PROBLEMS ASSOCIATED WITH THE CONSTRUCTION OF AN ELECTRON DIFFRACTION UNIT

by

ELDON JOHN MARAK

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INTRODUCTION

Although the applications of electron diffraction are relatively recent, it has offered another approach to the study of surfaces and has also given some experimental verification for the foundation of wave mechanics and justified to some extent its implications to atomic structure. It was not until 1924, when Louis de Broglie (4) conceived the idea that wave motion and moving particles are in some way associated, that this branch of physics emerged.

The wave characteristics of moving electrons allow methods of study similar to those of x-rays, however, this is not to be taken as an indication that cathode rays and x-rays are identical. To state a few fundamental differences, it is well to include that x-rays always travel at a constant velocity c in free space whereas an electron's velocity will be of any magnitude less than this. X-rays have no rest mass and are wholly a form of energy while electrons are elementary particles of matter. In addition, electrons are deflected by electric and magnetic fields while x-rays are not so influenced (16).

The first experimental work done in electron diffraction was by Davisson and Germer (3). They directed a beam of homogeneous electrons of low energy normally upon a single crystal of nickel which was cut with the (111) face in the plane of the surface. The electrons scattered through the Bragg angle were collected with a Faraday cylinder. The results of this experiment gave confirmation of de Broglie's theory. At a later date Thompson and Reid (19) carried out experiments with a beam of fast electrons that indicated the diffraction of electrons by thin films. It was essentially a transmission experiment using a thin sample of celluloid.

Thomson (17) did experimentation with metal films whose structure had already been determined. The specimens were prepared by thinning down commercial foils by use of solvents and also by sputtering metals on collodion and later dissolving away the base. To explain the resulting transmission pattern, it is assumed that a sufficient number of the randomly distributed crystals will be oriented in a manner to satisfy the Bragg equation for a given atomic spacing and thus that the diffracted electron waves will produce concentric rings on the exposed and developed photographic plate. Potentials varying from 10 to 40 kilovolts were used. With the aid of an external magnetic field the pattern as a whole could be shifted showing that the pattern did consist of cathode rays. It was shown that the wave length associated with the electrons, within experimental error, was as predicted by de Broglie's law. This was accomplished by calculating the dimensions of the crystal axes and comparing with data previously obtained by x-ray methods.

Thomson and Cochrane (18) gave reference to work done by Kikuchi with thin films of mica. By use of samples consisting of three different thicknesses, three different types of patterns were obtained. His interpretation of these patterns has since been found to be correct and has aided in the explanation of later work done by others.

Diffraction patterns obtained by allowing the electron beam to strike the surface of a crystal at a glancing angle were first shown by Nishikawa and Kikuchi (13). A crystal of calcite was used for a specimen. A very accurate test of the momentum relationship was conducted by use of an etched crystal of galena. By exercising extreme care in his work, the final error as expressed in terms of charge e was ± 0.10 percent. He assumed that most of the diffracted pattern was produced by portions of the specimen less than 10^{-6} centimeters in thickness. The diffraction unit utilized a slit parallel to the plane of the crystal instead of the conventional pinhole. The resultant diffraction pattern consisted of lines as in an optical spectrum.

A further check on the momentum relationship was made by the use of high energy β rays from a radon source with energies ranging up to 1037 kilovolts. Highes (8) used a spluttered film of gold for a sample and a long solenoid to focus the β rays. Using relativistic mass, his experimental results agreed to within three percent with the values predicted by the momentum relationship.

Theory of Waves Associated with Material Particles

A wave may be defined as an effect having a definite value at some specific place and time, but in general this value is not fixed over a period of time. At some specific point this effect is a function of amplitude, frequency, phase, and time. Two waves having approximately the same wave length form a group. The velocity at which the maximum of the resultant amplitude will advance is defined as the group velocity. The group velocity may or may not be the same as the wave velocity. It was with the group velocity that de Broglie associated the particle.

In developing the wave properties associated with material particles, de Broglie (4) used Einstein's fundamental relation between frequency and energy

$$hf_o = m_oc^2$$

where h is Planck's constant, f_o the frequency associated with the particle at rest, m_o the rest mass of the particle, and c the speed of light. The frequency f_o was regarded as a pulsation in the space immediately surrounding the particle. This may be written as

$$\psi = A \sin 2\pi f_o t_o$$

where t_o is the time measured by an observer at rest with the particle.

Upon substitution of the Lorentz transformation, and comparison with the equation of a wave propagated in one direction only, it follows that

$$V = \frac{c^2}{v}$$

where V is the wave velocity and v the group velocity. Although V is greater than the speed of light, the principle of relativity is not contradicted as no energy is transmitted at the wave velocity.

By substitution of the original relation between frequency and energy, the wave length λ associated with the material particle is given by

$$\lambda = \frac{h}{mv}$$

where m is the apparent mass of the particle and v the velocity at which it moves.

