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Koike

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[54] **CONVERTIBLE SCANNING ELECTRON MICROSCOPE**

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[52] **U.S. Cl.** **250/311,** 250/398

[51] **Int. Cl.** **H01j 37/26**

[58] **Field of Search** 250/311, 310, 397, 396, 250/358

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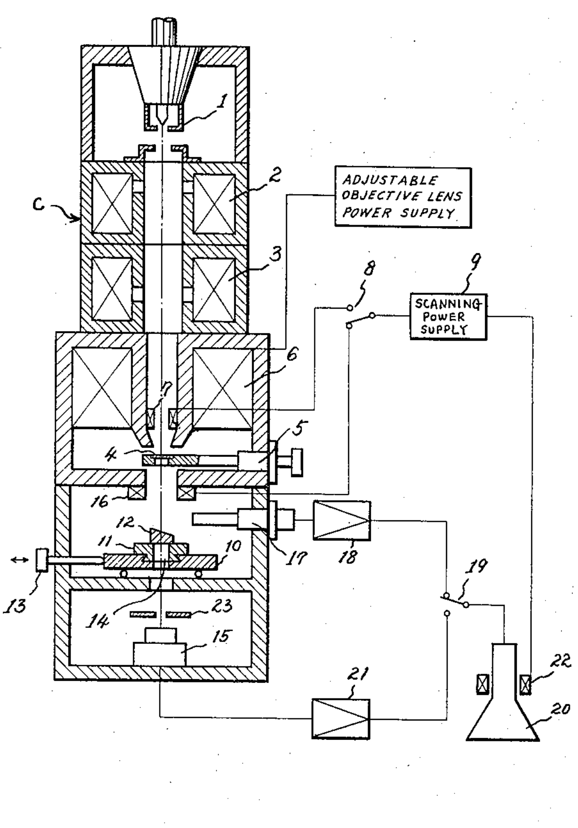
Attorney, Agent, or Firm—Webb, Burden, Robinson & Webb

[57] **ABSTRACT**

A convertible scanning electron microscope for obtaining transmitted electron and reflected secondary electron scanning images. The scanning electron microscope has a focusing lens system which is controllable to satisfy the optimum focusing condition for either the transmitted electron image or the reflected secondary electron image.

