Dec. 13, 1955 J. W. COLTMAN 2,727,153

ELECTRON DIFFRACTION CAMERA

Filed June 29, 1949

Fig.1.

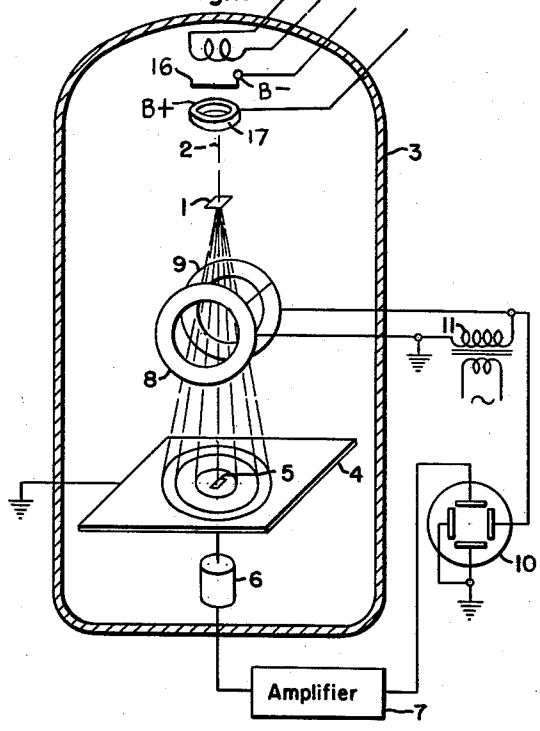


Fig.2.

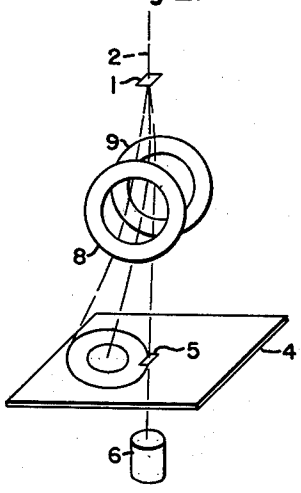


Fig.4.

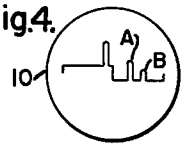
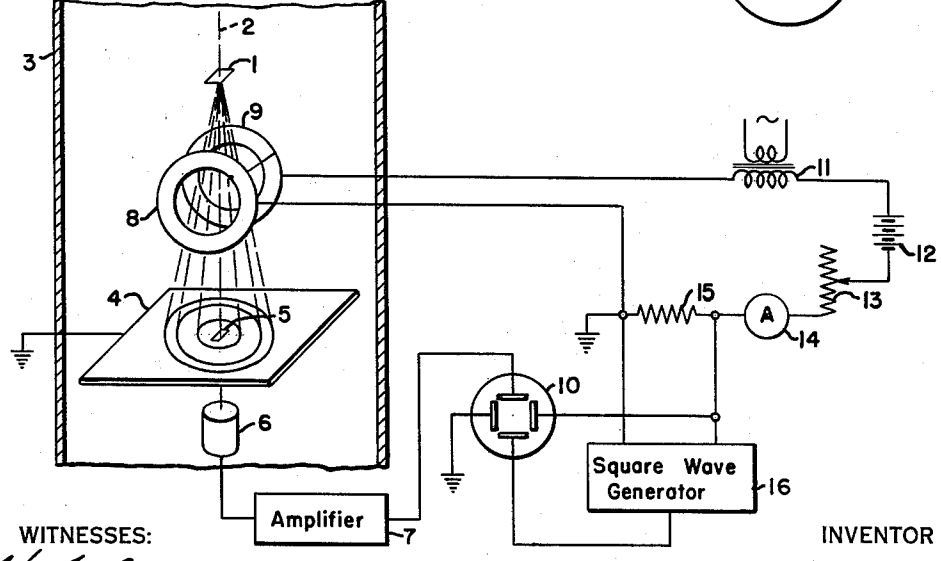


Fig.3.



WITNESSES:

N. F. Susan.

Leon M. Garman

INVENTOR

John W. Coltman.

BY F. W. Lyle.