To complete the theory it was postulated that the probability of any particular particle appearing at any given point is directly proportional to the wave intensity at that point. A more complete and rigorous proof of the momentum-wave length relationship may be found by methods adopted by Schroedinger.

Wave Theory as Applied to Electrons

The associated wave length λ of the electrons calculated in terms of the potential difference between the electron gun and the anode was attained by use of de Broglie's law

$$\lambda = \frac{h}{m_o v} \sqrt{1 - \frac{v^2}{c^2}}$$

and the kinetic energy-potential relationship

$$\frac{eE}{300} = \frac{m_o c^2}{\sqrt{1 - \frac{v^2}{c^2}}} - m_o c^2$$

in terms of relativity mechanics, where e is the electronic charge in the electrostatic system of units and E is the potential difference in volts. By eliminating v from the above equations and substituting the values of all constants the following relationship was obtained:

$$\lambda = \frac{12.26 \times 10^{-8}}{\sqrt{E}} \quad \frac{1}{\sqrt{1 + .97 \times 10^{-6} E}} \quad \text{cm}$$

For values of E less than 20 kilovolts an error of less than one percent is made if the equation is written

$$\lambda = \frac{12.26 \times 10^{-8}}{\sqrt{E}} \quad \text{cm}$$

Some Uses of the Electron Diffraction Unit

Investigations suitable for an electron diffraction unit are restricted to the very small penetrating power of cathode rays. Even high energy cathode rays are readily absorbed and inelastically scattered by atoms within the crystal lattice. The depth of penetration of high energy electrons of incidence normal to the surface of a crystal is of the order of 200 lattice planes, whereas at small glancing angles penetration is of about 10 lattice planes normal to the surface. These inherent characteristics of an electron beam, therefore, provide a method of investigating such phenomena as the surface structure of crystals and thin films. Since electrons are so readily scattered, about 10^7 times that of scattered x-rays, the resultant line intensity is relatively great. This allows short exposure times, even for rays scattered from vapors.

One of the first studies made by electron diffraction analysis was on thin films (17). The results of this work confirmed previous work done by use of x-rays on crystal orientation within the film. Additional experimentation on orientation changes of crystals at various temperatures and environments was carried out by Preston and Bircumshaw (14).

Considerable study of both metals and now metallic films have been made. Extensive work done on nickel, which was evaporated on cellulose, gave information on orientation and structure. Marked changes in orientation were found at temperature extremes. Dixit (5) found in all his experiments on evaporated films that the most closely packed plane of atoms assumed a position parallel and adjacent to the surface of the substrate.

It was shown that metals deposited by means of electrolysis on a neutral base of various metals seek the arrangement of the base metal for thin films (6). Thicker films gave evidence of an orientation which is characteristic of the deposited metal.

Various types of oxides have been studied by both the transmission and reflection techniques. Murison (10) investigated copper surfaces which had been heated in a flame. Further work on oxides have been conducted with aluminum, iron (12), zinc, tin, and magnesium.

A study of thin films of greases and oils has been of interest due to the large number of lubrication needs. Murison (11) conducted some of the first experiments on long-chain organic compounds such as oils, greases, and waxes backed on metal blocks. Andrew (1) examined commercial lubrication oils to establish a correlation between the lubricating properties and their diffraction patterns. The properties of graphite as a lubricant were analyzed by Jenkins (9). In all cases it was found that the crystal grains were so oriented that their cleavage planes were parallel to the base surface.

A summary of further applications for electron diffraction analysis may be found in Beeching (2), Sproull (16), and Thomson and Cochrane (18).

CONSTRUCTION OF THE ELECTRON DIFFRACTION UNIT

The electron diffraction unit was designed for temperature studies and for structure studies by transmission and reflection. The unit is a modification of the Thomson-Fraser design and it consists of five main parts: the electron gun, the focusing magnet, the specimen holder, the diffraction chamber, and the plate chamber (20).

The Electron Gun

The function of the electron gun is to provide a homogeneous beam of electrons originating from an effective point source and yielding a relatively high current per unit solid angle. The intensity of the resultant pattern is a function of current density and the resolution is dependent upon the size of the effective electron source. The original design and construction of the electron gun was accomplished by Mr. R. E. Joynson[1], Since only the filament supports were removable, proper alignment of the filament was difficult to attain. A later modification allowed the grid support and filament to be removed as a unit instead of only the filament. In addition, the distance of the anode from the focusing magnet was decreased.