3 Claims, 4 Drawing Figures



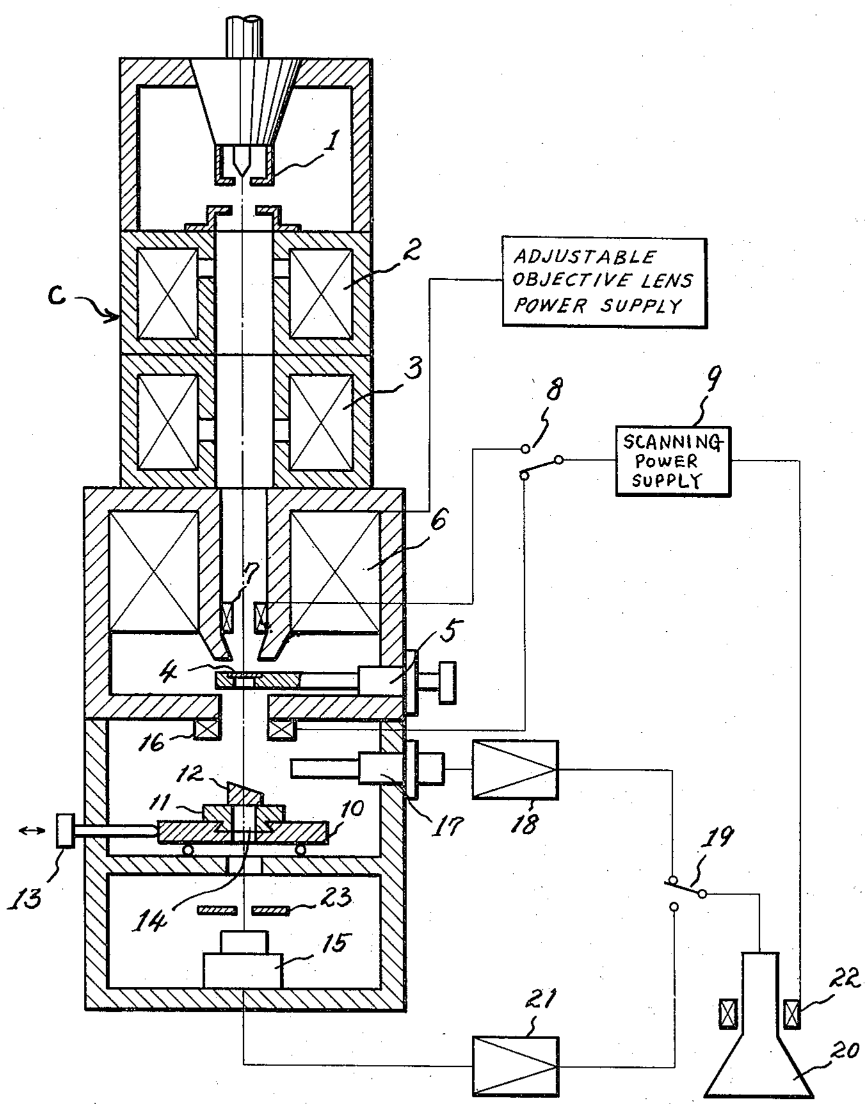

ADJUSTABLE OBJECTIVE LENS POWER SUPPLY
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Fig. 1

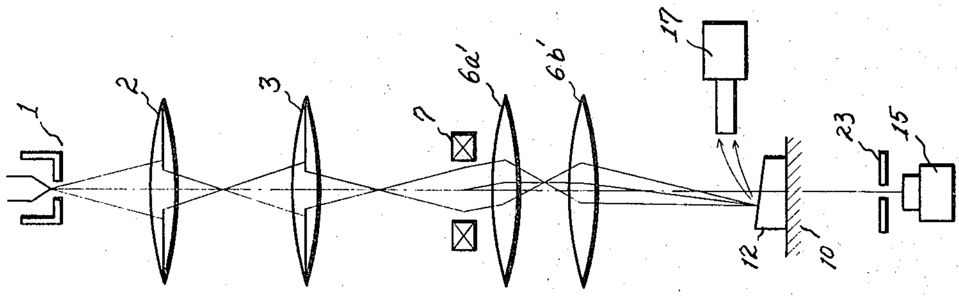

Fig. 4

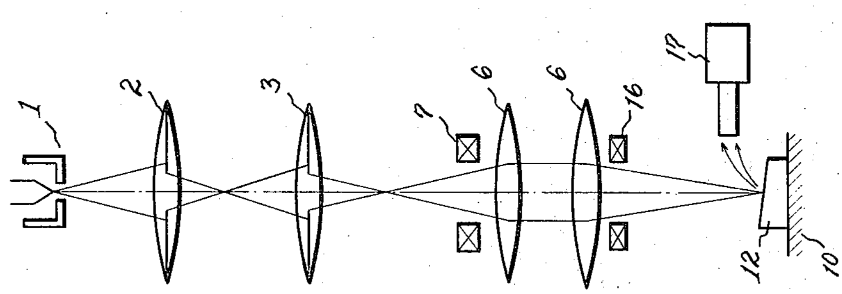

Fig. 3

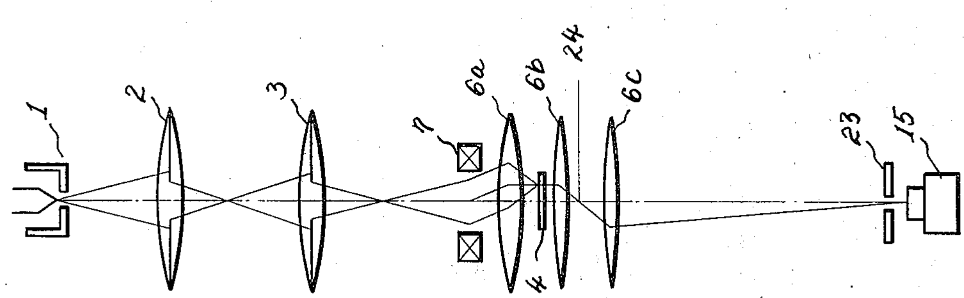

Fig. 2

CONVERTIBLE SCANNING ELECTRON MICROSCOPE

The present invention relates to a scanning electron microscope for observing either a scanning image of the electrons transmitted through a specimen of a scanning image of the secondary electrons emitted from a specimen.

In order to obtain a high resolution scanning image by using a scanning electron microscope, it is necessary to use a high brightness electron source such as a field emission type electron gun and also to reduce the diameter of electron probe irradiating on the specimen as small as possible by using focusing lenses having small spherical aberration. A scanning image of transmitted electrons with a resolving power about 5 A can be obtained by using an electron microscope that sufficiently satisfies these requirements. In order to obtain a still higher resolution transmitted electron image, it is essential to shorten the lens focal length which is proportional to the spherical aberration. In other words, to minimize the spherical aberration in a focusing lens, especially in the final stage focusing lens, the distance between the lens and the specimen must become extremely short.

