Meetings

Electron Microscopy

New methods for achieving high resolution at the atomic level with the electron microscope were discussed at a symposium held during the annual meeting of the Biophysical Society, Chicago, Illinois, 28 February 1964.

The novel, high-resolution, scanning electron microscope built by A. V. Crewe (Argonne National Laboratories) opens exciting new possibilities for revealing the structure of matter down to the atomic level. The source of the electrons is a cold tungsten tip. The electrons are drawn out and then accelerated by appropriately shaped anode surfaces at +50 kv. The beam is focused on the specimen through two quadrupole and three correcting octupole lenses. Scanning is possible by means of two pairs of parallel metal plates just above the specimen.

The transmitted electrons are passed into a velocity analyzer, and detectors are used to count electrons that have undergone inelastic collision with K-shell electrons in the specimen. The energy losses and the resulting velocities of the scattered electrons are highly characteristic of the atoms in the specimen. Thus, the elemental composition of the illuminated area can be inferred.

As the illuminating beam is scanned, the output from the detectors corresponds to different atoms and can be shown on different television screens. These screens then show the occurrence of the atoms in the specimen. The possibility of showing different atoms in different colors on a TV screen has also been proposed.

The vacuum system of the instrument, in accord with the best current practice, has only metal gaskets and operates with ion pumps at 10^{-9} mm-Hg.

The resolution of the instrument depends on the size of the illuminating spot. Crewe hopes that the spot can be reduced to perhaps 1 Å. His optimism is based on the small effective source obtained with a point filament; this source is about 30 Å if all the electrons are accepted in a 90° cone. If the angle is reduced to 1/10 or 1/100 of this value the apparent source will almost certainly decrease correspondingly. Therefore, the lenses need not demagnify strongly. The quadrupole lens system is suitable for projecting the small source on the specimen because a low spherical aberration is not tied to a short focal length as it is in cylindrical lenses.

The performance of the instrument was illustrated with pictures of gold particles on carbon films. The detectors tuned for gold scattering gave a bright field picture of the gold particles which appeared as dark spots through the detectors tuned to the unscattered beam. Until now high resolution work has not been attempted.

In reviewing the development of the electron microscope, E. Ruska (Fritz-Haber Institute, Max Planck Gesellschaft, Berlin) noted some of the recent important achievements. He mentioned the cold chamber, developed in his laboratory by H. G. Heide, in which the contamination of the specimen is prevented by a cold surface which almost completely surrounds the specimen and makes it impossible for contaminating molecules to strike the specimen. The effectiveness of the device was exhibited by the absence of materials on the specimen even after very long exposure to the beam. The stability characteristics were shown by examination of termaline crystals in which the 8.9 Å planes were clearly resolved. However, after very long radiation, the crystal structure was destroyed; this was indicated by the disappearance of the regularly spaced planes. This type of damage to the specimen at present is not clearly understood.

Ruska described the attempt made in his laboratory to construct a lens that conformed to the optimum design developed by Glaser. Such a lens requires a closer spacing of the pole pieces than is currently used and it operates with a higher magnetic field. The theoretical resolution limit is about 2 Å, which is two times better than currently available. This device is now under construction. He also mentioned the possibility of further improvement of contrast or resolution by the use of phase plates, such as those described by Hoppe and Lenz.

Fernandéz-Morán (University of Chicago) discussed the advantages and problems of low-temperature electron microscopy. With this technique, labile structures can be observed more clearly and thermal vibrations are suppressed. The specimen is kept at temperatures between −140° and −160°C. A point filament is used to obtain a small area of illumination, thus making it possible to retain low temperatures. The method was illustrated by directly examining the phase transitions of ice from cubic to hexagonal form. Preliminary data were presented on the possibility of sectioning unfixed, rapidly frozen, biological tissue. This requires the collection of the sections thus formed from liquid xenon or nitrogen. The former is attractive because it acts as a negative stain. Finally, plans for a cryogenic microscope were presented. This device has the advantages of perfect vacuum, a completely stable set of superconducting lenses, and the absence of thermal vibrations.

Michael Beer (Johns Hopkins University) discussed the attempts of his group to determine the sequence of nucleotides in the nucleic acids by direct electron microscopy. This work, which has three principal phases, begins with establishing the long tangled, nucleic acid molecules in an essentially unraveled form. This operation is now possible by a simple procedure which leads to straight, nucleic acid strands with a base-to-base separation of approximately 6 Å. Such a separation brings this approach within the realm of feasibility. The second stage is the development of selective markers. These markers would attach to one kind of nucleotide at a time and render the marked nucleotides visible in the final electron micrographs. It has been shown that certain diazonium salts are highly guanine specific as are also cupric salts at low *p*H. Osmium tetroxide formed an additional compound with the thymine component of DNA, while the gold chloride ion stained all nucleotides except the thymine and uracil. The third phase of the work includes the collection and analysis of the data. The main problem of this aspect concerns the visibility of the small markers made necessary by the close spacing of the bases. In this connection it was possible to show that a single polynucleotide chain in which one heavy gold atom is attached to every nucleotide is detectable by high resolution techniques. From such data, the level of visibility of single heavy atoms can be directly inferred and these most recent micrographs represent our most reliable statement to date on that quesion.