ATTORNEY

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ELECTRON DIFFRACTION CAMERA

John W. Coltman, Pittsburgh, Pa., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

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12 Claims. (Cl. 250—49.5)

My invention relates to electron diffraction cameras, and in particular relates to arrangements by which the variation of intensity of the diffraction pattern with angular displacement may be registered graphically and measured.

In electron diffraction cameras a fine beam of constant voltage electrons is projected onto a thin specimen of a substance for which it is desired to obtain a pattern. It is found that electrons are diffracted in such an arrangement at various angles from the axis of the impinging jet in such a way as to produce conical streams of electrons diverging at various angles to the axis of the impinging stream. The intensity distribution of the diffracted electrons at various angles relative to the axis of the cones is found to be a characteristic of the material undergoing study and is referred to as the electron diffraction pattern of that material.

In accordance with the prior art, such diffraction patterns have been recorded by positioning photographic films or plates to be intersected by the electron cones. However, this procedure is unsatisfactory in that it gives only rough measurements of intensity variation, and is somewhat time consuming because it is necessary to develop the photographs before the desired information as to the diffraction pattern is obtained. The procedure becomes especially burdensome if, as is sometimes the case, the physical characteristics of the sample being studied are changing with time. It is obvious that in any case where the changes are rapid it becomes practically impossible to record the diffraction patterns accurately by this means.

One object of my invention is, accordingly, to describe a procedure and apparatus by which a graphical representation of the intensity distribution in the diffraction pattern may be obtained.

Another object of my invention is to provide an apparatus and method for obtaining a nearly instantaneous record of the intensity distribution in an electron diffraction pattern.

Still another object of my invention is to provide an arrangement in which a curve representing the instantaneous distribution of intensity in the diffraction pattern in an electron diffraction apparatus may be produced on the screen of an oscilloscope.

A further object of my invention is to provide an apparatus by which instrument readings, which are of a high order of accuracy, of the intensity at various angular displacements in an electron diffraction apparatus may be obtained.

Other objects of my invention will become evident upon reading the following description taken in connection with the drawings, in which:

Figure 1 is a diagrammatic representation of the essential features of an electron diffraction apparatus embodying the principles of my invention at one instant in the cycle of its operation;

Fig. 2 is a similar diagram illustrating the conditions in the same apparatus at another instant in the cycle of its operations;

Fig. 3 is a circuit diagram of a modification of my apparatus of Fig. 1, particularly well adapted for making precise readings of the intensity distribution in the diffraction pattern; and,

Fig. 4 is a diagrammatic view showing the appearance of a graphical curve on the screen of an oscilloscope embodied in my invention when used in the connection of Figure 3.

Referring in detail to Fig. 1, a sample 1 of material which it is desired to obtain an electron diffraction pattern is supported by any suitable means (not shown) in the path of an extremely fine electron beam 2. The electron beam is generated by an electron gun comprising a cathode 16 and an acceleration electrode 17. The cathode 16 is connected to a negative source of potential B— and the acceleration electrode 17 is connected to a source of positive potential B+. So-called electron guns and other arrangements for producing such fine streams of electrons are well-known in the electronics art today and are believed to require no separate description.

The above-mentioned sample and electron beam may be enclosed within a suitable container 3 which may be vacuum tight if desired and which is believed to require no detailed description since such arrangements are well-known in the electronics art today. A publication entitled, "RCA Electron Diffraction Unit," published by Radio Corporation of America, Rockefeller Center, New York City, describes an apparatus employing such an electron beam.

The sample 1 may be in the form of a thin sheet disposed as illustrated, or simply a surface arranged so that the electron beam strikes it at nearly grazing incidence. After passing through the sample 1, it will be found that the electrons are diffracted in such a way as to produce, in effect, a number of cones having various aperture angles coaxial to the axis of the original electron beam 2. If the sample is mounted for grazing incidence, approximately one-half of each cone will be occulted, but this is of no importance in the description of the apparatus. The electron gun 16, 17 and its fine beam 2 as just described are thus a means to cause the sample material to produce an electron diffraction pattern. A metallic plate 4 of a material impervious to electrons is supported at a suitable distance from the sample 1 in a position normal to the axis of the above-mentioned cones. If a fluorescent plate were supported on the plate 4, it would be intersected by the conical beams of electrons above mentioned and would be caused thereby to fluoresce, showing successive rings representing the traces of these cones at the plate 4. Such arrangements as I have so far described are characteristic of diffraction cameras of the prior art on which my arrangement is an improvement.