On the other hand, when observing a secondary electron image with a scanning electron microscope, it is an advantage to be able to observe the shape of an uneven surface of a bulky specimen as has been frequently required in the past. In this case, besides a high resolving power for the image, a deep focal length is needed. It follows, therefore, that the focal length of the final stage focusing lens must be lengthened.

As can be seen from this discussion, the conditions for a focusing lens system for a secondary electron image are not the same as the conditions for a focusing lens system needed for a transmitted electron image. In consequence, there was no focusing lens system that was optimum for observing both these images in conventional electron microscopes.

It is an advantage of this invention to provide an electron microscope that is capable of observing the scanning image of transmitted electrons and the scanning image of reflected secondary electrons in optimum conditions with one convertible unit.

BRIEF DESCRIPTION

Briefly, according to this invention, a scanning electron microscope is provided with an evacuatable column surrounding an electron optical axis. An electron gun is provided at one end of the column followed by a focusing and condensing lens system spaced along the axis. An objective lens is provided beyond the focusing lens and is arranged with a transmission image specimen holder stage therein. A second specimen holder stage is axially spaced away from the objective lens opposite the electron gun for holding a specimen for secondary electron images. Specimens are only placed in one or the other specimen holder stage at a time. Deflection means are provided for scanning the electron beam over either specimen. Preferably, the deflection system comprises, for example, a deflection coil at or near the front focal plane of the objective lens. According to another embodiment, another scanning coil is provided between the objective lens and the second specimen stage. A detection and display system synchronized with the deflection system converts signals produced by detectors into a scanning electron image.

The detection system must have detectors arranged to pick up electrons transmitted through the transmission specimen or emitted from the secondary electron emission specimen. The objective lens coil is provided with an adjustable lens power supply enabling the strength or excitation of the lens to be adjusted such that it either focuses the electron beam upon the transmission specimen or upon the secondary electron specimen.

DETAILED DESCRIPTION

The present invention will be understood from the following detailed description referring to the attached drawings in which:

FIG. 1 is a schematic drawing showing an embodiment of a convertible electron microscope according to the present invention.

FIG. 2 is a schematic drawing showing an electron beam path in a system to obtain a scanning image of transmitted electrons by using the unit shown in FIG. 1.

FIG. 3 and FIG. 4 are schematic drawings showing electron beam paths to obtain respective reflective secondary electron images by using the unit shown in FIG. 1.

The schematic drawing of FIG. 1 shows a cross-sectional view of an exemplary electron microscope chamber C according to the present invention. A source of an electron beam may be, for example, a field emission type electron gun or a thermal emission type electron gun. The beam generated from the said electron beam source is focused by focusing lenses **2** and **3**, so as to be projected on a transmission specimen **4**. The transmission specimen is usually of thin film held by a first specimen holder stage **5** fixed within an objective lens **6** in such a way as is inserted between magnetic pole pieces of the objective lens. Consequently, the specimen **4** is disposed in a lens magnetic field of the said objective lens. First specimen holder stage has a mechansim (not shown in the drawings) to shift the specimen **4** within a plane perpendicular to an optical axis through an operation manipulated or controlled from outside the chamber C. The objective magnetic lens **6** is sufficiently excited (as described later) such that the magnetic field in front of the specimen acts as a focusing lens, while the magnetic field behind the specimen plays a role to make electrons transmitted through the specimen form an image. A first deflection coil **7** is arranged to scan electron beams on the specimen surface. Coil **7** is disposed at or near the front focal plane of the lens which is in the front magnetic field of the objective lens **6** and is supplied a scanning current from a scanning power supply **9** through a switch **8.**

A second specimen holder stage on a support **11** of which a specimen **12** is held is also capable of shifting within a plane perpendicular to the optical axis through an operation of a shifting lever **13** outside the chamber. In the second holder stage an opening **14** is provided about the electron beam optical axis such that the beam passes through the opening (if the specimen **12** is removed) to reach a detector **15** disposed below it. Near the upper part of the second specimen stage, a second deflection coil **16** is disposed and is supplied a scanning current from the power source **9** through the switch **8,** whereby an electron beam can be scanned on the specimen **12.** In passing, the secondary electrons or reflected electrons from the specimen **12** irradiated by the electron beam, are detected by a detector **17**, then directed into a cathode ray tube **20** through an amplifier **18** and a switch **19**. Further, the deflection means **22** of the cathode ray tube are supplied with signals synchronizing with the scanning of electron beam from the scanning power supply **9**. The detector **15** has an aperture **23**.

