the projection of a reticle in the object plane of a microscope. Quantitative measurements are made by observing the displacement of the ghost reticle in a previously calibrated system. The technique may be used on solid or liquid surfaces and does not require that they be highly reflective. It may be used to determine thickness and refractive index of transparent films and, being nondestructive, is of value in studying time-dependent behavior.

The proceedings of this meeting will be published and are expected to be available next fall at $5 per copy through the New York Microscopical Society, located at the Museum of Natural History, 79th Street and Central Park West, New York, N.Y.

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The Electron Microscope and Its Future Development

The first successful operation of an electron microscope in North America was announced in 1939 (*1*). Many of the formidable technical obstacles that lay in the way of obtaining electron optical images at high magnification were overcome in the encouraging atmosphere of E. F. Burton's laboratory at the University of Toronto. Accordingly, to commemorate the anniversary of the announcement, the Burton Society of Electron Microscopists held a special meeting at the university on 16 January 1965. The work of Burton's talented group of students (which included Cecil Hall, J. Hillier, W. A. Ladd, and A. F. Prebus) was described by Hillier (now at RCA, Princeton). The achievement of Hillier and co-workers in rapidly making a modified version of the Toronto microscope commercially available to biologists and physicists considerably influenced the pace of development of ultrastructural investigations.

J. H. Reisner (RCA, Camden) discussed the possibilities of viewing the electron optical image by an image intensifier–television system. It was pointed out that image intensifiers allow electron microscope images to be seen comfortably in a bright room, while the illuminating beam is actually reduced below normal operating intensity. Methods of recording images on video tape and of analyzing the image were discussed. A method of analyzing the final image by means of a pulse-height analyzer system was described. Each line of the TV scan can be separately analyzed to show the number and density of objects in this part of the image. R. K. Ham (McMaster University) reviewed some recent developments in the transmission electron microscopy of thin crystalline films, especially metals, and gave an outline of the principles of diffraction contrast and the use of selected area electron diffraction. R. D. Heidenreich (Bell Telephone Laboratories) discussed the resolution and contrast limitations in imaging single atoms. He used a wave optical approach, based on reconstruction of the diffraction image present in the back focal plane of the objective lens, to show the limitation in resolution due to the spherical aberration of the objective lens. Deterioration of the image due to inclusion of inelastically scattered electrons was also discussed. D. F. Parsons (University of Toronto) discussed biological applications of electron diffraction and, in particular, recent work on the configuration of polyamino acids in very thin, oriented films.

These lectures were followed by a panel discussion about future development of the electron microscope. Possible ways of enhancing electron optical contrast in order to avoid the use of heavy metal stains for biological materials were discussed. J. H. Reisner indicated that most microscopes in present use are not adjusted for maximum contrast. It is possible to find, for a given microscope, accelerating voltage, focal length for the objective lens, and size and position for the objective aperture which will give optimum contrast. Reisner pointed out that all the information necessary for making these adjustments has been published but has never been summarized in a convenient form for the electron microscopist.

Members of the panel agreed that the best approach to increased electron optical contrast was by use of in-focus phase contrast. This appeared more satisfactory than the low accelerating voltage approach, since there would be less damage to the specimen being examined. In fact, it appears desirable to increase the accelerating voltage above present levels (40 to 100 kv) in order to reduce such damage. Ham indicated that an extra-high-voltage electron microscope would enable thicker and more representative metal specimens to be examined with less loss of contrast due to inelastically scattered electrons. Possible methods of achieving phase contrast were discussed by Heidenreich, Hillier, A. F. Howatson (University of Toronto), and Reisner. Reisner considered that since the deposition of contamination (a layer of carbon formed by breakdown of hydrocarbon vapor) on objects in the beam can be minimized by surrounding them with a cooled metal surface, it is now more feasible to maintain a quarter wavelength phase plate in operating condition for a practical length of time. However, considerable technical difficulties in the manufacture of phase plates and in protecting them from damage by the electron beam have to be faced. F. W. C. Boswell (Waterloo University) considered that an improvement in contrast would be useful also, for inorganic specimens, in detecting vacancies and small dislocations in crystalline substances.

Hillier prefaced a discussion on improving the resolution beyond the present 5 Å for nonperiodic structures by asking whether such an improvement could be justified in terms of available specimens. At this level of resolution, the specimen would need to be very much thinner than the present minimum 50- to 200-Å thickness. A clear picture of molecular structure or individual atoms can only be obtained if the film is a few atoms or molecules thick. This would preclude the use of the relatively thick conventional Formvar or carbon support films and would require a different way of mounting the specimen. At present there appear to be more possibilities for improving the resolution of the microscope than for improving techniques for the preparation of specimens. Improvements in the objective lens design were discussed by Boswell, Heidenreich, Hillier, Reisner, and B. W. Schumacher (Ontario Research Foundation). The advantages of superconducting magnet lenses were described. With the use of such a lens, using a few turns of wire, it should be possible to make a dimensionally "thin lens" with the spherical aberration reduced to one-half or one-third of usual values. The high magnetic stability of such lenses was emphasized. Schumacher asked whether a mathematical analysis of strong magnetic and electrostatic lenses with intercombined fields should not be made in the hope of finding systems of smaller overall spherical aberration but still having rotational symmetry.

The early studies of Gabor along these lines were restricted to weak lenses and limited by the fact that computers were not then available. Hillier then brought up the possibility of obtaining a negative spherical aberration lens, suggesting that one type of negative correcting lens (having a very thin charged membrane across the aperture) should be reconsidered now that contamination can be reduced to small proportions. Heidenreich pointed out the necessity for filtering out inelastically scattered electrons. These electrons contain no determinate information about the structure of the object and only cause deterioration in resolution and contrast. However, Schumacher suggested that energy loss contrast is worth investigation where contrast, rather than the resolution, is the limiting factor. The intermediate or final image can be subjected to energy loss analysis in order to accentuate this type of contrast. Reisner pointed out that loss of resolution may also occur due to charging of the specimen. He suggested that a conducting type of resin might be advantageous for reducing charging over thin sections of tissue. More use might be made of thin carbon films evaporated over the specimen. Reisner considered that it would be difficult to neutralize the charges on the specimen with a low-voltage electron gun since the gun itself might cause the specimen to charge up. R. G. E. Murray (University of Western Ontario) indicated that a number of features of present-day microscopes could be improved; for instance, a more efficient phosphor for the viewing screen might be found and a better method of comparing exactly the dimensions of two specimens (or one specimen and a magnification standard) might be devised. There was also some discussion of the difficulties currently experienced by some electron microscopists in preventing significant etching of biological specimens while using cooled-surface, anticontamination devices.

The meeting was adjourned with the resolve to hold further discussions in the near future in Toronto on electron microscope development.

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Reference

1. A. Prebus and J. Hillier, *Can. J. Research* **A17**, 49 (1939); E. F. Burton, J. Hillier, A. Prebus, *Phys. Rev.* **56**, 1171 (1939).