June 24, 1947. C. H. BACHMAN 2,422,943

ELECTRON MICROSCOPE

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Fig. 1.

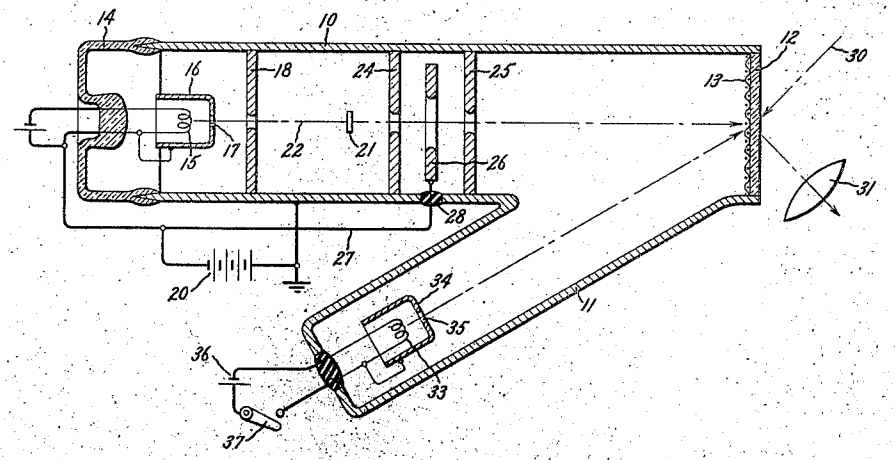
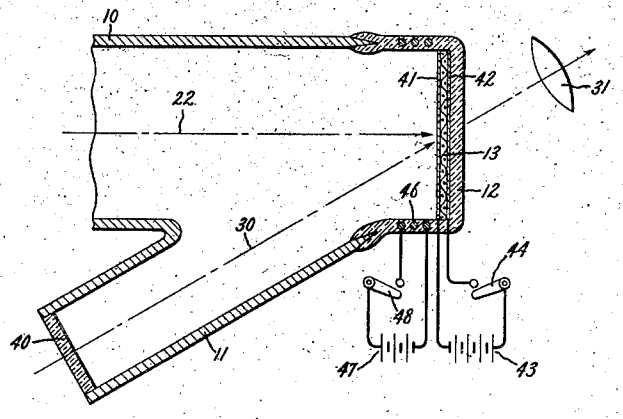


Fig. 2.



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ELECTRON MICROSCOPE

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2 Claims. (Cl. 250—49.5)

1

My invention relates to an electron microscope and, in particular, to new and improved means and method of reproducing electron images in an electron microscope.

The electron microscope achieves magnification effects by utilizing the power of electric or magnetic fields, or a combination of the two, to refract the component parts of an electron stream in a manner analogous to the refraction of light by the lenses of an optical microscope. In the usual type of electron microscope, a beam of electrons is passed through a sample to take on the character of the sample, and is magnified in electrostatic or magnetic lenses, ultimately striking a fluorescent screen or a photographic plate. Since there is a limit to the amount of current which can be crowded into an electron beam, there is also a limit to the magnification of the instrument, the magnification consisting of expanding the beam of electrons many times. Such expansion of course reduces the current density so that beyond certain magnifications the current density of the electron beam is reduced to a value which is insufficient to excite a fluorescent screen or which makes the length of electronic exposure of the photographic film of so great a duration as to introduce fogging of the film. A certain amount of improvement is obtainable by increasing the velocity of electrons, one limitation of this improvement being the reduction of contrast for very thin samples of objects to be magnified.

It is an object of the present invention to provide a new and improved electron microscope which permits increased magnification of an image without proportionate increase in the voltages employed.

It is another object of my invention to provide a new and improved electron microscope which permits reproduction of images from very weak image-carrying electron beams.

It is a further object of my invention to provide a new and improved electron microscope which permits the image produced on a viewing screen by an electron bombardment of short duration to be retained on the screen for relatively long periods of time.

It is still another object of my invention to provide a new and improved electron microscope which permits the imaging of objects very sensitive to electron bombardments.

It is a still further object of my invention to provide a new and improved electron microscope which permits the obtaining of permanent photographic records of images produced by very short

2

exposures to an electron stream without introducing the photographic film within the evacuated microscope chamber.

