# United States Patent [19]

**Heinemann**

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[54] **ELECTRON BEAM IMAGE PROCESSING DEVICE**


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[73] Assignee: **Electron Optical Research and Technology Corporation**, Fremont, Calif.



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[52] U.S. Cl. ..... **250/311**; 250/440; 250/442; 250/444; 250/457; 250/491

[51] **Int. Cl.**..... **G01n 21/26**; G01n 23/12

[58] **Field of Search** ..... 250/311, 439, 440, 442, 250/444, 457, 491



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[57] **ABSTRACT**

A device containing and providing selection between a plurality of electron beam processing units is located in the vacuum chamber of a microscope, so that the latter can be used in a wide variety of applications without breaking the vacuum.


**18 Claims, 4 Drawing Figures**

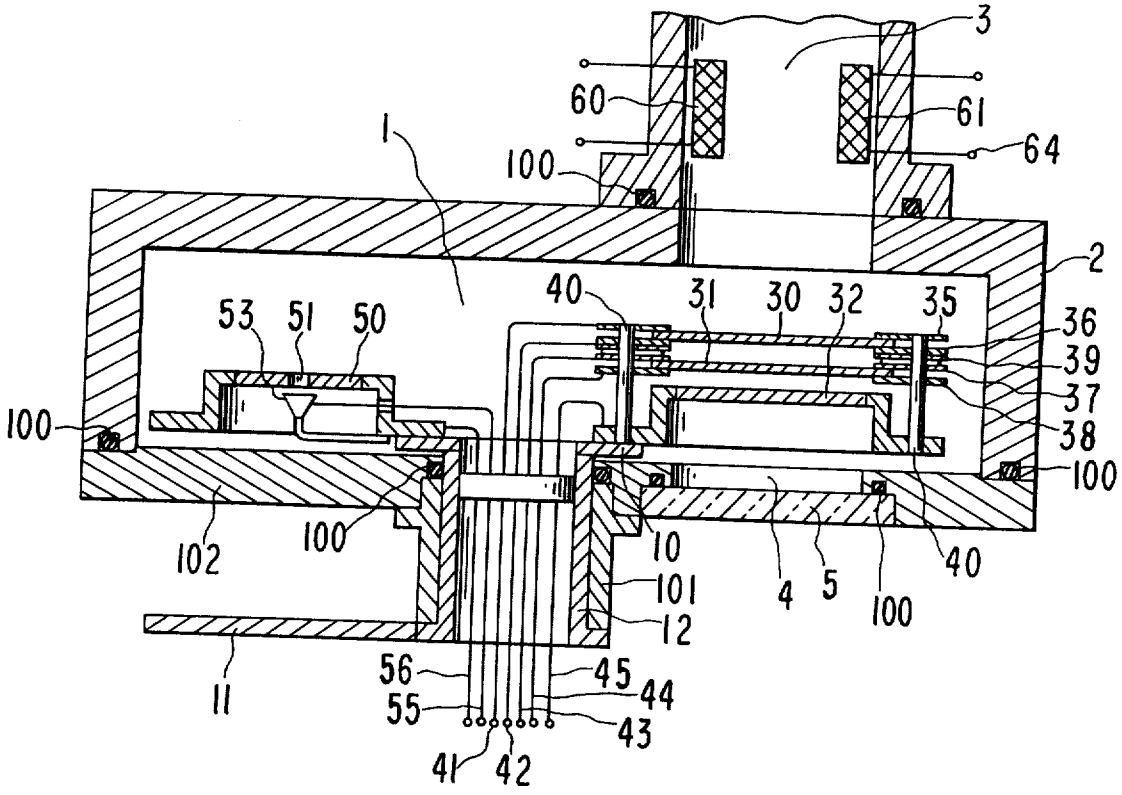


FIG.1

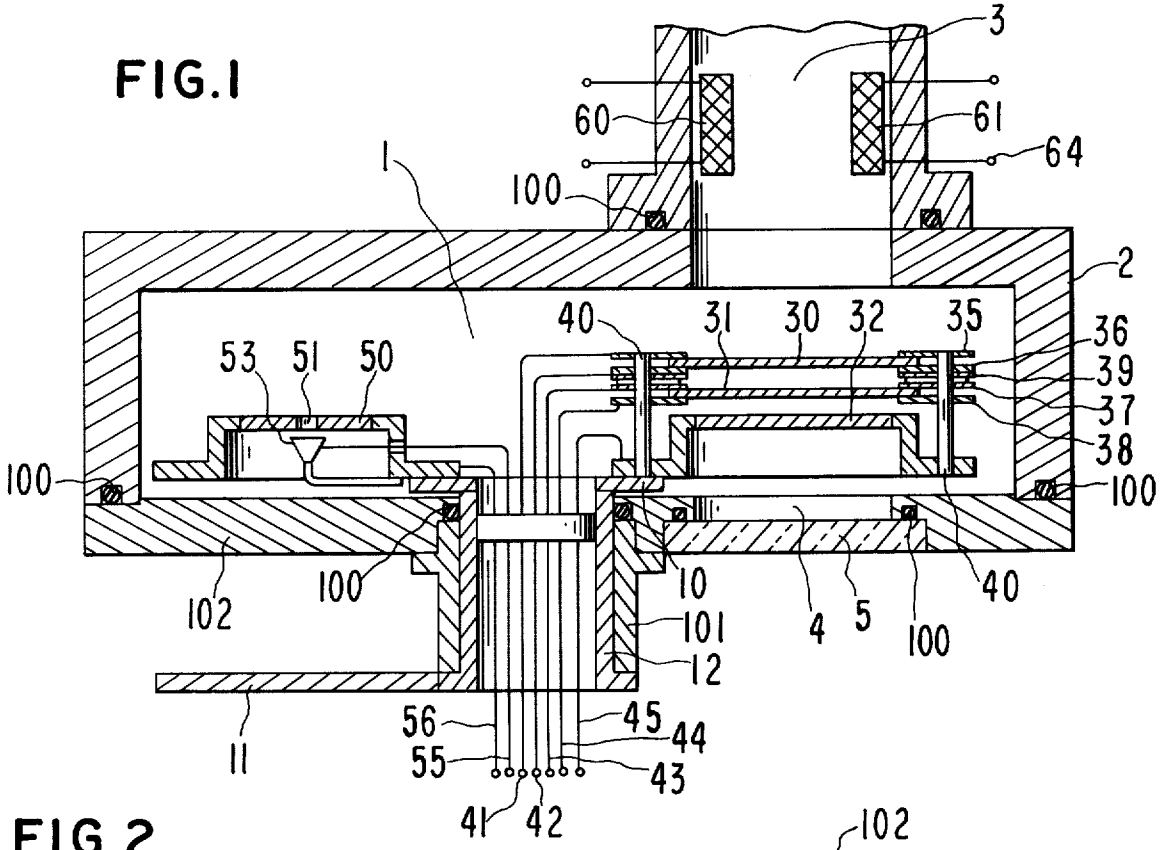
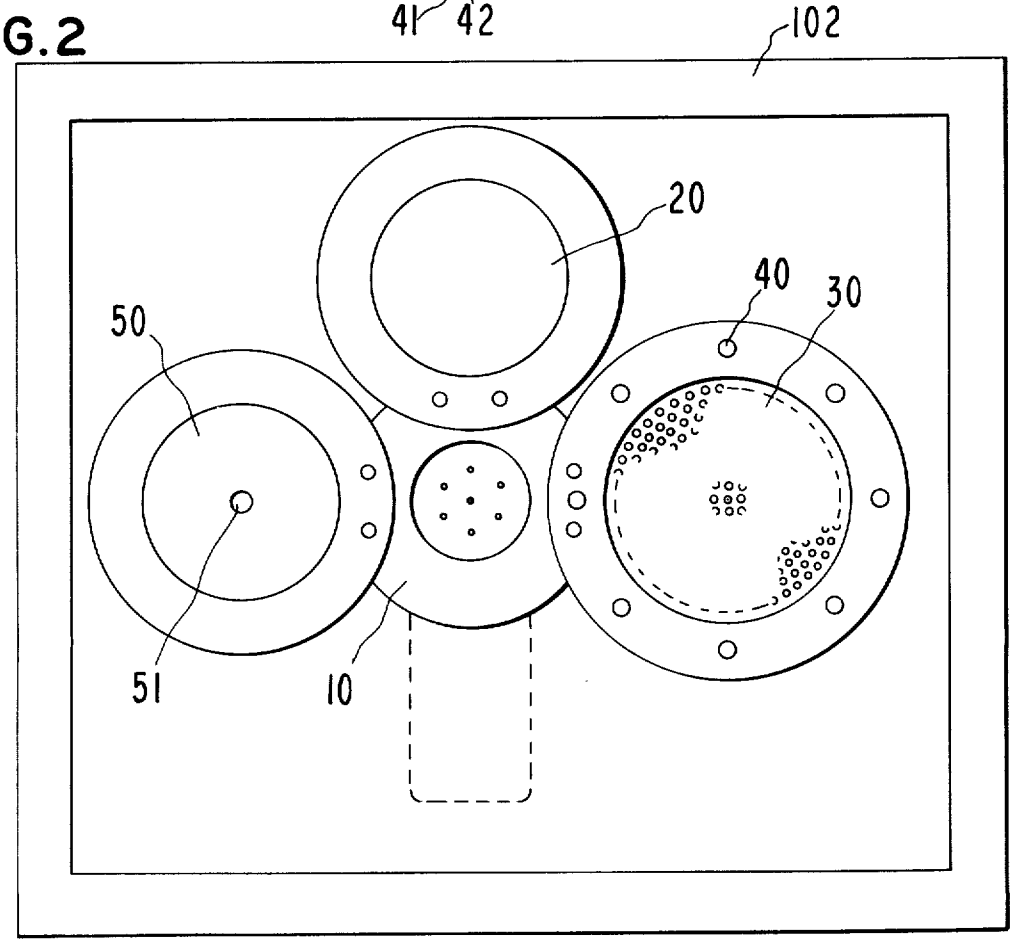

