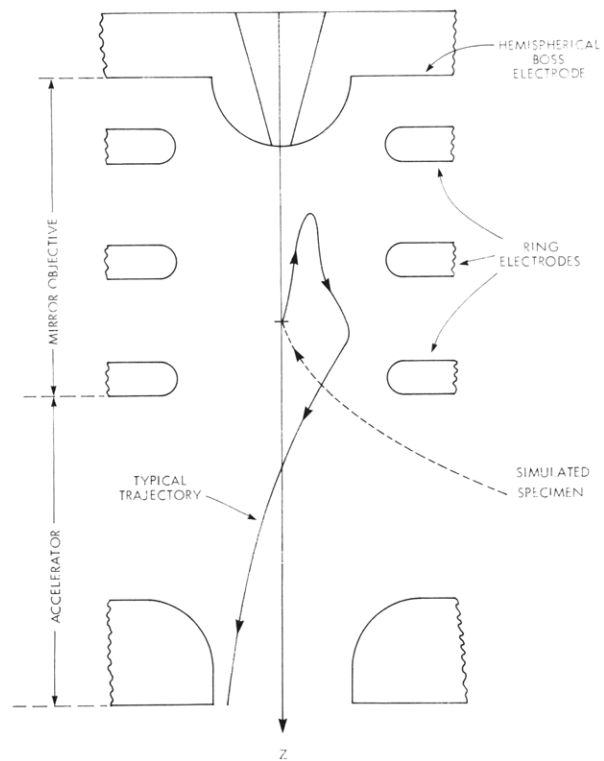


Fig. II-1. Geometry of the prototype.

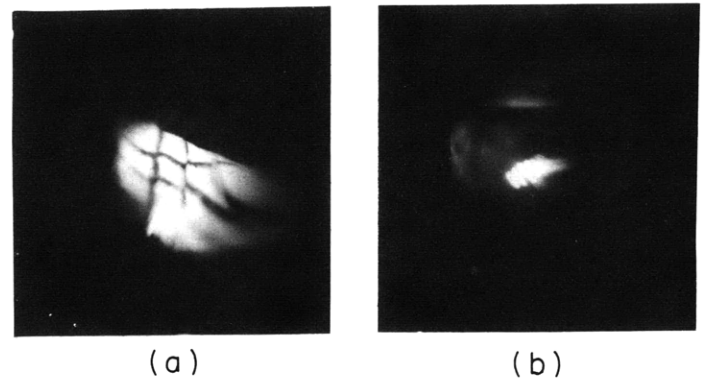


Fig. II-2. (a) 100 mesh/inch stainless-steel woven grid. The weaving of the .001 wire is resolved, and indicates a resolution of 10-15 μm in this totally uncorrected image taken with the mirror objective collecting through a solid cone of ~9° semiangle. The emitting coil (simulated Auger source) is 3 mm below the mesh and the image is out of focus.

(b) Microcoil thermionic emitter (simulated Auger source). The mirror objective has been focused on the coil, which is below the mesh, with the mesh still in position.

3. Optimal potential ratios have been determined for pairs of electrode voltages. These ratios are well within the expected ranges predicted by the earlier computer studies.

4. The energy window inherent in the mirror objective accelerator is ± 40 eV at voltage settings for 300 eV electron input, and ± 90 eV at voltage settings for 1000 eV input. The relatively narrow widths of the windows over the 100-1400 eV input range have somewhat lessened the anticipated background illumination problem.

5. It has been possible to obtain quality images of the simulated Auger source over the 100-1400 eV range, although the resolution is a function of energy with the AEM-1 system, which by design is uncorrected for aberration and unequipped for downstream energy filtering. The optimal voltages on the electrodes throughout this energy range give a consistent picture of the optical mode of operation of the compound lensing system.

6. The attainable resolution of the uncorrected AEM-1 system is of the order of tens of microns. This was the working goal and the theoretical prediction for this scaled-up (4X) first prototype of the final AEM (see Fig. II-2a).

7. The depth of field and focus is such that either the 100 mesh/inch grid (Fig. II-2a) or the electron emitter coil beneath it (Fig. II-2b) can be imaged reproducibly. The optimal voltage differentials for changing from imaging one to imaging the other have been tabulated.

Conclusions

The next prototype AEM, which is now under construction, will use fixed-beam excitation to produce Auger electrons that have energy characteristic of the atoms from which they are emitted. The optical system, scaled-down by a factor of 4, will be essentially the same as that investigated in AEM-1, but will incorporate the changes indicated by our studies and be fully corrected by means of a foil lens² for both chromatic defects and spherical aberration. The information gained through design, construction, and study of AEM-1 has given us the knowledge to make faster progress than we had anticipated, and with the AEM that is now under construction, we hope to investigate silicon in depth profiles with spatial resolutions to a few angstroms.

References

1. J. W. Coleman and E. H. Jacobsen, "Fixed-Beam-Excitation Auger EM with Simulated Specimens: AEM-1," Proc. Thirty-third Annual Meeting, Electron Microscopy Society of America, Las Vegas, Nevada, August 11-15, 1975, pp. 118-119.
2. N. D. Wittels and E. H. Jacobsen, "The Unipotential Foil Lens," Proc. Thirty-third Annual Meeting, Electron Microscopy Society of America, Las Vegas, Nevada, August 11-15, 1975, p. 142.

