PHYSICS

Shooting Electrons

Auxiliary equipment for electron microscope enables scientists to push back frontiers in exploring new field of electron optics. Methods have important war uses.

By DR. MORTON MOTT-SMITH

➤ PHYSICISTS on war fronts of science train four new weapons on our enemies at home and abroad.

Shooting electrons instead of bullets, these laboratory instruments will see service in the sub-microscopic world—that land beyond the reach of ordinary light microscopes.

Results of scouting activities with the new electron miscroscope (magnifying 40,000 times and more) have turned the march of science into new channels of attack. Out of the nation's laboratories have come strange-sounding tales of what was seen on the new frontiers revealed by the electron microscope.

But now new instruments developed for use with the electron microscope not only show physical appearances—they reveal composition and structure of sub-microscopic particles. Scientists can also look at impenetrable substances, such as war metals, at gigantic magnifications—a former impossibility.

The first of these instruments is an "adapter" which quickly converts a standard electron microscope into a diffraction camera. By measuring how much the electron particles are turned from their path, or diffracted, by the atoms in the specimen, physicists can piece together how these atoms are arranged in the object observed. This principle has been used in the past apart from the microscope to explore the crystal and molecular construction of matter.

Double Duty

Now by a slight twist of controls, the same instrument which can "see" and take the portrait of even large single molecules, can be used to peer still deeper to reveal the fundamental structure of matter.

The scanning microscope, another new device, "scans" the specimen television fashion. It holds out the possibility that electron microscope pictures will one day be transmitted by radio or wire. Meanwhile, it vastly improves the examination of opaque objects, such as the surfaces of metals, revealing details of enormous importance in providing better metals for our ships, tanks, guns and planes.

An older device for the same purpose has recently been greatly improved. This is based on making a thin plastic replica of the surface, the same principle used to prepare permanent replicas of snowflakes. The copy, being transparent to electron rays, is viewed in the microscope in place of an opaque object, which cannot be used.

The "adapter" and scanning microscope were both developed in the RCA research laboratories.

Electrons "Tire"

The electron spectrometer, another instrument used with the microscope, aids in identifying and determining the composition of the materials examined. It was developed at Ohio State University by Dr. Albert Prebus.

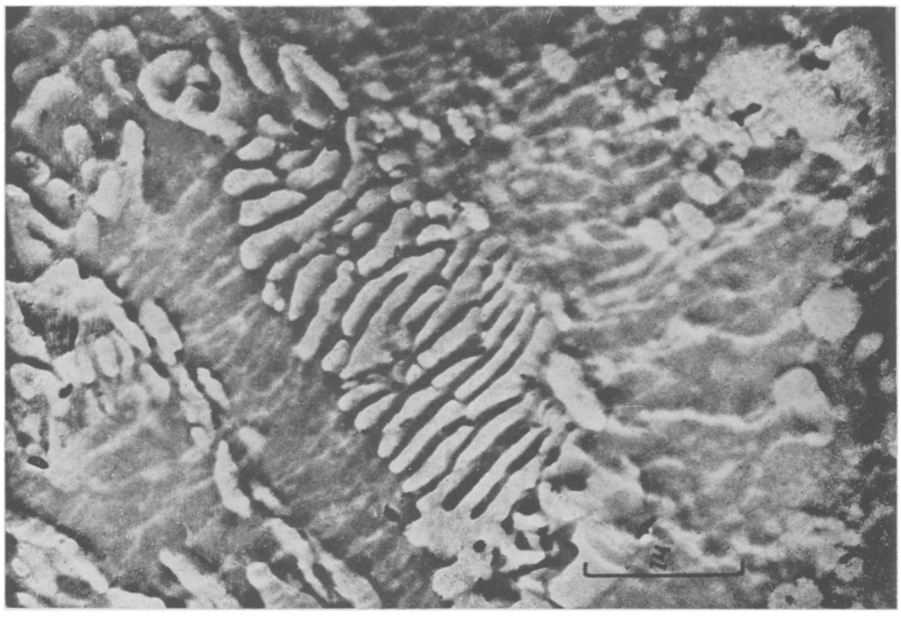
As the electrons are shot through the specimen, some of them get "tired" and lose more energy than others. This depends on the chemical nature of the elements through which they must shoulder their way. This pattern of resultant energies is constant for specific substances and can be used to interpret the composition of the specimen.