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61
64
1
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100
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102
100
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101
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FIG.2


102
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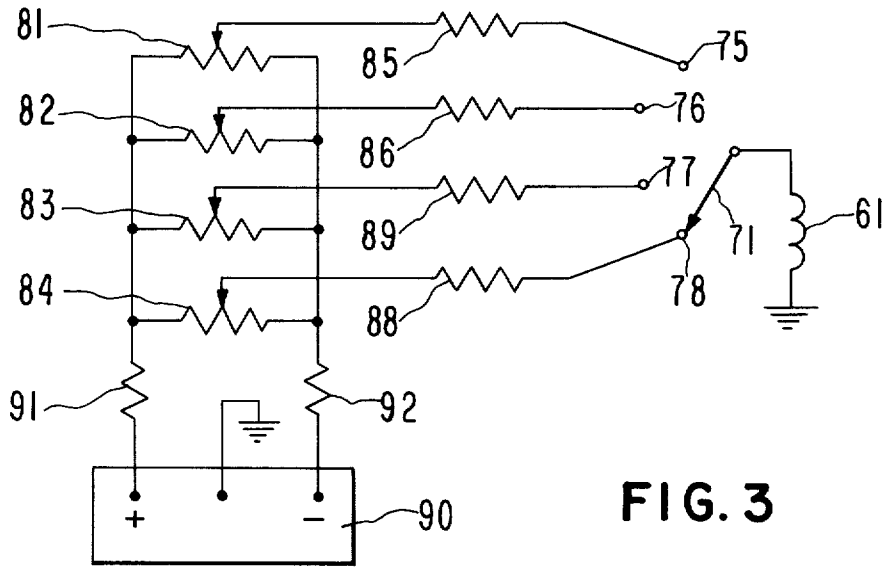
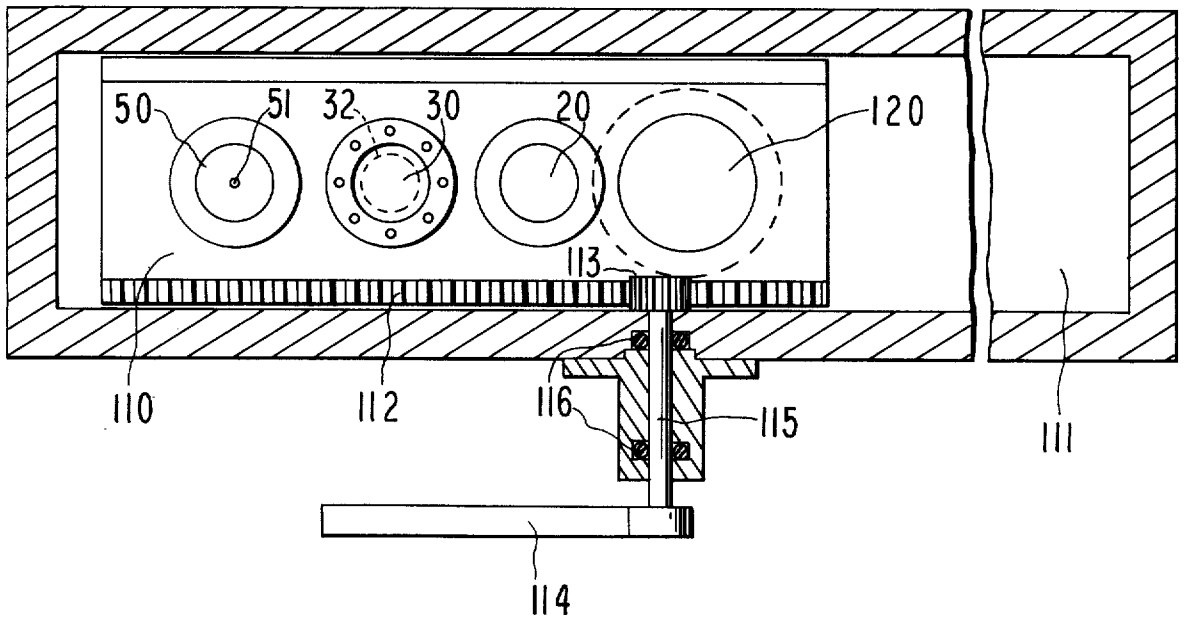

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78
71
61
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90

FIG. 3

FIG. 4


50
51
32
30
20
120
113
110
112
116
115
111
114

# ELECTRON BEAM IMAGE PROCESSING DEVICE

## BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a device for a method of multiple analysis of corpuscular rays, such as electron beams. In particular, this invention relates to a device containing, and providing selection between, a plurality of electron beam processing units for use in transmission electron microscopy.

2. Description of the Prior Art

Transmission electron microscopy enables visual examination to be made of structures too fine to be resolved with ordinary, or light, microscopes, and thus has become an essential research tool in such fields as biology, chemistry and metallurgy.

Briefly, the transmission electron microscope comprises a "light" source supplying a beam of electrons of uniform velocity, a condenser lens for concentrating the electrons on a specimen, a specimen stage for displacing the specimen which transmits the electron beam, an objective lens, several projector lenses, and a fluorescent screen that receives electrons and emits corresponding light rays to provide an image. Electrons are strongly scattered by all forms of matter including air, so that the entire microscope is evacuated to about $10^{-4}$ millimeters of mercury (that is, $10^{-7}$ atmospheric pressure).