An important feature of the invention consists in the use in an electron microscope of a viewing screen constituted by a thin layer of alkali halide crystals and permitting the image-carrying stream of electrons to strike these crystals, the electrons producing a change of color of the crystals, which change is characterized by its long duration. The length of time of the color change is controllable by a number of factors including the temperature of the crystals, the wave length of radiation incident on the screen, and irradiation by another beam of electrons of suitable density and velocity.

The features of the invention which are desired to be protected herein are pointed out with particularity in the appended claims. The invention itself, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the drawing in which Fig. 1 represents a cross-sectional view of an electron microscope suitably embodying the invention, and Fig. 2 is a partial view of a modification of the microscope of Fig. 1.

Referring particularly to Fig. 1, there is shown an electron microscope comprising an elongated vacuum-tight container which consists mainly of a cylindrical metal part 10 having an angularly disposed portion 11. At one end, the container is closed by a transverse glass wall 12 which is provided on its inner surface with a screen 13 which is adapted to form an image under the impact of electrons. The exact construction of the window 12 and the image-forming screen 13 is pointed out in greater detail later in this specification. At the end of the microscope remote from the window 12, there is provided a glass insulating structure 14 which serves to support an electron source in the form of a filamentary cathode 15. The cathode is surrounded by an apertured cup-shaped member 16 having a narrow slit or opening 17 which confines the emitted electrons to a narrow beam and which is cooperatively positioned with respect to a diaphragm 18 supported in contact with the main envelope part 10. In the normal use of the apparatus, the envelope 10 and the electrode 18 are maintained at ground potential, while the cathode is held at several thousand volts below ground, by connection to a potential source represented by the battery 20, so that electrons emitted from the cathode are projected toward the window 12.

Between the cathode 15 and the image-reproducing screen 13, there is provided an object-supporting means indicated generally at 21. In the intended use of the apparatus, this means is to be employed as a support for an object which is to be examined and which is transradiated with electrons, i. e. through which an electron beam is projected. The supporting structure 21 can be provided with means for holding such an object in a plane substantially transverse to the electron beam 22. Between the specimen holder 21 and the screen 13 there are provided one or more electron lens systems for exerting a refractive force on the electron rays proceeding from the specimen under investigation. These lens systems comprise a pair of apertured metal diaphragms 24 and 25 which are maintained at ground potential by connection to the envelope 10 and an intermediate diaphragm 26 which is insulated from the envelope 10 and connected to cathode potentials by means of a lead-in conductor 27 which extends through an insulating bushing 28.

The electron beam 22 leaves the source and, in passing through the sample within the holder 21, takes on characteristics identifying it with the sample. The beam is then magnified as it passes through the electron lens and the magnified image is formed at the screen 13. In order to provide a screen which will permit reproduction of images from very weak image-carrying electron beams, the screen 13 is composed of alkali halide crystals which are electron-sensitive and are characterized by the fact that, when they are subjected to an electric field and struck by a beam of electrons, the electrons tend to travel toward the anode of the electric field through the crystal structure which is composed of alternate positive alkali ions and negative halogen ions. After a certain time of free travel, an electron is captured by a positive alkali ion, resulting in a sort of loosely bound alkali atom which absorbs light of the visible spectrum and which is known as a color center. One suitable alkali halide material is potassium chloride (KCl) which is evaporated onto the window 12 in a thin layer. When bombarded by electrons, this layer changes color, changing from white to deep purple in color. The contrast reached depends to some extent upon the current density of the electron velocity and the time of duration of the bombardment. Other factors which control the extent of the contrast include the temperature and the wave length of the radiation incident on the electron opaque surface 13. Most important, the color change persists for a length of time which can be controlled primarily by these same factors and, under proper conditions, the bombarded area may be maintained discolored almost indefinitely. The screen construction described in the foregoing possesses a marked advantage over previously used screens of the fluorescent-material type. One particular advantage is the ability of the alkali halide material to become more and more densely colored with continued subjection to bombarding electrons, making it possible to use greater magnifications and lower voltages than hitherto used since, by allowing a very weak image-carrying beam to strike the screen for a sufficient period of time, an image which would be too weak to be visible on a fluorescent screen gradually builds up to a degree of contrast which makes viewing possible.

