II. ELECTRON OPTICS

Academic and Research Staff

Prof. J. G. King
Dr. J. W. Coleman
Dr. E. H. Jacobsen
Dr. M. G. R. Thomson

Graduate Students

N. D. Punsky

RESEARCH OBJECTIVES AND SUMMARY OF RESEARCH

Joint Services Electronics Program (Contract DAAB07-71-C-0300)

J. G. King

We are developing new electron microscope lenses with foil correction for reduction of spherical aberration. This should not only give higher resolution but also, through the identification of the characteristic energy of Auger electrons, higher contrast. These lenses will also make higher current density spots available for electron-beam microprobes.

The objective of our work in electron optics is to produce lenses, possibly retrofittable, that increase resolution and contrast in electron microscopy. At the same time the developmental electron optics group provides necessary support to the molecule microscope project through the development of modular electron sources and related equipment and the solution of various problems in electron optics.

1. Modular Electron Optical Illumination System

A primary research goal in our laboratory is to desorb neutral atoms and molecules from prepared surfaces, with good spatial resolution of the binding sites. To help facilitate this research, we have designed and built a modular electron optical illumination system (EIS) to provide the heat for desorption by means of a programmable, focused spot of electrons. Three such assemblies have been built and tested, and are now being installed on the apparatus used for surface research.

Through a choice of assembly arrangements and operating modes, the EIS allows control of electron spot size, flux, and position. A source module and one or two control modules are used in building up the 10 possible arrangements, and electron spots down to 3 μm or better are obtainable, at working distances of a few centimeters. Beam current can be varied according to whether the source module has a pure thermionic emitter or a field-enhanced thermionic emitter (Schottky source). Because of its staggered double-deflection programming facility, the EIS can also be used as a low-resolution SEM, once a suitable detector is brought near the specimen to read secondaries, back-scattered electrons, and so forth.

2. Multioptical Bench

Laboratories all over the world engaged in such diverse work as research on polymers, semiconductors, and problems of wear and corrosion, and so forth, are increasingly realizing the need to perform multiple microscopy (as well as spectroscopy) upon the same specimen, if not simultaneously at least in very swift sequence. Anticipating this need in our laboratory, we have converted an obsolete electron microscope into a multioptical bench (MOB), with the capability of allowing simultaneous use of the tools of electron optics, ion optics, molecule optics, light optics, and/or x rays to study a given specimen. We have completed the following general instrumentation.

The electron microscope objective has been replaced by a variable-height "pigeon-hole" into which a universal specimen chamber and combinations of other special-purpose devices may be placed on axis. The completed specimen chamber is a vacuum-isolated, independently valved and pumped stainless-steel device with 7 access ports to the work center. We also have designed and built a new state-of-the-art high-energy objective lens for electrons, and a new double condenser system for electron illumination of the sample. We have tried, through a full and comprehensive study of the analysis of optical design needs, to ensure that research in multioptics with the MOB is not fundamentally limited by any aspect of the instrumentation design.

3. Spherical Aberration Corrector Module (SACM)

High-resolution, high-contrast electron microscopy and related electron optical research techniques are powerful tools in several areas of research spanning the whole gamut of natural science. Of particular impact is the effect in the area of materials science research. We aim to increase this impact even more through the development of better (that is, more optically perfect), electron lenses. In particular, we are continuing development of the foil type of spherical aberration corrector, which will be useful for retrofitting the thousands of electron microscopes that are now in use. In this way, we expect to provide increased electron flux for samples in SEM, and, in the case of TEM, to enable increased electron gathering power in the objective lens. Finally, we intend to develop the ultimate magnetic objective, with built-in 100% correction for spherical aberration, which is now the main obstacle that limits resolution.

We have completed the SACM assembly, including foil holders and electrode sub-assemblies, cold baffle, and chamber, and have refined the procedures for synthesis of electron-transparent carbon foils. The main value of the SACM for TEM will be that it improves the resolution of existing instruments from approximately 8 Å to a new level of 4-5 Å. For probe-type instruments, SACM will allow twofold or threefold more current into a given focused spot.

4. Auger Emission Microscope

Our goal is to develop an emission microscope capable of resolving the positions and identifying the types of individual atoms in complex molecules and on surfaces, without the use of heavy metal stains or shadow casting. Of particular interest is the location and identification of atoms with low atomic numbers (for example, carbon, nitrogen, and oxygen) in biological and organic specimens without recourse to isomorphic replacement. We have designed, built, and just begun to test a prototype instrument for low-energy Auger electrons emitted by such light atoms, and we anticipate obtaining the first rudimentary Auger electron emission images within a few months.

Our prototype instrument, whose geometry is based on computer studies, uses a mirror lens that has the theoretical ability to accept and focus electrons with an energy spread of up to 1-2% because of the inherent chromatic aberration correction. For correction of spherical aberration, the facility has been incorporated to use electron-transparent foils. For use in these preliminary characterizations of the optics, we have designed and built a simulated source of Auger electrons (a 300 eV injector) which will simplify data taking, since electrons from other sources (excitation gun, secondaries, etc.) will not be present in the system. We have built a two-lens magnetic projection system for magnifying the Auger image, and are in the final phases of building all electrical circuitry.