In the prior art, several approaches have been used to process electron beams after they leave the specimen stage of an electron microscope. One, mentioned above, comprises a fluorescent screen that receives electrons and produces a visual image. A fluorescent screen projects a bright, usuable image provided that a large number of incident electrons are available at the screen.

Another approach is used when the large number of electrons needed at the fluorescent screen for a bright image would damage or detrimentally affect a specimen located in an earlier stage of the microscope. A low number of electrons are used at the specimen stage, which are then increased after the specimen stage to a large number by use of multi-channel electron multipliers located between the specimen stage and the fluorescent screen. A multi-channel electron multiplier functions to increase greatly the number of electrons in a beam passing therethrough without distorting the electron pattern. When the increased number of electrons reach the fluorescent screen, a bright usuable image is produced. Use of a low number of electrons at the specimen stage thus prevents damage to the specimen, while use of the multiplier allows a bright image to be obtained from the screen.

Still another approach is used when it is desirable to determine the number of electrons per unit area in a beam, that is, the electron density. An electron detector is placed before or after the fluorescent screen, which indicates the density as an image is produced by the screen.

As mentioned above, the chamber of the electron microscope is a vacuum to avoid scattering of electrons. Keeping a vacuum in the chamber makes it difficult to change easily an electron-beam processing unit in the microscope. As a consequence, use of the microscope is limited to applications compatible with the processing unit already located therein. For other applications,



another microscope must be used, or else the vacuum in the first microscope must be broken in order to change the processing unit, and the chamber must then be re-evacuated. Either way is undesirable. Therefore, a device and method are needed that allow selection between various electron-beam processing units for use in a single electron microscope, without affecting its vacuum.

## SUMMARY OF THE INVENTION

The device containing, and method for selecting between, a plurality of electron-beam processing units overcomes the above-mentioned disadvantages of the prior art because, according to the invention, a number of different processing units are located in the chamber of a single microscope at the same time, and selection is made between the units without affecting the vacuum in the chamber. Briefly, the device of the invention comprises a movable platform located in the chamber and a lever mechanically coupled thereto, the lever extending outside the chamber. A plurality of electron-beam processing units are mounted on the movable platform and are selectively aligned by use of the lever. A deflection apparatus is also provided so that the electron beam can be selectively deflected at various angles.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified cross-sectional view of a portion of the chamber of an electron microscope modified to contain the movable platform located therein, the lever mechanically coupled to the platform and extending outside the chamber, and the plurality of electron-beam processing units mounted on the platform.

FIG. 2 is a simplified two-dimensional top view of three electron-beam processing units mounted on the platform within the microscope chamber.

FIG. 3 is a simplified schematic drawing of circuitry for a switch to control deflection of electron beams.

FIG. 4 is a simplified two dimensional top view of a portion of a chamber of an electron microscope modified to contain an alternative embodiment of the movable platform.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, the device for multiple analysis of corpuscular rays, such as electron beams, comprises a chamber 1 having walls 2 enclosing space that is relatively devoid of matter, such as a vacuum. Suitably, the space is evacuated to below $10^{-4}$ millimeters of mercury ($10^{-7}$ atmospheric pressure). The evacuated space avoids unwanted scattering of electrons, which are caused by collisions between electrons and particles including air in the atmosphere. Preferably, chamber 1 is a portion of a microscope, such as a transmission electron microscope, and is located after the specimen stage thereof. An opening 3 is provided to allow an electron beam to enter chamber 1 from another portion of the microscope. Another opening 4 provides for external viewing of a portion of the contents of chamber 1. Suitably, opening 4 is covered by a transparent material 5, such as glass or clear plastic, that allows retention of the vacuum seal in chamber 1.