In the center of the plate 4, I make a small aperture 5 through which any electrons properly directed may pass and enter an electron detector 6 suitably supported below it. The detector 6 is connected to energize a suitable amplifier 7 to produce an output current which, at any instant, is representative of the intensity of the electron stream incident on the aperture 5.

I arrange, by suitable windings 8, 9, to produce a magnetic field in a direction preferably normal to that of the electron beam 2, but in the region between the sample 1 and the plate 4. The windings 8, 9 are preferably energized with a periodic current, which may, for example, be a 60-cycle alternating current derived from a transformer secondary 11. I so position the plate 4 that its aperture 5 is aligned with the axis of the conical electron distribution above described when the current flowing from the transformer secondary winding 11 is zero. It will then be evident that when the current from the trans-

former secondary 11 passes through its alternating cycle in the windings 8 and 9, the conical electron streams passing through the magnetic field due to these windings will undergo a deflection perpendicular to the direction of propagation of the electrons and to the magnetic field. That is to say, for practical purposes, the entire set of cones representing the diffracted electrons from sample 1 will be deflected from side to side. When the current in the alternating cycle is zero, the electron detector 6 will be energized in proportion to the intensity of the electron stream in the center of the conical distribution and as the current through the windings 8 and 9 passes through other values in its cycle current to the detector 6 will continually vary in time in such a way as to represent the distribution of the electron intensity of the various diffraction-electron cones.

I connect the output of the amplifier 7, in a way well-known to the art, to the vertical deflecting plates of an ordinary oscilloscope 10 the horizontal deflecting plates of which are connected to the output of the transformer 11. As a result, the electron beam of the oscilloscope 10 will trace on the fluorescent screen thereof a curve which will be a graphical representation of the distribution of the electron intensity at various angular directions relative to the central axis of the above-mentioned conical electron streams. To make this clearer, Fig. 2 shows the condition of the diffraction electron cones at a time when the elements of one of the conical distributions line up with the aperture 5 in plate 4.

While I have described the current supplied to the windings 8 and 9 as derived from an ordinary 60-cycle alternating current source, it will be readily apparent to those skilled in the art that the currents of windings 8 and 9 may be of saw-tooth wave form derived from a generator of a type too well-known in the electronics art to require detailed description here. With either arrangement, the abscissae of the curve on the fluorescent screen of oscilloscope 10 will accurately represent the angle relative to the axis of the various cones, while the electron intensity in each cone will be represented by the ordinate corresponding thereto on the fluorescent screen. This trace will have the form of a succession of "pips" such as A and B, each pip corresponding to an electron-cone of a particular aperture-angle. Since the horizontal deflecting plates of the oscilloscope are synchronized with the lateral deflections of the electron cones by windings 8 and 9, the periodic displacement of these cones will cause the electron beam to periodically trace the same curve on the fluorescent screen of oscilloscope 10 on each succeeding cycle as long as the characteristics of the sample 1 undergo no change.

In order to obtain a more precise measurement of the aperture angles of the various diffraction-electron cones, I may substitute for the circuit supplying the windings 8 and 9 in Fig. 1, a more elaborate circuit as shown in Fig. 3. In Fig. 3, the transformer secondary 11 is connected through a direct-current source 12, a variable resistor 13, a suitable direct-current ammeter 14 and a resistor 15, to the windings 8 and 9. Across the terminals of the resistor 15 is connected the input circuit of a square-wave generator 16 of any type well-known in the art which is adapted to change the form of the sinusoidal input wave derived from the resistor 15 to that of a square-topped output wave having the same frequency and phase. The output of the square-topped wave generator is connected to impress in the circuit from amplifier 7 to the vertical plates of the oscilloscope 10 a square-topped voltage wave which will, in effect, periodically displace the zero of the graphical curve traced on the screen of the oscilloscope 10 by a predetermined amount at the zero point in each cycle of the source 11. Since direct current from source 12 is added to the alternating current from source 11 in windings 8 and 9 the common axis of the electron cones will no longer pass through the aperture 5 when the alternating current passes through its zero value. Hence by varying this direct current the particular "pip" on the fluorescent screen curve which occurs at zero abscissa (where the sudden displacement of the zero of the graphical curve on the oscilloscope screen occurs) can be varied at will. With this arrangement, the various "pips" may be brought successively into coincidence with the vertical edge of the square-topped waves and will be plainly seen on the oscilloscope. A calibration relating direct current through windings 8 and 9, as shown on ammeter 14, with aperture angle of the cone which intersects aperture 5 can readily be made in advance, so that the aperture angles of the various cones may be determined from the readings of ammeter 14.

