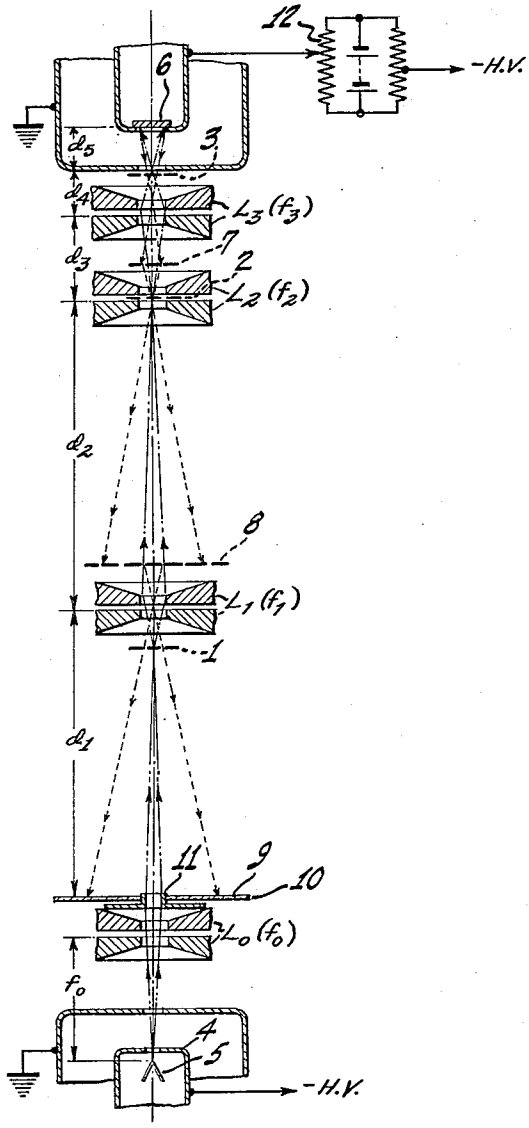
Oct. 14, 1952 E. G. RAMBERG 2,614,223

METHOD OF AND APPARATUS FOR MAKING ELECTRON-MICROGRAPHS OF OPAQUE METALLOGRAPHIC SPECIMENS

Filed Aug. 3, 1949



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Patented Oct. 14, 1952

2,614,223

UNITED STATES PATENT OFFICE

2,614,223

METHOD OF AND APPARATUS FOR MAKING ELECTRON-MICROGRAPHS OF OPAQUE METALLOGRAPHIC SPECIMENS

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Application August 3, 1949, Serial No. 108,352

5 Claims. (Cl. 250—49.5)

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The invention herein described is a method of and apparatus for making electron-micrographs of specimens which are opaque to electrons.

The principal object of the invention is to obtain high-resolution images of metallographic and other electron-opaque specimens by direct electron-imaging, thus avoiding the necessity of the preparation of replicas (see Ramberg 2,347,965) or the application of scanning methods (see Von Ardenne 2,257,774 and Snyder 2,330,930).

The above mentioned and related objects are achieved in accordance with the principle of the invention by transmitting an electric current through at least a portion of a metallographic specimen whereby to establish, in the ambient adjacent to the heterogeneous surface of the specimen, an electric field of a heterogeneous intensity corresponding to the physical characteristics of different elemental areas of said surface, then projecting a beam of low velocity electrons upon said electric field whereby the electrons are reflected from said field in various proportions determined by the heterogeneous potentials of said field adjacent to said different elemental areas of said surface and, finally, converting said reflected electrons into an electron-micrograph of said heterogeneous surface as by causing them to impinge upon the fluorescent screen or photographic plate.

In the accompanying drawing, there is shown, schematically, a metallographic electron microscope constructed and operated in accordance with the principle of the invention.

In the metallographic electron microscope of the drawing, the lenses L_0, L_1, and L_3 (with focal lengths f_0, f_1, and f_3) form a series of enlarged images, 1, 2 and 3, of the electron source. The latter may be produced by a normal electron microscope gun 4 with a hairpin filament 5 and be of the order of 0.001 inch in diameter. The gun consists, as indicated on the drawing, of a cathode and grid cylinder at high negative potential and an anode, which is, along with the rest of the instrument except the specimen mount at ground potential. The electrons diverging from the enlarged image 3 are retarded by an electric field as they approach the specimen 6, either just failing to reach the latter or reaching it with a kinetic energy of a few electron volts. The specimen is maintained at high voltage negative potential. It is surrounded by a grounded shield having an aperture through which electrons incident upon the specimen and reflected therefrom may pass. The electrons which reverse their direction before reaching the specimen, as well as the fraction of the incident electrons which are reflected by the specimen, are accelerated by the potential difference between the specimen and ground and are focused at points in the planes 7, 8 and 9 by lenses L_3, L_2 (located at one of the intermediate images of the source), and L_1 on a photographic film, fluorescent screen or other image converter 10, placed just above lens L_0. The image converter or target 10 is provided with a perforation 11 to permit passage of the illuminating beam. In the enlarged image on the electron-sensitive target 10, portions of the specimen surface which are more negative will thus appear brighter, more positive portions, darker. Thus the resulting optical image reflects small variations in surface potential which exist on any heterogeneous surface, such as that of a metallographic specimen. The limiting resolving power of the instrument should be the same as that for the electron emission microscope, i. e., less than 100 A. U.