A movable platform, such as turntable 10, is located within chamber 1. Preferably, turntable 10 is mounted so as to provide rotational movement about an axis. A

lever 11 extends outside of chamber 1 and is mechanically coupled to the turntable 10 by means of torus 12. Lever 11 provides external control of the position of turntable 10 in chamber 1. Mounted on turntable 10 are a plurality of electron-beam processing units. For example, one processing unit on turntable 10 comprises a fluorescent screen 20 (shown in FIG. 2). Fluorescent screen 20 functions in a manner similar to that of a cathode ray tube, that is, screen 20 receives electrons on one side and emits corresponding light rays from the other side thereof. Screen 20 comprises a suitable fluorescent material well known in the art and hereinafter is referred to as a phosphor screen. Phosphor screen 20 is aligned between openings 3 and 4 of chamber 1 by use of lever 11, so that an electron beam entering opening 3 strikes one side of screen 20 and an image on the other side thereof corresponding to the electron pattern is viewed through opening 4. Phosphor screen 20 produces good images when the energy of electrons in the beam is in the range of 50 to 200 kiloelectron volts, and when the electron intensity is in the range of $10^{-8}$ to $10^{-11}$ amperes per square centimeter.

Another example of an electron-beam processing unit located in turntable 10 comprises a plurality of electron multipliers 30 and 31 located over a phosphor screen 32 (see FIGS. 1 and 2). Preferably, each electron multiplier comprises an array of cylindrical channels or tubes formed of an insulative material, such as glass. A high resistive coating having secondary emissive effects is located on the inside of each channel or tube. For example, the coating resistance is about 1,000 megohms per square, and the coating material comprises tin oxide or antimony oxide. The diameter of each tube is relatively small compared to its length, so that electrons entering the tube impinge upon the resistive coating, causing secondary emission and multiplication of electrons.

Preferably, the channels or tubes in multipliers 30 and 31 are tilted at a small angle from the direction of the electron beam. For example, the angle of tilt of the channels in multiplier 30 is 8° in a clockwise direction from the path of the electron beam, and the angle of tilt in multiplier 31 is about 8° counterclockwise from the electron beam path. The use of the channels or tubes tilted at a small angle increases the number of times electrons travelling therein collide with the high resistive coating, and thereby increases the secondary emission effects.

The ends of the channels or tubes on one side of an array are electrically connected to each other and to a lead, such as lead 35 for multiplier 30 (see FIG. 1). Suitably, lead 35 comprises a thin metal strip or film of conductive material. The ends of the channels or tubes on the other side of the array are electrically connected to each other and to a lead, such as lead 36, for multiplier 30. An accelerating field across the channels or tubes can be provided by applying the proper voltages to leads 35 and 36. Leads 37 and 38 provide electrical connections respectively to the two sides of the array of channels or tubes of multiplier 31. Electrical insulation between leads 36 and 37 is provided by a thin insulation material 39, such as mylar. Suitably, the arrays are supported securely above the phosphor screen 32 by posts 40, which are also of an insulating material, such as ceramic. An external voltage source is coupled to electrical leads 35 to 38 and screen 32 by use of conductive wires 41 to 45 that extend from leads 35 to 38 and screen 32 through the mid portion of turntable 10 and torus 12 to an external source.

Still another example of an electron-beam processing unit comprises a phosphor screen 50 with a small hole 51 extending completely therethrough, the screen 50 mounted on turntable 10. Hole 51, for example, has a diameter of about 3 millimeters. Underneath screen 50 and aligned with hole 51 is an electron multiplier 53. Unlike multipliers 30 and 31, multiplier 53 has a single channel. The lining of the channel of multiplier 53 comprises a resistive coating. When incoming electrons impinge upon the coating, secondary emission effects occur, resulting in electron multiplication that is proportional to the number of electrons entering the multiplier. An ammeter capable of indiating very low current values, such as in the picoampere range, can be electrically coupled to the output of multiplier 53 to detect electrical impulses generated when electrons have passed through hole 51 and entered multiplier 53. The magnitude of a pulse is proportional to the number of electrons passing through hole 51.

