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ELECTRON MICROSCOPE

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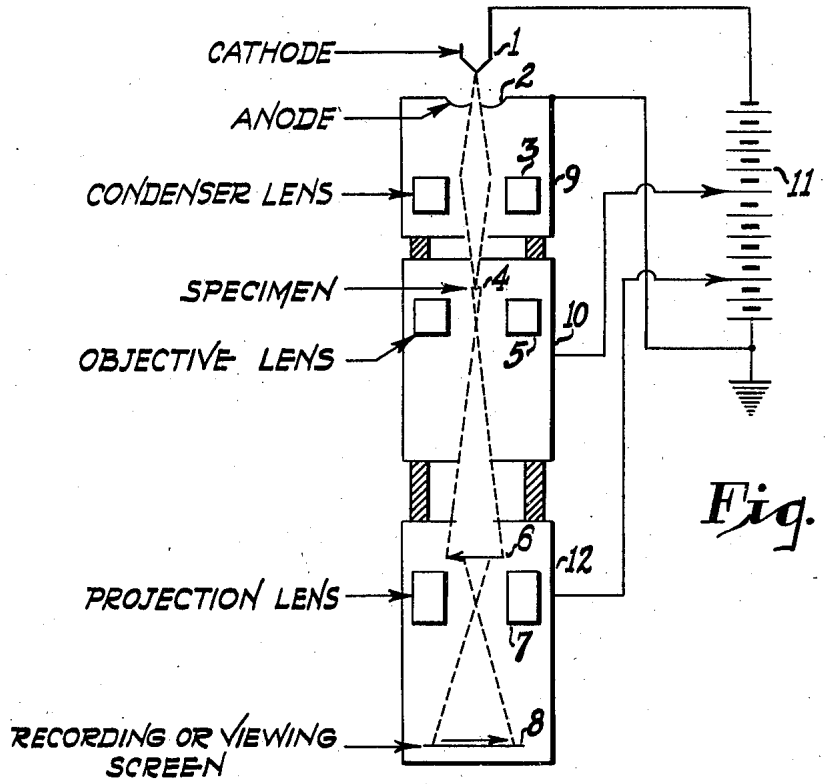

Fig. 1.

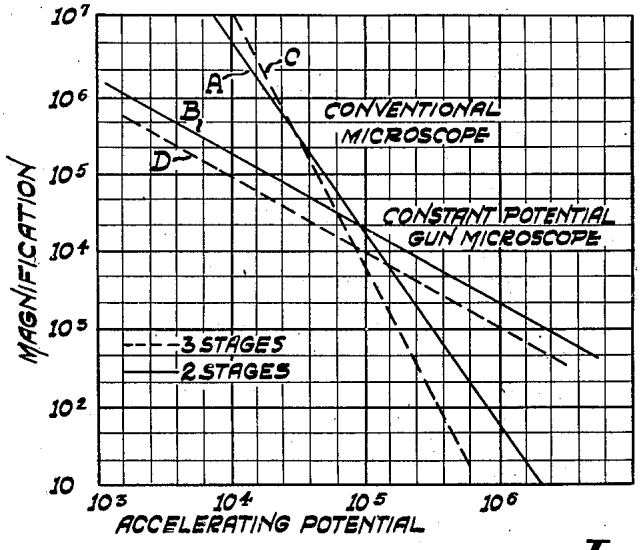

Fig. 2.

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ELECTRON MICROSCOPE

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10 Claims. (Cl. 250—49.5)

This invention relates generally to electron microscopes and particularly to an improved means for and method of controlling the electron velocities within an electron microscope to obtain desired specimen electron penetration and optimum electron velocity for the microscope image reproducing means.

In electron microscopes which use high velocity electrons for the observation (by transmission) of suitable specimens, it is necessary that the electron velocity used be sufficient to afford complete penetration of the specimen. In an electron microscope used for studying many different types of specimens it is necessary, therefore, that the potential used to accelerate the specimen-irradiating electrons be variable over a wide range. The maximum possible magnification which can be obtained from a plurality of electron lenses, as arranged in a conventional electron microscope, varies inversely as the accelerating potential is raised to a power which is determined by the number of lenses. In other words, in an electron microscope comprising only an objective lens and a projection lens, the maximum possible magnification varies inversely as the square of the accelerating potential. For example, in such an electron microscope using electrons accelerated by a potential of 20 kilovolts, a magnification of 500,000 is possible. The same instrument using electrons accelerated by 500 kilovolts would be capable of a magnification of only 800.