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Laser Flash Lamps

The use of flash lamps as pumping sources for high-power lasers was discussed at a conference held at Stanford Research Institute, Menlo Park, California, 20 February 1964. The purpose of the conference was to define the present boundaries, both experimental and theoretical, in this specialized field of gaseous discharges, and to delineate promising avenues for future research and development toward the general goal of effective pumping of large laser systems.

As representative of the best available high-power lamps, Stig Claesson (Uppsala University) described his flash photolysis program, oriented primarily toward production of extremely short pulse, high-intensity ultraviolet radiation. Claesson reported on his 6-meter quartz tube filled with oxygen, through which 120,000 joules can be discharged in 180 microseconds (670 megawatts). Actinometric determinations indicate a conversion efficiency of 15 percent from electrical input into photons of wavelengths between 2000 and 4500 angstroms. This conversion efficiency appears to remain constant for any lamp configuration, including his 2.5-cm lamp, through which he has been able to discharge 200 joules in 2 μsec (100 Mw). An important innovation, as compared with more usual flash lamps, at least, is the use of a 2-mm hole, drilled through the base, connecting to a large ballast volume also filled with oxygen at 20 to 30 torr. The purpose, here, is to allow the quartz which distills off the walls of the tube to collect outside the flash lamp, thus continually polishing and cleaning the walls and allowing these lamps to be used for a year or more. Also, data were presented on the well-known phenomenon of brightness saturation in which, for a given photon wavelength, increasing discharge energy finally fails to produce more photons.

Charles Church described Westinghouse's research in high-energy coaxial lamps, with particular reference to absolute spectral irradiance for xenon lamps at various pressures and current densities. Further comment on the "saturation" effect was made. Time-resolved spectra on xenon lamps doped with metallic halides indicated weak enhancement of the major emission of thallium iodide, for example, coupled with an unusually high emission in the normally weak bands, according to Church. He described briefly the use of a coaxial lamp for pumping a neodymium-doped, Eastman Kodak laser glass rod, 30 cm long and 1.3 cm in diameter. Efficiency of 0.5 percent up to an output of 95 joules was reported.

John Emmett (Stanford University) summarized direct measurements of the opacity of a PEK XE-17-6½ xenon lamp. The gas pressure is 300 torr and the tube diameter is 12 mm. Data obtained by Emmett, Schawlow, and Weinberg on the transmission as a function of wavelength from 2500 to 10,000 Å and at current densities up to 5000 amp/cm², show that absorption increases with current and with wavelength. Above 5000 Å and a current of 4000 amp/cm², a discharge tube 1 cm thick is nearly opaque. For shorter wavelengths or lower currents, the discharge is fairly transparent.

Efforts to utilize nonthermal excitation of the optical radiators through the use of a theta pinch discharge were described by J. M. Feldman (Carnegie Institute of Technology). By this method, current densities of 10^6 amp/cm² are obtained in a 400-joule, 1-μsec discharge, radiating from a 9 cm² surface area. Electron temperatures of 360,000°K are inferred from comparison of several lines of known statistical weights, assuming a Maxwellian energy distribution. Direct measurements of resistivity, using a relationship developed by Spitzer, appear to confirm this theoretical value. Following this paper, a lively discussion ensued, directed primarily toward the interpretation of the data leading to estimates of electron temperature. Spectroscopic data on lines such as argon I and II, which were fairly dense, would, it was remarked, make it impossible for such high electron temperatures to have existed. This controversy was allowed to develop further during the afternoon, since the advantages of an electrodeless, cool-wall, high-spectral radiation lamp are manifest.

Reviewing recent work at the Naval Research Laboratory, Alan C. Kolb discussed double-pulsed techniques similar to those of Emmett and Schawlow, and pointed out that at wavelengths below 3000 Å the ultraviolet enhancement remains for a long time after the short second pulse has terminated. He observed that, with xenon at a pressure of 100 to 400 torr, the total power emitted, due to silica distilled from the walls in the 2000- to 3000-Å region during the short pulse, is comparable to the entire output above 3000 Å. Kolb further described T-type shock tubes which, operating in helium at 10 to 50 torr, produce 100 kw/cm² for every 100 Å of bandwidth in the near ultraviolet. Nearly all of this portion of the spectrum was described as being silica line spectra. A new mechanism for lamp damage was also described. The intense line radiation below 1900 Å is absorbed within 0.1 mm of air external to the tube, thus producing a hot layer and a pressure pulse, which results in destruction of the tube wall by external shock. Theta pinch calculations coded for use with an IBM 7090 were also reported as a part of the NRL activities.

H. Koenig (General Electric) reported on attempts to use xenon lamps doped with gallium and thallium iodide. As might now be anticipated from the opacity measurements reported above, little enhancement can be observed for reasonably large bore tubes.

Attendance at the conference was limited to approximately 40, including scientists from the research departments of companies presently engaged in manufacturing flash lamps or holding government contracts in this area, as well as university and government researchers. Six invited papers occupied the morning session, while the afternoon was devoted to an informal discussion among all participants. Arthur Schawlow served as moderator of the afternoon session. He called first for