The electron gun is shown in Plates I and II. The filament supports were constructed of brass tubes sealed and insulated from each other by "O" rings. Brass slip-rings insulated with lucite washers allowed longitudinal adjustment of the supports with respect to each other. By either or both longitudinal and

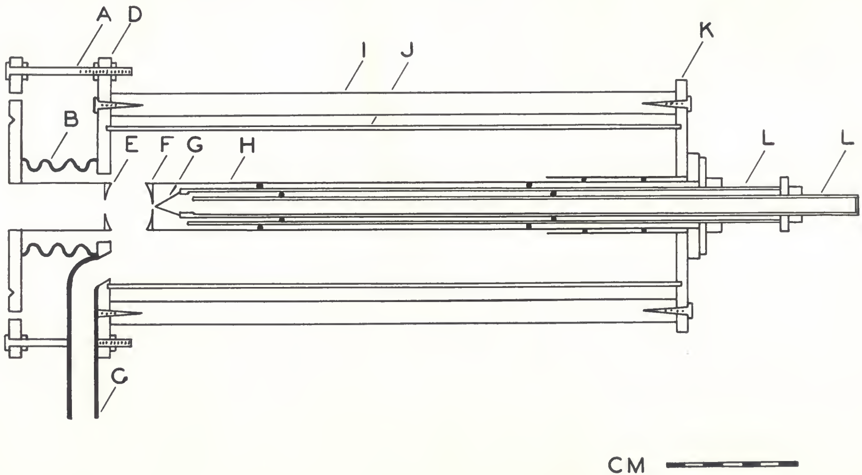
1. Graduate student, Department of Physics, Kansas State College.

EXPLANATION OF PLATE I

The electron gun

A - Adjustment support
B - Flexible bellows
C - Exhaust tube
D - Accelerating anode end plate
E - Accelerating anode
F - Grid
G - Filament
H - Grid support
I - Grid end plate support rod
J - Glass tube
K - Grid end plate
L - Filament support

Plate I



EXPLANATION OF PLATE II

The electron gun and focusing magnet

Plate II

rotational adjustment of the filament supports, the filament could be aligned with respect to the grid.

The filament was made of three mil tungsten wire bent in the form of either a hairpin or a "V". The latter shape was found to yield a more intense electron source. By inserting the tungsten wire in a drilled brass rod and squeezing the rod tip together, a satisfactory mechanical and electrical connection was made. The rods in turn were secured to the filament supports by set screws. A plano-concave copper disc with a 0.33 mm aperture was used for the grid. Copper was used for this purpose since zinc vapor from heated brass leads to an electrical breakdown at accelerating voltages and pressures used in this system (15). The accelerating anode was a plano-concave disc of brass with a 3.0 mm aperture supported on a brass tube.

The grid end plate was supported and insulated by three lucite grid end plate support rods and a 9 cm diameter x 30 cm glass tube. The filament and grid assembly may be adjusted into any position, either transverse or longitudinal, with respect to the accelerating anode by the adjustment support on the accelerating anode end plate and by the tilting of the "O" ring seal on the grid end plate.

An oil-filled x-ray filament transformer was used to supply the current to the filament of the electron gun. The input voltage to the primary winding of the transformer was adjusted by a variac.

The Focusing Magnet

The focusing magnet is shown in Plates II and III. The outer case, including the end plates, was made of ½ inch No. 2 relay iron plate manufactured by the Alleghany Ludlum Steel Corporation. The pole pieces were machined out of Alleghany Ludlum No. 2SS round stock to a 6.4 mm inside diameter. They were arranged within the brass separator to a 3.2 mm air gap. The coil winding contains 6072 turns of No. 23 B&S gauge formax covered wire having a resistance of 54 ohms. Since the pole pieces and outer case are removable, the vacuum seal was made by welding the brass separator to the end plates.

The current was supplied by a 6 volt D. C. battery. Adjustment of the focal length of the magnetic lens was accomplished by inserting a 200 ohm potentiometer in parallel with the coil.

The Diffraction Chamber

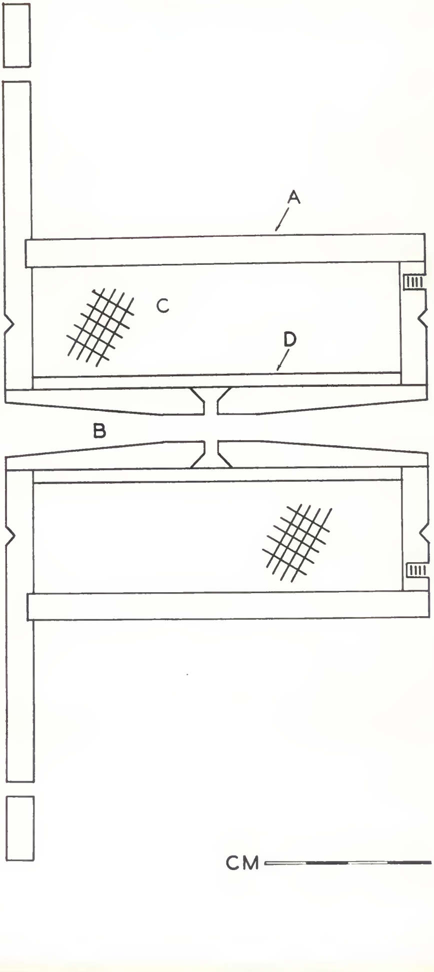
The diffraction chamber is shown in Plates IV and V. A brass tube 20.3 cm in diameter with a wall thickness of 0.32 cm was used for the main tube. The aperture tube, which is secured by a friction joint in the focusing coil, protrudes through the end plate. A 1 cm brass tube having a thin disc soldered on the front end was used for this aperture tube. The aperture opening is 0.32 mm in diameter. Between the end plate of the main tube and the focusing coil was placed a screw-type adjustment which enabled alignment of the focusing coil.