Conductive wires 55 and 56 extend through the mid portion of torus 12 and turntable 10 and are electrically connected to electron multiplier 53 and phosphor screen 50 respectively, thereby providing connections to an external voltage source.

An electron beam striking one side of screen 50 results in the image appearing on the other side thereof, while at the same time a portion of electrons in the beam pass through hole 51 and enter multiplier 53, thereby allowing determination of electron density at the same time the image is being viewed.

Referring to FIG. 1, spaced deflecting coils or plates 60 and 61 are provided for deflecting thet incoming electron beam as it enters through opening 3. The deflecting elements may be electrostatic or electromagnetic. For deflection in two directions, such as X- and Y-directions, a pair of spaced coils is provided, one pair for each direction. The degree of deflection in each direction is determined by the magnatude of the potential applied to a selected pair of deflection coils. Spaced electrical leads 63 and 64, coupled respectively to electrical terminals of deflectors 60 and 61, extend outside the chamber to enable application of voltage potentials to deflectors 61 and 62 from an external source.

An insulating material, such as "TorrSeal" or equivalent, is provided at the location where the leads 63 and 64 pass through the chamber wall, in order to protect the vacuum in the chamber.

A multiposition switch, such as switch 70 as shown in FIG. 3, along with the circuit components, is provided to selectively control the magnitude of the potential applied to deflectors 60 and 61, and thereby control the various degrees of deflection in one direction. Each of four terminals 75 through 78 of multiposition switch 70 is electrically coupled via resistors 85 through 88 to a center tap of one of four voltage dividers 81 through 84. Resistors 85 through 88 ensure linear deflection upon adjustment of the center tap. The output from the center arm 71 of switch 70 is electrically coupled via electrical leads 63 and 64 to deflectors 60 and 61 in the microscope chamber, indicated symbolically in FIG. 3 as coil 61. The source of the voltage potential, for example, can be a direct-current power supply 90 coupled across voltage dividers 81 through 84 by resistors 91 and 92. Preferably, the center arm 71 of switch 70 is connected to a timer (not shown), which periodically

moves arm **71** through each of the four terminals **75** through **78**, thereby changing the potential on coil **61** and controlling the degree of deflection of an incoming electron beam in chamber **1**. Switch **70** enables one to determine the electron density of four different portions of the beam. Another switch is provided for shifting the beam in another direction, such as the Y-direction. If desired, a multilevel switch can be used for shifting the beam in various directions at the same time.

As mentioned above, the entire chamber **1** is sealed to preserve the integrity of the vacuum therein. Suitably, the sealing means comprises a rubber or viton O-ring seal **100** (FIG. **1**) at each place where portions of the chamber come together. In addition, a cylinder **101** may be fastened to the chamber wall **102** in the vicinity of the torus **12** in order to compress the O-ring seal against the torus **12** and prevent any leakage of air into the chamber, especially during axial rotation of the torus **12**.

Referring to FIG. **4**, an alternative embodiment of the movable platform provides for longitudinal movement, rather than rotational. Platform **110** is moved longitudinally in chamber **111** by means of a gear mechanism **112** and **113**. Gear **113** is mechanically coupled to external lever **114** by member **115**. Rubber or viton O-ring seals **116** are provided to maintain the vacuum in the chamber. Mounted on platform **110** are various electron beam-processing units similar to those located on turntable **10** of FIG. **1**. For example, one processing unit comprises a phosphor screen **20**. Another unit comprises a phosphor screen **32** with microchannel electron multipliers **30** located thereover. Still another unit comprises a phosphor screen **50** with a small hole **51** extending therethrough to accommodate an electron detector located thereunder. As desired, platform **110** can also contain an empty hole or leaded plate **120**, particularly in applications where no special processing unit is required.

While the invention has been described with reference to particular embodiments, it includes numerous other modifications, which will be obvious to one skilled in the art.