In addition to the advantages just mentioned, another valuable feature of the electron sensitive screen is its ability to hold the image on the screen by maintaining the color change for fairly long periods of time, even though the electron beam which actually caused the image has bombarded the screen for only a very short time. Thus, when it is desired to view an object which is very sensitive to electron bombardment and which would change its characteristics while under the bombardment required for viewing it on a fluorescent screen or for photographing it on a photographic film, by the use of the electron sensitive screen 13 it is possible to pulse the electron beam 22 by any suitable pulsing system so that bursts of electrons of most efficient density and velocity are passed through the sample for only a very short time and the image resulting on the screen is maintained as long as desired for viewing purposes.

The semi-permanent image on the electron sensitive surface 13, since it persists for a considerable time, may be viewed in artificial light or daylight such as the light beam 30 projected on the window 12 and the reflected beam may be magnified by the use of an optical lens system denoted generally by the lens 31. Particularly effective results are obtained when the light beam 30 is monochromatic and of the same wave length as the image formed on screen 13. In this case the light is absorbed by the image-portion of the screen and reflected by all other portions. Moreover, the light beam 30 may be of sufficient brightness so that exposures may be obtained which are suitable for ordinary cameras and photographs of the image on the screen 13 may be taken. As a result, even though specimens are examined for which it is necessary to use very short exposure time of electron bombardment, it is unnecessary, when the electron sensitive screen 13 is employed, to place a photographic film in the evacuated chamber 10 to obtain a permanent record of the image produced by the electron beam.

When it is desired to remove the image from the screen 13, an electron beam of different voltage or current characteristics may be used to cause fairly rapid decay of the color of screen 13 making the screen ready for another image. Such an erasing electron beam may be obtained by means of an electron gun provided in the angularly disposed portion 11 of the enclosure and may comprise a filament 33 surrounded by a tubular member 34 having a narrow aperture 35. The filament 33 may be energized from a potential source indicated as the battery 36, the energization time being controlled by any suitable means such as a switch 37.

In the modification of the electron microscope illustrated in Fig. 2, the viewing or projecting light beam 30 is of a color complementary to the color of the image formed on screen 13 and is transmitted through the electron sensitive screen 13 and the window 12. Erasure of the image is effected by a different phenomenon. In the portion of the structure there shown, the tubular metallic vacuum-tight container 10 has a glass window 40 sealed across the end of the angularly disposed portion 11. The light beam 30 is projected through the glass window 40 upon the screen 13 and is transmitted therethrough to the optical lens system 31. In this modification of the invention, moreover, an electric field is applied through the screen 13 by means of semi-transparent conducting films 41 and 42 deposited on the faces of the screen 13. These films may take the form of extremely thin layers of a suit-

able metallic material, such as aluminum. An electric field may be applied between the layers **41**, **42** by means of a potential source, such as a battery **43**, the time of application being controlled by means of switch **44**. Upon application of this electric field, the previously described loosely bound alkali atoms which are color centers which form the image are caused to migrate to the positive face of the screen and disappear. This migrating action may be accelerated by heat from any suitable surrounding heater, such as the heating coil **46** disposed within the glass portion **40** of the tube about the screen and energized from any suitable source of potential **47** through control switch **48**. Alternatively, the erasure of the film may be caused by radiation alone. A suitable wave length for such radiation is usually in the infra-red region and infra-red rays may be projected on the screen through window **40** to operate in the manner of the erasing electron beam illustrated in Fig. 1. The infra-red radiation of such an erasing beam readily produces thermal agitation within the alkali halide material causing deterioration of the active color centers.

While the invention has been described by reference to constructions which have been employed in electrostatic lens systems, it may also be used in magnetic lenses. I aim to cover in the appended claims this and all other variations which come within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An electron microscope comprising means for producing a directed beam of electrons, means for suporting an object desired to be examined in the path of said beam, an electron lens positioned to act upon said beam after it leaves said object, a viewing screen constituted by a thin

layer of alkali-halide crystals and characterized by the fact that said crystals are changed in color by said electrons and retain said change in color for a substantial period of time, and means comprising an auxiliary source of radiation for erasing said color change from said screen.

2. An electron microscope for producing an enlarged image of an object relatively opaque to an electron beam comprising, means for producing a continuously focused directed beam of electrons, means for supporting said object in the path of said beam, an electron lens positioned to act upon said beam after it leaves said object, and a viewing screen positioned to receive said electrons subsequent to passage through said lens, said screen comprising a thin layer of potassium-chloride crystals and characterized by the fact that said crystals are changed in color by said electrons and retain said change in color for a substantial period of time.

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