EXPLANATION OF PLATE III

The focusing magnet

A - Outer case
B - Pole pieces
C - Coil
D - Brass separator

Plate III

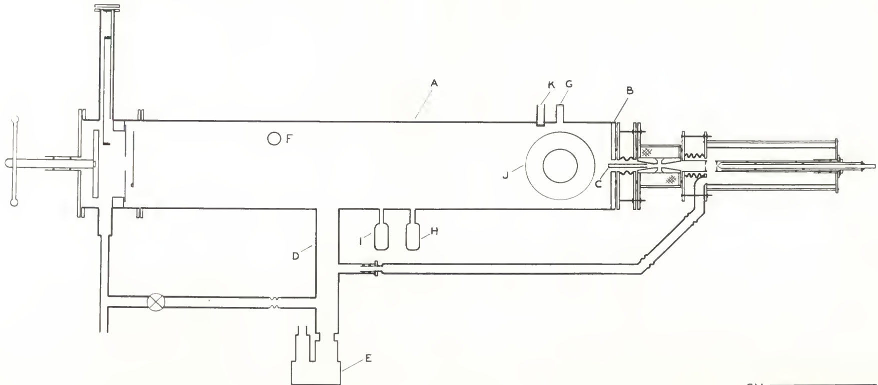


EXPLANATION OF PLATE IV

The electron diffraction unit

A - The diffraction chamber
B - End plate
C - Aperture tube
D - Main exhaust tube
E - Oil diffusion pump
F - Screen viewing port
G - Specimen viewing port
H - Thermocouple vacuum gauge
I - Ionization vacuum gauge
J - Specimen holder support
K - Specimen illumination port

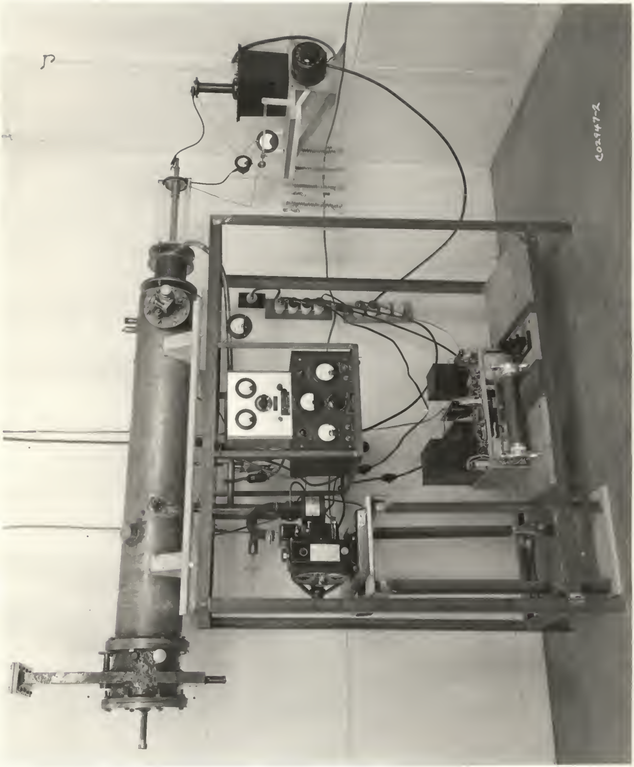
Plate IV



EXPLANATION OF PLATE V

The electron diffraction unit

Plate V



Directly above the specimen a brass tube with a glass window was used for the specimen viewing port. The specimen illumination port protrudes slightly within the chamber. A small light bulb placed inside the port provided sufficient specimen illumination. The screen viewing port, which was originally placed in a horizontal position, is now situated at an angle of about 45° with the vertical and was moved closer to the fluorescent screen. This allowed greater comfort for the operator. The screen viewing port consists of a brass tube with a glass window on the portion outside the main tube. Within the diffraction chamber, a right-angle prism was secured to the screen viewing port in such a way that the complete fluorescent screen can be observed.

The main exhaust tube was centrally located beneath the main tube. A small exhaust tube leading to the electron gun was fitted to the main exhaust tube by use of "O" rings. This allows an easy removal should the electron gun need to be disassembled.

The diffraction chamber was isolated from any stray magnetic fields by inserting within the main tube a sleeve of Mu-metal, manufactured by the Alleghany Ludlum Steel Corporation, Pittsburg, Pennsylvania.

The Specimen Holder

The specimen holder was designed and constructed by Mr. W. G. Wilson. Its function was to provide a convenient method of insertion and withdrawal of the specimen, and to allow proper placement of the sample with respect to the electron beam. The specimen holder is shown in Plate VI.