Another factor which must be considered in the design of an electron microscope is the fact that there exists an optimum electron velocity for the exposure of a sensitized emulsion subjected to the electron image. It is therefore desirable to irradiate the specimen with electrons having a velocity which will provide specimen penetration to a degree necessary for desired image contrast, and at the same time control the electron image velocity to obtain optimum electron exposure of the image recording means. It is therefore the purpose of this invention to provide separate electron beam velocity control means for each stage of a conventional electron microscope. These means include, in one modification of the invention, separately insulated electrodes surrounding the desired portions of the microscope column, and connections for applying to each electrode the potentials required to obtain the desired electron velocities in each region. The electrodes should include apertures to permit the electron beam to pass freely through the enclosed regions without distorting the fields of the electron lenses. For example, in a conventional electron microscope, the anode and condenser lens are enclosed within one of the accelerating electrodes, the specimen and objective lens are enclosed within a second accelerating electrode, and the projection lens and the recording or viewing screen are enclosed within a third velocity control electrode. The second electrode is insulated from the first and third electrodes, which may be insulated from each other. In one arrangement thereof, suitable electron accelerating potentials are applied to the electrodes to obtain optimum electron beam velocity for the exposure of the recording screen. An adjustable potential is applied to the second accelerating electrode to vary the electron beam velocity for desired penetration of the specimen enclosed therein. With this arrangement the magnification obtainable with the instrument is inversely proportional to the accelerating potential applied to the electrons passed through the specimen. With this arrangement, the photographic sensitivity of the recording screen may be maintained constant regardless of the velocity of the electrons traversing the specimen.

The invention will be described by reference to the accompanying drawing of which Fig. 1 is a schematic diagram of one embodiment of the invention, and Fig. 2 is a group of graphs illustrating the operating characteristics thereof.

Referring to Fig. 1, a conventional electron microscope includes a cathode 1 connected to a source of negative potential. An anode 2, having a suitable aperture, is connected to a source of positive potential and accelerates and concentrates the electrons emitted by the cathode 1. A condenser lens 3, which may be of either the electromagnetic or electrostatic types well known in the art, images the cathode to irradiate the specimen 4. An objective lens 5, which may also be of either the electromagnetic or electrostatic type, forms an image of the specimen at the plane 6. The image at the plane 6 is magnified by a projection lens 7, which may also be of either electromagnetic or electrostatic type, to form an enlarged image of the specimen on the recording or viewing screen 8.

The anode 2 and condenser lens 3 are enclosed within a first velocity control electrode 9, which is apertured to provide a path for the electron beam. The electrode may be of any suitable construction. By way of example, the electrode may be of the general type disclosed in the copending application of J. L. Whittaker, Ser. No. 435,788, filed March 23, 1942, and assigned to the

same assignee as the instant invention. The velocity control electrode 9 is connected to the anode and is therefore at the same positive potential. A second velocity control electrode 10, enclosing the specimen 4 and the objective lens 5, is insulated from the first velocity control electrode 9, and is connected to the desired potential derived from the source 11, illustrated as a battery. The projection lens 7 and the recording or viewing screen 8 are enclosed within a third velocity control electrode 12, which is insulated from the second velocity control electrode 10. The third velocity control electrode 12 may be at the same potential as the first velocity control electrode 9, or the potential thereof may be varied, to control further the magnification of the system and the electron image velocity applied to the recording screen 8.

Fig. 2 includes a Graph A showing the magnification of a conventional two-stage microscope with variation of the electron beam accelerating potential. Graph B indicates the magnification, with electron beam accelerating potential, of a two stage microscope of the type described herein. Graph C is similar to Graph A, and indicates the magnification characteristic of a conventional three stage microscope. Graph D is similar to Graph B and indicates the magnification of a three stage microscope of the type described herein.

Thus the invention described provides an improved means for controlling the velocity of an electron beam irradiating the specimen in an electron microscope while at the same time maintaining an optimum velocity at the microscope recording screen for optimum exposure thereof. It should be understood that the use of the accelerating electrodes described herein may be extended to other applications of electron lenses, since the velocity control electrode is in reality a lens magnification control as explained heretofore.