Gold and Mosquitoes

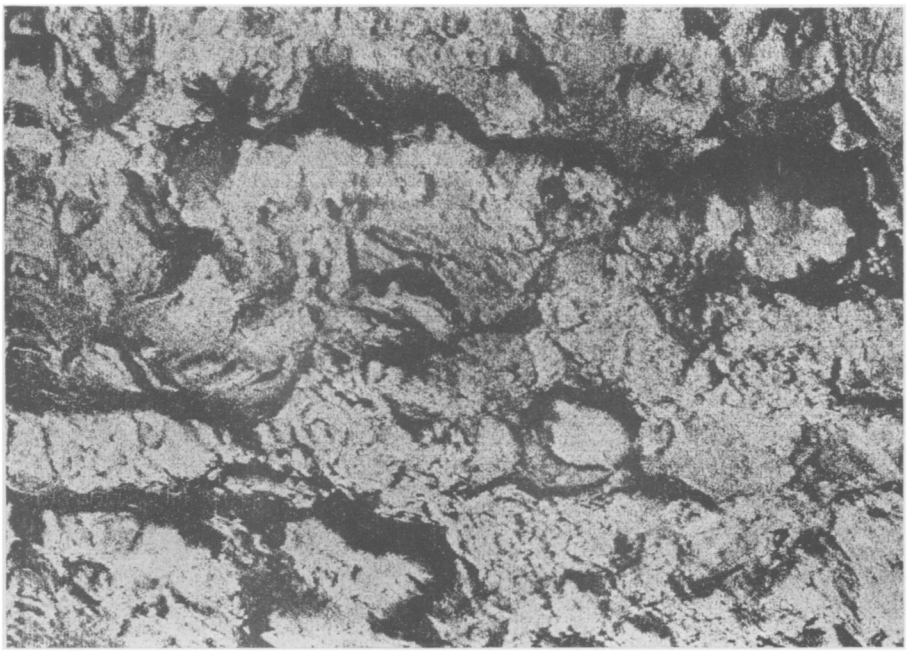
While these four new devices were being developed, the all-seeing eye of the electron microscope was looking at anything and everything that could withstand the vacuum and a shower of electrons—from the breathing tube of a mosquito to colloidal gold particles as small as 1/2,000,000 inch diameter.

There is hardly a field of science where the extra-acute vision of the electron is not of tremendous advantage. Physics, chemistry, biology, medicine, engineering and agriculture, all have benefited. In the scrutiny of metals, clays, plastics, synthetic rubber and other materials astonishing things have been revealed.

Specks of rouge and of some kinds of face powder were found to be as rough and jagged as lumps of coke.



ETCHED STEEL, .4% carbon content, is shown as it appears under the electron microscope using a replica prepared by the "snowflake" technique developed by Vincent J. Schaefer and David Harker at the General Electric research laboratory. The magnification, as shown, is about 25,500 diameters.



***ETCHED NICKEL** is shown in this photograph from the RCA laboratories, as it appears under the scanning electron microscope. The smallest detail visible, measures about two-millionths of an inch. The scanning method was developed by Dr. V. K. Zworykin, Dr. James Hillier and R. L. Snyder.*

Some kinds of smoke particles were like sharp needles. The developed silver bromide crystal in a photographic emulsion looks like a tangled string. Many things were found to look much different than had been expected.

Kaolinite, chief constituent of kaolin, white clay used in chinaware and which can also be used as a source of aluminum, was found to consist of six-sided plate-like crystals instead of the rod-shaped crystals previously supposed. Different clays exhibited a great variety of crystal shapes unrevealed by the ordinary light microscope. More than 2,000 electron photographs have been made of clay particles by Dr. Byron T. Shaw and associates at Ohio State University.

In medicine, the electron microscope revealed the fine internal structure of disease germs. Even the germs themselves can scarcely be seen with a light microscope.

The influenza virus which is of molecular size, and may indeed be a single huge molecule, has also been seen for the first time.

Germicide Action

A recent triumph was the showing of just what happens when a disease germ is attacked by a germ-killing agent such as bichloride of mercury. This was observed by Dr. Stuart Mudd of the University of Pennsylvania, and Dr. Thomas F. Anderson of the RCA Manufacturing Company, and is reported in the Journal of Experimental Medicine.

When a typhoid fever germ is attacked by silver nitrate, the flagellae which serve the germ as propellers are destroyed, the protoplasm becomes black, and the entire germ shrinks. With the chemical lead acetate, however, the germ swells and protoplasm, the life-stuff of the organism, escapes through the cell walls.

Wavelength Shorter

Here is why we can now observe these formerly invisible details by using the electron microscope.