The axis of the specimen mounting table is situated perpendicular to both the axes of the inner shaft and the electron beam. The chambered periphery of the mounting table was thrust against the beveled polythene drive wheel on the inner shaft. Rotation of the inner shaft by this friction contact allows complete rotation of the specimen mounting table about its axis. This arrangement also permits the mounting of more than one specimen. Transmission samples were mounted on trimmed brass washers which could be grounded to the specimen mounting table.

The specimen mounting table can be oriented in any position about the axis of the inner shaft by use of the tilt control. By clamping the mounting table support on the tilt control shaft, the worm gear drive allowed positive adjustment with respect to this degree of freedom.

Rotation of the threaded cap would shift the sample along an axis perpendicular to the axes of the electron beam and the specimen mounting table. Adjustment of the three vertical positioning controls gave a combination of three degrees of freedom, two perpendicular, and one parallel to the electron beam.

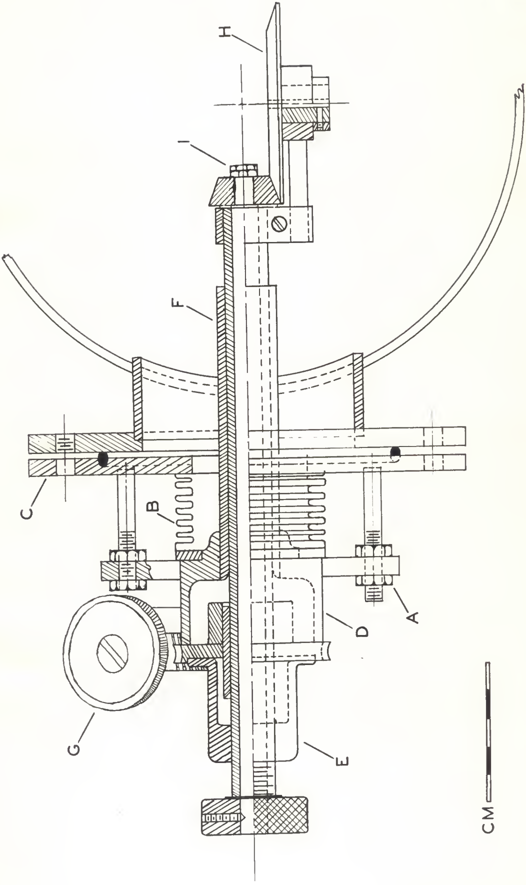
The mounting flange as well as the control shafts were sealed with "O" rings. A flexible brass bellows was used to seal the sleeve case to the mounting flange.

EXPLANATION OF PLATE VI

The specimen holder

A - Vertical position control
B - Flexible bellows
C - Mounting flange
D - Sleeve case
E - Threaded cap
F - Outer shaft
G - Tilt control
H - Specimen mounting table
I - Inner shaft

Plate VI



The Plate Chamber

The plate chamber, shown in Plates VII and VIII, was designed to permit the following: more than one exposure before removing the photographic plate, the insertion or removal of the film from the plate chamber in a lighted room, and the sealing off of the diffraction chamber when photographic plates are exchanged.

The plate chamber housing was constructed of 6.3 mm brass plate with brazed joints. This allowed sufficient rigidity to permit the proper functioning of all movable parts. The plate chamber end plates and the plate chamber valve seat were machined from brass castings. Brass stock was used for the entire component with the exception of the plate chamber valve shaft and the film cassette control.

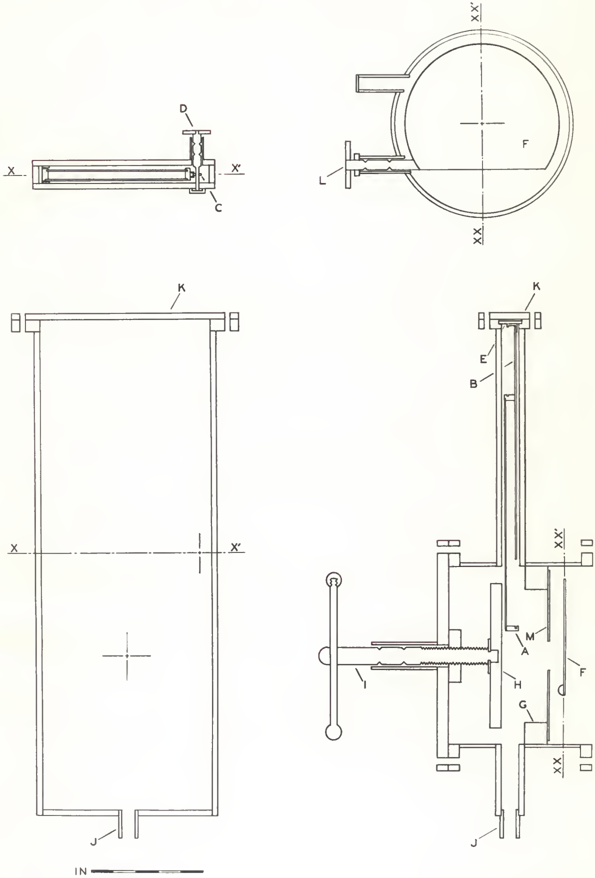
The film cassette was made light proof by allowing the cassette cover to slide in a grooved recess machined in the bottom and edges of the cassette. The film was held in place by screw-type clamps. Upon insertion of the cassette in the plate chamber, the film cassette cover stop would seat in a grooved recess in the cassette port allowing for further positioning of an uncovered photographic plate. The cassette was raised or lowered with a rack and pinion combination. Side plates on the rack allowed the pinion to minimize any motion of the cassette in a nonperpendicular plane with respect to the undeviated electron beam. The end plate on the film cassette slides in a groove in the plate chamber housing.