I claim as my invention:

1. In an electron microscope having electron beam producing means, an anode, objective and projection lens, a source of potential, a specimen, and image forming means, the method of controlling specimen electron penetrability while maintaining constant the electron velocities at said image, comprising, accelerating said electron beam to a predetermined initial velocity, applying a first predetermined potential to adjust said velocity of said beam in the region of said specimen and said objective lens, and applying a second predetermined potential to adjust said adjusted velocity of said beam in the region of said projection lens and said image forming means.

2. In an electron microscope having electron beam producing means, an anode, objective and projection lenses, a source of potential, a specimen, and image forming means, the method of controlling the total magnification thereof including applying an initial accelerating potential between said beam producing means and said anode, applying a first adjustable potential to said beam in the region of said specimen and said objective lens to control the magnification thereof, and applying a second potential to said beam in the region of said projection lens and said image forming means to provide optimum electron velocities for said image forming means.

3. Apparatus for controlling the electron penetration of a specimen in an electron microscope including in combination electron beam generating means, an objective lens, a projection lens, a source of potential, image forming means, means including said source of potential for initially accelerating said beam to a predetermined velocity, means including said potential means and said objective lens for varying said initial velocity to control the specimen penetration of said electron beam, and means including said potential means and said projection lens for controlling the electron beam velocity at said image forming means.

4. In an electron microscope including electron beam generating means, a specimen, objective and projection lenses, a source of potential, and image forming means, the method comprising applying first predetermined electron velocity determining potentials to said electron beam at said specimen to provide desired electron penetration of said specimen and applying second predetermined electron velocity determining potentials to said electron beam at said projection lens for providing optimum image reproduction at said image forming means.

5. An electron microscope including in combination electron beam generating means, an anode, a condenser lens, an objective lens and a projection lens, a specimen, a source of potential, image forming means, means comprising an electrode, surrounding said anode and said condenser lens, and including apertures for said beam, second means comprising an insulated electrode surrounding said specimen and said objective lens and including apertures for said beam, third means comprising an electrode surrounding said projection lens and said image forming means and including an aperture for said beam, and means including said source of potential for applying predetermined beam accelerating potentials to each of said electrodes.

6. An electron microscope including in combination electron beam generating means, an anode, a condenser lens, an objective lens and a projection lens, a specimen, a source of potential, and image forming means, means comprising an electrode surrounding said generating means, said anode and said condenser lens and including apertures for said beam, second means comprising an insulated electrode surrounding said specimen and said objective lens, and including apertures for said beam, third means comprising an electrode surrounding said projection lens and said image means and including apertures for said beam, and means including said source of potential for applying the same predetermined accelerating potentials to said first and third electrode means and an adjustable potential to said second electrode means.

7. In an electronic device, the combination of means for establishing an electron beam, an electron lens for concentrating said beam on a specimen to be imaged, an electron lens for enlarging the image of said specimen, reproducing means for said enlarged image, and means for adjusting the velocity of the electrons of said beam to produce the desired penetrating velocity at said specimen and to produce optimum electron velocity at said image reproducing means.

8. In an electronic device, the combination of means for establishing an electron beam, an electron lens for concentrating said beam on a specimen to be imaged, an electron lens for enlarging the image of said specimen, reproducing means for said enlarged image, means for adjusting the velocity of the electrons of said beam to produce the desired penetrating velocity at said specimen,

and means for producing optimum electron velocity at said image reproducing means.

9. In an electronic device, the combination of means for establishing an electron beam, an electron lens for concentrating said beam on a specimen to be imaged, an electron lens for enlarging the image of said specimen, reproducing means for said enlarged image, and means disposed in the region of said specimen for adjusting the velocity of the electrons of said beam to produce the desired penetrating velocity at said specimen and to produce optimum electron velocity at said image reproducing means.

10. In an electronic device, the combination of means for establishing an electron beam, an electron lens for concentrating said beam on a specimen to be imaged, an electron lens for enlarging the image of said specimen, reproducing means for said enlarged image, means disposed in the region of said specimen for adjusting the velocity of the electrons of said beam to produce the desired penetrating velocity at said specimen, and means disposed in the region of said reproducing means and said enlarging lens for producing optimum electron velocity at said image reproducing means.

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