FIG. **2** shows the electron beam path for obtaining a high resolution scanning image of transmitted electrons. In FIG. **2** (and FIGS. **3** and **4**) the magnetic lens is shown schematically by its optical analogue. Hence, one magnetic lens **6** is shown as three lenses, **6***a* **6***b* and **6***c*. In FIGS. **3** and **4**, lens **6** is shown as two lenses. This optical condition is achieved if the objective lens **6** is highly excited, the specimen **12** is removed from the second stage **10** and the switch **8** and the switch **19** are necessarily connected to the side of deflection coil **7** and the side of the detector **15**, respectively. In the optical system of FIG. **2**, the objective lens **6** is excited to provide a relatively strong magnetic field and the specimen is placed in the magnetic field of the lens, thus the magnetic field in front of the specimen acts as a focusing lens **6***a*, while that behind the specimen acts as image forming lenses **6***b* and **6***c*. The deflection coil **7** is placed approximately at a front focal plane of the lens **6***a*, and an electron beam deflected by the said deflection coil, is therefore, focused by the lens **6***a* and simultaneously irradiates the specimen approximately perpendicular to the surface thereof. The electrons which are transmitted through the specimen without being scattered are once focused on a position shown as **24** in the drawing, by the lens **6***b*, and next focused on a position of the incident aperture **23** of the detector **15** by the rear lens **6***c* again. In this optical system regardless of the position of an electron beam scanning on a specimen, electrons transmitted through the specimen can be detected by the detector **15**, and by such the detection signal amplified by an amplifier **21** a specimen image can be displayed on the cathode ray tube **20**, therefore.

FIG. **3** shows the electron beam path for obtaining a secondary electron scanning image; that is, observation of the uneveness on a specimen surface. In this optical system, the objective lens **6** is excited to provide a relatively weak magnetic field and the specimen **4** is removed from the first stage holder **5** and switch **8** and switch **19** are necessarily connected to the side of the deflection coil **16** and the side of the detector **17**, respectively. In this optical system, since the objective lens **6** is weak, its focal length is lengthened and its focal depth is also lengthened. A big specimen **12** can be easily inserted on the second holder stage **11**.

FIG. **4** is also a drawing showing another optical system for obtaining a secondary electron image. In this optical system as compared with that shown in FIG. **3**, the objective lens **6** is stronger, but weaker by about 10% than that shown in the embodiment shown in FIG. **2**. In this optical condition, electron beams are once focused inside the objective lens by a front lens **6***a'*, then on a surface of the specimen **12** again by a rear lens **6***b'* to form an electron probe. The scanning movement of the electron probe on a specimen surface is caused by the deflection coil **16**, otherwise it may be carried out by the deflection coil **7**. The magnetic excitation of objective lens **6** in this optical system differs only slightly from the optical system shown in FIG. **2**. The resolving power of secondary electron image can be, therefore, kept high because the final focusing lens has low spherical aberration.

Having thus described the invention with detail and particularity as required by the Patent Laws, what is desired protected by Letters Patent is set forth in the following claims.

I claim:

1. A convertible scanning electron microscope comprising an evacuated chamber surrounding an electron optical axis, an electron beam generating source at one end of the optical axis, a focusing lens along the axis, an objective lens following the focusing lens along the axis, a first specimen holder stage arranged to hold a transmission specimen within the objective lens, a second specimen holder stage arranged to hold a specimen spaced beyond the objective lens along the axis, a deflection system comprising a deflection means disposed along the axis between the focusing and objective lenses and a means for detecting and displaying signals detected and converting them into a scanning electron image of either the transmitted electrons from the transmission specimen or the emitted electrons from the secondary electron specimen, the said objective lens having an excitation power supply adjustable to provide an adjustable focal length such that the electron beam can be focused on the transmission specimen or alternately on the secondary electron specimen such that in a transmission scanning mode, the focusing lens and objective lens focus the electron beam upon the specimen, and the objective lens also serves as a first image forming lens, and such that in a secondary electron scanning mode, the focusing lens and objective lens serve to focus the electron beam upon the sample.

2. A convertible scanning electron microscope according to claim **1** wherein the deflection means comprises a deflection coil at the front focal plane of the objective lens when it is focused upon the transmission specimen.

3. A scanning electron microscope according to claim **2**, wherein the deflection means comprises a deflection coil beyond the objective lens whereby the scanning coil at the front focal plane of the objective lens operates scanning the electron beam over the transmission specimen and the scanning coil beyond the objective lens operates to deflect the electron beam over the secondary electron specimen.

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