EXPLANATION OF PLATE VII

The plate chamber

A - Film cassette
B - Film cassette cover
C - Film cassette rack pinion
D - Film cassette control
E - Film cassette cover stop
F - Viewing screen
G - Plate chamber valve seat
H - Plate chamber valve
I - Plate chamber valve shaft
J - Plate chamber exhaust tube
K - Cassette port
L - Shutter control
M - Image border slit

Plate VII



EXPLANATION OF PLATE VIII

The plate chamber

Plate VIII

When the film cassette is raised in its uppermost position, the plate chamber can be isolated from the diffraction chamber by closing the plate chamber valve. Polythene, a chemically inert gasket material manufactured by Du Pont, was used to insure a seal between the plate chamber valve and the plate chamber valve seat.

A Patterson Type B-2 fluorescent screen mounted on a thin brass plate provided a visual means of viewing the diffraction pattern during adjustment and was used for the shutter control.

The removable image border slits allow a series of five 3.2 cm x 12.8 cm exposures to be taken on a 12.8 cm x 17.8 cm lantern slide plate.

When the plate chamber valve is in the closed position, air may be allowed to enter the plate chamber through the exhaust tube. A valve placed in the exhaust line between the plate chamber exhaust tube and the main exhaust tube of the diffraction chamber permits the changing of film without allowing air to enter the diffraction chamber.

All metal to metal welds of the entire diffraction unit were Tobin bronze, silver solder, or soft solder. Glass to metal joints were sealed with Apiezon W wax. All moving and removable parts, with the exception of the plate chamber end plates and the cassette port, were sealed with "O" rings and vacuum wax. The plate chamber end plates and the cassette port were sealed with polythene gaskets. All brazed joints were covered with glyptol.

The Vacuum System

The complete unit was evacuated with an oil diffusion pump backed by a mechanical pump. The fore pump is a Welch Duo-Seal Vacuum Pump, Model 1400B. A Type VMF 10-W oil diffusion pump manufactured by Distillation Products, Incorporated was used to attain a vacuum which was of the order of 9×10^{-5} mm of Hg.

Pressures down to one micron were measured with a Type 501 thermocouple gauge manufactured by the National Research Corporation. Lower pressure measurements were made with a Type VG-1A ionization gauge manufactured by Distillation Products, Incorporated.

The High Voltage Power Supply Unit

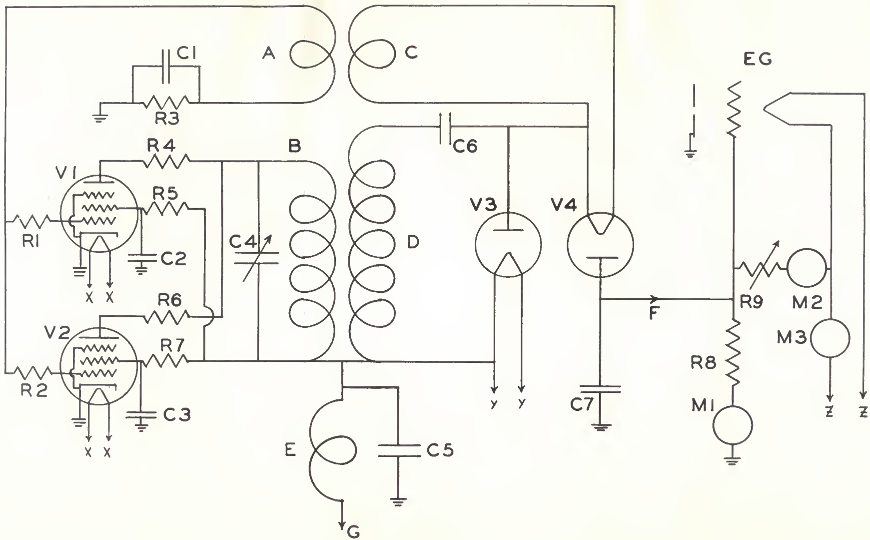
The radio frequency high voltage power supply is shown schematically in Plate IX. The primary winding of the high voltage transformer was used as the plate inductance of the r.f. oscillator. The grid-tickler winding supplies feedback to sustain oscillation. The filament current for the parallel connected Type 6L6 oscillator tubes is supplied by a 6.3 volt A.C. filament transformer. The two rectifier tubes are Type 1B3. The secondary winding of the high voltage transformer was connected to the rectifier tubes which function as a voltage doubling circuit. The filament supply for the doubling circuit consists of two separate sources. The filament supply for the first rectifier tube was supplied by an insulated 6.3 volt A.C. filament transformer. The voltage doubling rectifier tube re-