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To obtain a concrete idea of the dimensions required, assume that d_1 and d_2 are very large compared to the focal lengths of all the lenses, which may, of course, be either magnetic or electrostatic. If an aperture small in diameter compared with the specimen distance is placed in the plane of the final image of the source, a distance d_5 from the specimen, the apparent distance of the specimen from lens L_3 is $d_4+(4/3)d_5$. The lens equations, furthermore, lead to

$$d_4=\frac{d_3 f_3}{d_3-f_3}$$

$$d_3-f_2=\frac{\left(d_4+\frac{4}{3}d_5\right)f_3}{d_4+\frac{4}{3}d_5-f_3}=\frac{\left(d_3 f_3+\frac{4}{3}d_3 d_5-\frac{4}{3}d_5 f_3\right)f_3}{\frac{4}{3}d_3 d_5-\frac{4}{3}d_5 f_3+f_3^2}$$

The magnification "M_{sp}" of the specimen is

$$\frac{d_1}{f_1}\frac{d_2}{f_2}\frac{(d_3-f_2)(d_3-f_3)}{d_3 f_3+\frac{4}{3}d_3 d_5-\frac{4}{3}d_5 f_3}$$

The magnification "M_{so}" of the source is

$$\frac{d_1}{f_0}\frac{d_2}{f_1}\frac{d_4}{d_3}$$

For

$$f_0=2 \text{ cm.}, \quad f_1=f_2=f_3=d_5=0.5 \text{ cm.}$$

we must have

$$d_4=0.833, \quad d_3=1.25 \text{ cm.}$$

Hence, with

$$d_1=d_2=40 \text{ cm.}$$
$$M_{sp}=3200$$
$$M_{so}=1100$$

A potentiometer 12 is provided to permit varying the potential of the specimen 6 by a few volts with respect to the cathode, so that an optimum potential, duly compensating contact potentials, may be applied. It will be noted that the system will function as a normal emission microscope if the electron gun is disconnected and a heater, or ultraviolet illumination, is provided for the specimen. (As to this, see Journal of Optical Society, April 1936, p. 181.) Furthermore, if the specimen is held at a voltage which is a few hundred volts positive with respect to the cathode, the system will operate as a secondary emission microscopic. If small amounts of gas are admitted into the system (with the electron gun cold), the resulting positive ion bombardment may serve to clean or etch the specimen surface. With relatively low gas pressure in the specimen chamber, and still lower pressures in the remainder of the electron microscope, the secondary electrons ejected by the positive ions may also serve to form the electron image. The system is primarily intended for conducting specimens with a substantially plane surface, such as are normally encountered in metallography. Insulating specimens may be employed if their surface is rendered conducting by the evaporation of a conducting film on their surface.

What is claimed is:

1. In the art of electron microscopy, the method of making an electron-micrograph of a heterogeneous surface of a metallographic specimen, said method comprising: transmitting an electric current through at least a portion of said specimen whereby to establish adjacent to the exterior of said surface an electric field of a heterogeneous intensity corresponding to the physical characteristics of different elemental areas of said surface, forming a beam of electrons, projecting said beam with a low velocity upon said electric field whereby said electrons are reflected from said field in various proportions determined by the heterogeneous potentials of said field adjacent to said different elemental areas of said surface, and then accelerating and converting said reflected electrons into an electron micrograph of said heterogeneous surface.

2. The invention as set forth in claim 1 and including the step of regulating the velocity of said electron-beam to a value such that any electrons which succeed in passing entirely through said electric field will impinge upon said surface with a velocity less than that required to release more than one secondary electron, per impinging electron, from said surface.

3. An electron microscope for the examination of electrically conductive heterogeneous surfaces, said microscope comprising: a specimen holder, means for subjecting the surface of a specimen mounted on said holder to an electric current whereby to establish adjacent to the exterior of said surface an electric field of a heterogeneous intensity corresponding to the physical characteristics of the various elemental areas of said specimen, a source of electrons, means for deriving a beam of electrons from said source and for directing said beam upon said electric field whereby said electrons are reflected from said field in proportion determined by the heterogeneous potentials of said field adjacent to said different elemental areas of said surface, and an electron-sensitive target mounted in the path of said reflected electrons for converting said reflected electrons into a light image.

4. An electron microscope for the examination of electrically conductive heterogeneous surfaces, said microscope comprising: a specimen holder, means for subjecting the surface of a specimen mounted on said holder to an electric current whereby to establish adjacent to the exterior of said surface an electric field of a heterogeneous intensity corresponding to the contour of the various elemental areas of said surface, a point source of electrons mounted remote from said specimen, a series of electron lenses mounted in spaced array in the space between said source and specimen for forming a series of enlarged images of said source in said space and for divergingly directing the electrons constituting the last of said series of said images upon said electric field whereby said electrons are reflected from said field in proportions determined by the heterogeneous potentials of said field, an electron-sensitive target mounted in the path of said reflected electrons, and electron-lens means mounted in the space intermediate said specimen and said target for divergingly directing said reflected electrons upon said target whereby to form an enlarged optical image of said heterogeneous surface of said specimen upon said target.

5. The invention as set forth in claim 4 wherein said last-mentioned electron-lens means comprises a plurality of discrete lenses at least one of which is of the series constituting said beam-focusing lenses.

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The following references are of record in the file of this patent:

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