While I have described the impression of a square-topped wave as one convenient method of marking the point on the abscissa (time) corresponding to the instant at which voltage of source 11 passes through zero, the methods of indicating that instant on the oscilloscope screen, such as complete interruption of the oscilloscope beam for an instant or deflection of it to produce a small "pip," will be evident to those skilled in the electronic art.

Since the electron detector 6 must be able to respond to very small currents of the order of 10^{-14} amperes and have a short time constant, an electron multiplier or a photomultiplier in combination with a fluorescent screen such as is described in Coltman and Marshall Patent 2,512,355, issued June 20, 1950, for an X-ray thickness gauge may suitably be employed for the detector 6.

Since numerous changes may be made in the above-described construction, and different embodiments of the invention may be made without departing from the spirit and scope thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. In combination, means to cause a sample material to produce an electron diffraction pattern, electrically responsive means to deflect the diffracted electrons therein, a circuit to supply said electrically responsive means with a periodic voltage, a material impervious to electrons mounted in the path of said diffracted electrons and having an aperture covering a limited area of said path, an electron detector to receive such of said diffracted electrons as pass through said aperture, an oscilloscope having its scanning movement synchronized with said periodic voltage and impressed with the output current from said electron detector to record periodic variations therein.

2. In combination, means to cause a sample material to produce an electron diffraction pattern, electrically responsive means comprising windings producing a magnetic field transverse to the path of the diffracted electrons, a circuit to supply said electrically responsive means with a periodic voltage, a material impervious to electrons mounted in the path of said diffracted electrons and having an aperture covering a limited area of said path, an electron detector to receive such of said diffracted electrons as pass through said aperture, an oscilloscope having its scanning movement synchronized with said periodic voltage and impressed with the output current from said electron detector to record periodic variations therein.

3. In combination, means to cause a sample material to produce an electron diffraction pattern, electrically responsive means to deflect the diffracted electrons therein, a circuit to supply said electrically responsive means with a periodic voltage, a material impervious to electrons mounted in the path of said diffracted electrons and having an aperture covering a limited area of said path, an electron detector to receive such of said diffracted electrons as pass through said aperture, an oscilloscope having its scanning movement synchronized with said periodic voltage and impressed with the output current from said electron detector to record periodic variations therein, means to impress a square-topped wave on the scanning circuits of said oscilloscope to cause a sharp displacement

in the zero line thereon at a predetermined point in the cycle of said periodic voltage.

4. In combination, means to cause a sample material to produce an electron diffraction pattern, electrically responsive means comprising windings producing a magnetic field transverse to the path of the diffracted electrons, a circuit to supply said electrically responsive means with a periodic voltage, a material impervious to electrons mounted in the path of said diffracted electrons and having an aperture covering a limited area of said path, an electron detector to receive such of said diffracted electrons as pass through said aperture, an oscilloscope having its scanning movement synchronized with said periodic voltage and impressed with the output current from said electron detector to record periodic variations therein, means to impress a square-topped wave on the scanning circuits of said oscilloscope to cause a sharp displacement in the zero line thereon at a predetermined point in the cycle of said periodic voltage.

5. In combination, means to cause a sample material to produce an electron diffraction pattern, electrically responsive means to deflect the diffracted electrons therein, a circuit to supply said electrically responsive means with a periodic voltage, a material impervious to electrons mounted in the path of said diffracted electrons and having an aperture covering a limited area of said path, an electron detector to receive such of said diffracted electrons as pass through said aperture, an oscilloscope having its scanning movement synchronized with said periodic voltage and impressed with the output current from said electron detector to record periodic variations therein, means to impress a square-topped wave on the scanning circuits of said oscilloscope to cause a sharp displacement in the zero line thereon at a predetermined point in the cycle of said periodic voltage, a direct current source and means for regulating its current output in series with said electrically responsive deflecting means, and a current measuring instrument in series with said direct current source.