EXPLANATION OF PLATE IX

The high voltage power supply unit

A - Grid tickler winding
B - Primary winding
C - Filament winding
D - Secondary winding
E - 2 mh choke
F - High voltage output
G - Positive 300 V. D.C. input
C1, C2, C3, C5 - .01 mf condenser
C4 - 500-700 mmf variable condenser
C6 - 300 mmf 30,000 V. condenser
C7 - 150 mmf 30,000 V. condenser
R1, R2 - 500 ohm resistors

R3 - 50,000 ohm resistor
R4, R6 - 10 ohm resistors
R5, R7 - 33,000 ohm resistors
R8 - 150 megohm variable resistor
M1, M2 - 0-1 milliammeters
M3 - 0-5 ammeter
V1, V2 - Type 6L6 vacuum tubes
V3, V4 - Type 1B3 vacuum tubes
XX - 6.3 V. A.C. filament connectors
YY - 1.25 V. A.C. filament connectors
ZZ - electron gun filament connectors


C1
A
C
R3
EG
R4
B
C6
V1
R5
V3
V4
R1
C4
D
C2
X X
R6
R9
M2
F
V2
R7
M3
R8
R2
y y
C7
M1
C3
Z Z
X X
E
C5
G

ceives its filament current from a single winding about the high voltage transformer coil.

The output of the power supply, which was connected to the grid of the electron gun, supplies a maximum negative potential of 24,000 volts. This potential could be decreased by varying the 300 volt input or by changing the screen voltage in the oscillator circuit. The bleeder resistance on the high-voltage output consists of a resistance bank of 300 megohms. The grid bias of the electron gun was adjusted by a one megohm potentiometer inserted between the filament and the high voltage output.

RESOLUTION OF THE ELECTRON DIFFRACTION UNIT

The resolving power of an electron diffraction unit is a function of the lattice spacing of the specimen as well as the physical characteristics of the unit. The following expression for the resolving power was derived by Hillier and Baker (7).

$$\frac{\Delta d_{hkl}}{d_{hkl}} = \frac{1.73\, d_d\, d_{hkl}}{2\, l\, \lambda} \qquad (1)$$

where l is the distance from the specimen to the photographic plate, λ is the wave length associated with the electron beam, d_d is the diameter of the main electron beam at the photographic plate, and d_{hkl} is the lattice spacing of the specimen. The value d_d may be calculated from the expression

$$\frac{d_d}{2} = \frac{d_c m}{2} + \frac{v}{f} K r^3 + S \qquad (2)$$

where m is the magnification of the magnetic lens, d_c is the diameter of the aperture stop, v is the distance from the lens to the photographic plate, k is the spherical aberation constant of the lens, r is the radius of the lens aperture, and f is the focal length of the lens. The variation in spot size, as a result of the specimen entering the beam, is represented by S.

The term d_d may be obtained by neglecting the last two terms of Equation 2. The variation in spot size is negligible since the specimen support was carefully grounded. The radius of the lens aperature is small, and the value of k is of the order of 10^{-2} cm.

By using the values $l = 118$ cm, $\lambda = 0.087$ A.U., $d_c = 0.033$ cm, and $m = 11.3$, the resolving power was found to be approximately $d_{hkl}/32$, where d_{hkl} is expressed in A.U.

The value used for m was calculated from the geometrical thin lens relationship $m = v/u$, where u is the distance from the electron source to the magnetic lens and v is the distance from the magnetic lens to the photographic plate.

It was found that the addition of a second lens to the collimating system greatly improved the resolving power of the electron diffraction unit (7). In this diffraction unit the short focus lens was located between the original lens and the specimen. An additional improvement could be obtained by reducing the size of the grid aperture.

SUMMARY

The following alterations have been accomplished since this thesis problem was started: the accelerating anode and the filament assembly were placed nearer to the focusing magnet thereby allowing a larger beam of electrons to enter the diffraction chamber. The insertion of a brass bellows between the diffraction chamber and the focusing magnet permitted the beam to be easily adjusted as to its direction of entrance into the main diffraction chamber. The substitution of a copper grid eliminated an electrical breakdown, formerly produced by zinc vapor from the brass grid in the electron gun chamber. The addition of a vacuum line to the electron gun made possible the production of a sufficiently high vacuum to prevent an electrical breakdown between the grid and the surrounding components. The resolving power was determined by measurement and calculation. The filament found most satisfactory was three, three-mil, tungsten wires twisted together and then formed into a "V" shape. As a result of the above alterations, the quality of the electron beam was sufficient to permit diffraction studies.

Several methods of sample preparation have been used, but the evaporation technique was found the most satisfactory for controlling the specimen thickness. Thin films of collodion were used to support a thin layer of evaporated aluminum. Magnesium oxide smoked on a collodion film was also used for transmission samples.