The smallest object that can be seen in any microscope depends on the wavelength of the light or electrons used. The average wavelength of visible light is about 1/50,000 inch. Objects only slightly smaller than that can be seen.

Electrons, although particles, act also like waves and have an equivalent wavelength. This depends on how fast they are going, and this in turn depends on the voltage applied. Thus, 55,000-volt electrons have a wavelength of only about 1/500,000,000 inch.

Electron lenses, however, are not as perfect as optical glass lenses and do not reach anything like the theoretical limit. The smallest objects so far distinguished are about 1/5,000,000 inch in size.

The diffraction camera, into which the electron microscope is converted by means of the "adapter," produces a pattern of concentric circles from which the spacing and arrangement of the atoms in the specimen can be determined.

For the present, the scanning microscope receiver consists of a facsimile printer such as is used for sending pictures by wire or radio. The reason for using this in place of a television receiver is to slow down the scanning rate.

No Response

The trouble with fast scanning is that in this work the beam must be focussed to a submicroscopic point or spot 1/2,500,000 inch in diameter, an extremely difficult job in itself. The area covered by this spot is the smallest detail that will be distinguishable in the magnified picture. At television speeds it was impossible to get enough response from this small spot to affect a receiver.

Even at the slower speed of the facsimile printer, the impulses had to be amplified 1,000,000 times to operate the instrument. This again would have been impossible with any ordinary amplifier, but the electron multiplier, which Dr. Zworykin of RCA has perfected, does the job.

But while the scanning microscope cannot broadcast pictures directly, and perhaps never will, it has been found to be a definitely superior instrument for the examination of opaque objects.

The ordinary electron microscope can use only transparent objects, for the rays must pass through the specimen. Two ways of getting around this have been devised. One is to tilt the opaque specimen so that the rays are grazingly reflected and so pass on to the viewing screen. But this produces distortion.

The other way, already mentioned, is to make a thin transparent plastic replica of the surface, which can then be used in the microscope in the usual way. But this, it is claimed, fails to reproduce the finest details.

Recently, however, the technique of plastic replicas has been greatly improved by the researches of Vincent J. Schaefer and David Harker of the General Electric Research Laboratories, and reported by them in the Journal of Applied Physics.

These scientists found that the best thickness of replica (*Turn to Page 175*)

Books Just Off the Press

ADAPTING FRUIT AND VEGETABLE PRODUCTS TO WAR NEEDS—W. V. Cruess, M. A. Joslyn and Gordon Mackinney—*Univ. of California Press,* 38 p., 25c.

ALL ABOUT BROADCASTING — Creighton Peet—*Knopf,* 67 p., illus., $1.75.

ANNOTATED GEOLOGICAL BIBLIOGRAPHY OF VIRGINIA—Joseph K. Roberts—*Dietz Press,* 482 p., $7.50, paper $5.

ATLAS OF THE SCALE INSECTS OF NORTH AMERICA—(Ser. 4)—Gordon Floyd Ferris—*Stanford Univ. Press,* various paging, illus., $6.75, unbound $5.75.

BASIC RADIO; THE ESSENTIALS OF ELECTRON TUBES AND THEIR CIRCUITS — J. Barton Hoag—*Van Nostrand,* 379 p., illus., $3.25.

BIRDS AROUND NEW YORK CITY—Allan D. Cruickshank—*American Museum of Natural History,* 489 p., illus., $1.75.

A BRAND NEW BABY—Margaret A. Stanger—*Beacon,* 132 p., illus., $1.75 (Juv.)

CHEMICAL GARDENING—D. R. Matlin—*Chemical Publishing Co.,* 159 p., illus., $2.25.

CIVIL DEFENSE IN WAR—Mrs. Anthony Billingham — *Transatlantic Arts,* 72 p., $1.80 (Britain at war series).

THE CODEPODS OF THE PLANKTON GATHERED DURING THE LAST CRUISE OF THE CARNEGIE—Charles B. Wilson—*Carnegie Institution of Washington,* 237 p., illus., $2.50, paper, $3.50, cloth.

THE DYNAMIC STATE OF BODY CONSTITUENTS — Rudolf Schoenheimer — *Harvard Univ. Press,* 78 p., $2.

FACTS FOR CHILDLESS COUPLES—E. C. Hamblen—*Thomas,* 103 p., diagrs., $2.

A HANDBOOK OF ALLERGY FOR STUDENTS AND PRACTITIONERS — Wyndham B. Blanten—*Thomas,* 190 p., illus., $3.