I claim:

**1.** Device for analysis of corpuscular rays, such as an electron beam after the beam has left the specimen stage of a transmission electron microscope, the device comprising:

a chamber having walls enclosing a space relatively devoid of matter, a portion of the chamber adapted to admit incoming corpuscular rays, such as an electron beam;

a plurality of spaced electron-beam processing units located within the chamber, the units comprising:

a first processing unit comprising:

a phosphor screen having a relatively small hole extending through a portion thereof; and,

a single channel electron multiplier aligned with the hole, with the screen located in front of the multiplier relative to an incoming electron beam;

a second processing unit comprising:

a plurality of spaced multichannel electron multipliers; and

a phosphor screen, with the multipliers located in front of the screen relative to an incoming electron beam;

a third processing unit comprising a phosphor screen:

means for selecting a processing unit and aligning said unit with an electron beam in the chamber; and

means for selectively applying voltage potentials to a selected processing unit.

**2.** Device of claim **1** wherein said means for selecting and aligning a processing unit comprises a moveable platform within which said processing units are mounted, and a lever mechanically coupled to the platform and extending outside the chamber.

**3.** Device of claim **2** wherein the lever is mechanically coupled by a gear mechanism, and the platform has longitudinal movement.

**4.** Device of claim **1** wherein said chamber is a portion of an electron microscope.

**5.** Device of claim **2** wherein the moveable platform comprises a rotatable turntable.

**6.** Device of claim **1** wherein said voltage potential applying means comprises a plurality of spaced electrical leads electrically coupled between an external power source and electrical terminals of processing units within the chamber.

**7.** Device of claim **1** further defined by a portion of one wall of the chamber comprising transparent material, so that an image produced by an electron-beam processing unit can be viewed external to the chamber.

**8.** Device of claim **1** further defined by a deflection means located along a portion of the chamber adapted to admit incoming electron beams, and means for selectively applying voltage potentials to the deflection means.

**9.** Device of claim **8** wherein the deflection means comprises a plurality of spaced coils.

**10.** Device of claim **8** wherein the deflection means comprises a plurality of spaced conductive plates.

**11.** Device of claim **8** wherein the voltage potential applying means comprises spaced leads electrically coupled between an external power source and electrical terminals of the deflection means.

**12.** Device of claim **11** further defined by a multiposition switch located outside the chamber, and having output terminals electrically coupled to the electrical leads, so that when potentials of different magnitudes are applied to the input terminals of the switch, the position of the switch controls the potential applied to the deflection means.

**13.** Device of claim **12** further defined by a timer coupled to the switch to move periodically the switch through each of its positions.

**14.** Method of selecting between electron beam processing units for use in an electron microscope without breaking the vacuum in the chamber thereof, the steps comprising:

modifying a portion of the microscope chamber;

mounting a plurality of electron beam processing units onto a movable platform having a lever mechanically coupled thereto;

inserting a movable platform into the modified portion of the chamber so that the lever extends outside the chamber; and,

moving the lever so as to align a processing unit with an incoming electron beam.

**15.** An electron image processing device for use in an electron beam instrument, the device comprising:

a microdensitometer unit;

an image intensifier unit;

a transmission phosphor screen unit; and,

a moveable platform within which each of the units is mounted and spaced apart.

**16.** Device of claim **15** wherein the microdensitometer unit comprises:

a phosphor screen having a relatively small hole extending through a portion thereof; and,

a single channel electron multiplier aligned with the hole, with the screen located in front of the multiplier relative to an incoming electron beam.

**17.** Device of claim **15** wherein the image intensifier unit comprises:

a plurality of spaced multichannel electron multipliers; and,

a phosphor screen, with the multipliers located in front of the screen relative to an incoming electron beam.

**18.** A microdensitometer device comprising:

a phosphor screen having a relatively small hole extending through a portion thereof; and,

a single channel electron multiplier aligned with the hole, with the screen located in front of the multiplier relative to an incoming electron beam.

* * * * *