ACKNOWLEDGMENTS

The author is indebted to the following people for their cooperation and assistance during this research. Acknowledgment is extended to Dr. R. D. Dragsdorf for his instructive advice and criticism. Special appreciation is extended to Mr. R. E. Joynson for his assistance in constructing portions of the unit. Grateful recognition is expressed to Mr. W. G. Wilson for building the specimen holder, and to Mr. D. A. Rittis for his advice and assistance in the shop.

LITERATURE CITED

(1) Andrew, L. T.
Electron diffraction analysis of the orientation of the molecules of lubricating oils. Trans. Far. Soc. 32: 607-612. 1936.

(2) Beeching, R.
Electron diffraction. London: Mehuen. 1946.

(3) Davisson, C. and L. H. Germer.
Diffraction of electrons by a crystal of nickel. Phys. Rev. 30: 705-707. 1927.

(4) de Broglie, L.
A tentative theory of light quanta. Phil. Mag. 47: 446-450. 1924.

(5) Dixit, K. R.
Investigation of the orientations in thin evaporated metallic films by the method of electron diffraction. Phil. Mag. 16: 1049-1057. 1933.

(6) Finch, G. I. and C. H. Sun.
An electron diffraction study of the structure of the electron-deposited metals. Trans. Far. Soc. 32: 852-858. 1936.

(7) Hillier, J. and R. F. Baker.
On the improvement of resolution in electron diffraction cameras. Jour. App. Phys. 17: 12-22. 1946.

(8) Hughes, J. V.
The diffraction of β-rays. A verification of de Broglie's law for very high velocity electrons. Phil. Mag. 19: 140-145. 1935.

(9) Jenkins, R. O.
Electron diffraction experiments with graphite and carbon surfaces. Phil. Mag. 1934.

(10) Murison, C. A.
Investigation of copper oxide films by electron diffraction. Phil. Mag. 17: 201-225. 1934.

(11) Murison, C. A.
Investigation of thin films of organic substances by electron diffraction. Phil. Mag. 17: 201-225.

(12) Nelson, H. R.
The primary oxide films on iron. Jour. Chem. Phys. 5: 252-259. 1937.

(13) Nishikawa, S. and S. Kikuchi.
Diffraction of cathode rays by mica. Nature. 121: 1019-1020. 1928.

(14) Preston, G. D. and L. L. Bircumshaw.
The effect of heat treatment of the structure of gold- and silver-leaf. Phil. Mag. 21: 713-727. 1936.

(15) Ramler, W. J. and M. S. Freedman.
The scintillation efficiency of anthracene for low energy electrons. Rev. Sc. Instr. 21: 784. 1950.

(16) Sproull, W. T.
X-rays in practice. New York: McGraw-Hill. 1946.

(17) Thomson, G. P.
Experiments on the diffraction of cathode rays. Proc. Roy. Soc. 117A: 600-609. 1928.

(18) Thomson, G. P. and W. Cochrane.
Theory and practice of electron diffraction. London: Macmillan. 1939.

(19) Thomson, G. P. and A. Reid.
Diffraction of cathode rays by a thin film. Nature. 119: 890. 1927.

(20) Zworykin, V. K. and others.
Electron optics and the electron microscope. New York: John Wiley and Sons. 1945.

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OF AN ELECTRON DIFFRACTION UNIT

by

ELDON JOHN MARAK

B.S., Kansas State College
of Agriculature and Applied Science, 1949

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Department of Physics

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

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In 1924 Louis de Broglie postulated a theory which stated that all moving particles have an associated wave length. Many investigators verified this theory with various experiments. By applying de Broglie's momentum relationship to electrons, a useful tool was developed which aided in the study of surface phenomena. Electron diffraction, as this method of research is known, has been used increasingly to study oxide coatings, films, crystal growth, gas molecules, and various surface structures. The patterns formed by the diffracted electron beam are analyzed with the aid of Bragg's law.

The electron diffraction unit which was constructed consisted of the following components: the electron gun, the magnetic focusing coil, the diffraction chamber, the specimen holder, the plate chamber, the power supply, and the vacuum system. The electron gun was designed such that the filament could be easily replaced and the filament and grid could be properly aligned with respect to the accelerating anode. The focusing coil was mounted on the diffraction chamber with an adjustable bellows. The diffraction chamber supported the magnetic focusing coil, the specimen holder, and the plate chamber. Observation ports were placed on the diffraction chamber such that the specimen and the fluorescent screen could be observed directly. The design of the specimen holder permitted a convenient method of changing specimens and of placing the specimen in the electron beam. The functions of the plate chamber were to permit the film to be changed in a lighted room, to permit several diffraction patterns to be recorded on one film, to permit sealing off the plate chamber from the diffraction chamber when the film cassette is removed, and to provide a shutter to control the length of the exposures. The power supply was adjustable up to a potential of 24,000 volts. The vacuum system consisted of a mechanical fore pump and an oil diffusion pump.