HANDBOOK SUPPLEMENT TO SPECIAL LIBRARIES: PART 2 MEMBERSHIP LIST — (Vol. 33, no. 2) — *Special Libraries Ass'n.,* 78 p., $1.

HOME CANNING FOR VICTORY — Anne Pierce—*Barrows,* 106 p., illus., $1.25.

INDUSTRIAL CHEMISTRY (4th ed.)—E. R. Riegel—*Reinhold,* 861 p., illus., $5.50.

MEMORABLE DAYS IN MEDICINE—Paul F. Clark and Alice Scheidt—*Univ. of Wisconsin Press,* 305 p., illus., $2.

MICROBIOLOGY AND MAN—Jorgen Birkeland—*Croft,* 478 p., illus., $4.

MICROWAVE TRANSMISSION—J. C. Slater—*McGraw-Hill,* 309 p., $3.50.

MODERN SANITARY ENGINEERING—George Eric Mitchell—*Chemical Publishing Co.,* 169 p., $5.

1000 PICTORIAL SYMBOLS — *Pictograph Corporation,* 56 p., $2.

PLANE TRIGONOMETRY, SOLID GEOMETRY AND SPHERICAL TRIGONOMETRY—Walter W. Hart and William L. Hart—*Heath,* 124 p., $2.60 with tables, $2.35 without tables.

PUBLIC RELATIONS FOR HIGHER EDUCATION—Stewart Harral—*Univ. of Oklahoma Press,* 292 p., illus., $3.

THE RISE OF MAMMALS—George Gaylord Simpson—*American Museum of Natural History,* 21 p., illus., 25c.

SPITFIRE! THE EXPERIENCES OF A FIGHTER PILOT—B. J. Ellan (pseud.)—*Transatlantic Arts,* 110 p., $1.50.

TABOO, A SOCIOLOGICAL STUDY — Hutton Webster—*Stanford University Press,* 393 p., $4.

THEATRES OF WAR: INDIA, 18 p., AUSTRALIA AND NEW ZEALAND, 16 p., THE NORTH PACIFIC, 19 p., — Institute of Adult Education—*Teachers College, Columbia Univ.,* Series of 3 titles, 40 ea., single copies, 15c.

THE TRIUMPH OF MAMMALS—Edwin H. Colbert—*American Museum of Natural History,* 15 p., illus., 25c.

WAR MEDICINE, A SYMPOSIUM—Winfield Scott Pugh, ed.—*Philosophical Library,* 565 p., illus., $7.50.

WEBSTER'S DICTIONARY OF SYNONYMS—*G. & C. Merriam Co.,* 907 p., $4 with thumb index, $3.50 without thumb index.

WHAT THE CITIZEN SHOULD KNOW ABOUT SUBMARINE WARFARE—David O. Woodbury—*Norton,* 231 p., illus., $2.50.

WHITE BOOK OF THE U. S. FOREIGN POLICY, 1932-1942—Committee for National Morale—*Authentic Publications Co.,* 48 p., 25c.

WOOD AND CHARCOAL AS FUEL FOR VEHICLES—R. Ruedy—*National Research Council, Canada, Research Plans and Publications Section,* 106 p., plates, $2.

• Glances at New Books •

➤ THROUGH the concept of function, algebra, trigonometry, analytic geometry and the elements of calculus are united to a complete college course in BASIC COLLEGE MATHEMATICS, A GENERAL INTRODUCTION, by Carl Wallace Munshower and James Fletcher Wardwell (*Henry Holt*). For those who wish to pursue mathematics further, the book may serve as an introduction.

Science News Letter, September 12, 1942

➤ BY FIRST pointing out the uses of mathematics in our social and industrial life, the authors of LIVING MATHEMATICS, G. M. Ruch, F. B. Knight and G. E. Hawkins (*Scott, Foresman & Company*), aim to make the study of arithmetic more interesting and useful to young children. Intriguing "Side-Trips in Mathematics" give the brighter child a chance to exercise his wits.

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is much thinner than has been used before. It lies between 1/500,000 inch, which is 1/10 the wavelength of yellow light, and 1/300,000 inch.

If thinner than this, the contours on the bottom of the film, next to the metal, will be repeated in less degree on the top surface, and the picture will lack details and contrast.

If thick beyond the flat part of the top surface, there will be extra material on top which will dim and wash out the picture. This technique which Mr. Schaefer originally developed for the preservation of snowflakes will now add its bit to this formidable array of laboratory methods for helping the war effort.

Science News Letter, September 12, 1942