6. In combination, means to cause a sample material to produce an electron diffraction pattern, electrically responsive means comprising windings producing a magnetic field transverse to the path of the diffracted electrons, a circuit to supply said electrically responsive means with a periodic voltage, a material impervious to electrons mounted in the path of said diffracted electrons and having an aperture covering a limited area of said path, an electron detector to receive such of said diffracted electrons as pass through said aperture, an oscilloscope having its scanning movement synchronized with said periodic voltage and impressed with the output current from said electron detector to record periodic variations therein, a direct current source and means for regulating its current output in series with said electrically responsive deflecting means and a current measuring instrument in series with said direct current source.

7. In combination, means to cause a sample material to produce an electron diffraction pattern, electrically responsive means to deflect the diffracted electrons therein, a circuit to supply said electrically responsive means with a periodic voltage, a material impervious to electrons mounted in the path of said diffracted electrons and having an aperture covering a limited area of said path, an electron detector to receive such of said diffracted electrons as pass through said aperture, an oscilloscope having its scanning movement synchronized with said periodic voltage and impressed with the output current from said electron detector to record periodic variations therein, and means for marking on said oscilloscope an indication of a predetermined time in the cycle of said periodic voltage.

8. In combination, means to cause a sample material to produce an electron diffraction pattern, electrically responsive means to deflect the diffracted electrons therein, a circuit to supply said electrically responsive means with

a periodic voltage, a material impervious to electrons mounted in the path of said diffracted electrons and having an aperture covering a limited area of said path, an electron detector to receive such of said diffracted electrons as pass through said aperture, an oscilloscope having its scanning movement synchronized with said periodic voltage and impressed with the output current from said electron detector to record periodic variations therein, means for marking on said oscilloscope an indication of a predetermined time in the cycle of said periodic voltage, a direct current source and means for regulating its current output in series with said electrically responsive deflecting means, and a current measuring instrument in series with said direct current source.

9. In combination, means to cause a sample material to produce an electron diffraction pattern, electrically responsive means comprising windings producing a magnetic field transverse to the path of the diffracted electrons, a circuit to supply said electrically responsive means with a periodic voltage, a material impervious to electrons mounted in the path of said diffracted electrons and having an aperture covering a limited area of said path, an electron detector to receive such of said diffracted electrons as pass through said aperture, an oscilloscope having its scanning movement synchronized with said periodic voltage and impressed with the output current from said electron detector to record periodic variations therein, means for marking on said oscilloscope an indication of a predetermined time in the cycle of said periodic voltage, a direct current source and means for regulating its current output in series with said electrically responsive deflecting means and a current measuring instrument in series with said direct current source.

10. In combination, means for producing a stream of high velocity electrons, means to hold a sample of material in the path of said stream, electrically responsive means to deflect the electrons diffracted by said sample, a circuit to supply said electrically responsive means with a periodic voltage, a material impervious to electrons mounted in the path of said diffracted electrons and having an aperture covering a limited area of said path, an electron detector to receive such of said diffracted electrons as pass through said aperture, and an oscilloscope having its scanning movement synchronized with said periodic voltage and impressed with the output current from said electron detector to record periodic variations therein.

11. In combination, means for producing a stream of high velocity electrons, means to hold a sample of material in the path of said stream, electrically responsive means comprising windings producing a magnetic field transverse to the path of the electrons diffracted by said sample, a circuit to supply said electrically responsive means with a periodic voltage, a material impervious to electrons mounted in the path of said diffracted electrons and having an aperture covering a limited area of said path, an electron detector to receive such of said diffracted electrons as pass through said aperture, and an oscilloscope having its scanning movement synchronized with said periodic voltage and impressed with the output current from said electron detector to record periodic variations therein.

12. In combination, means to cause a sample material to produce an electron diffraction pattern, electrically responsive means to deflect the diffracted electrons therein, a circuit to supply said electrically responsive means with a periodic voltage, a material impervious to electrons mounted in the path of said diffracted electrons and having an aperture covering a limited area of said path, an electron detector to receive such of said diffracted electrons as pass through said aperture, an electronic recording instrument capable of producing a two-dimensional picture in response to potentials applied thereto which has its scanning movement synchronized with said periodic voltage and impressed with the output current from

said electron detector to record periodic variations therein.

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