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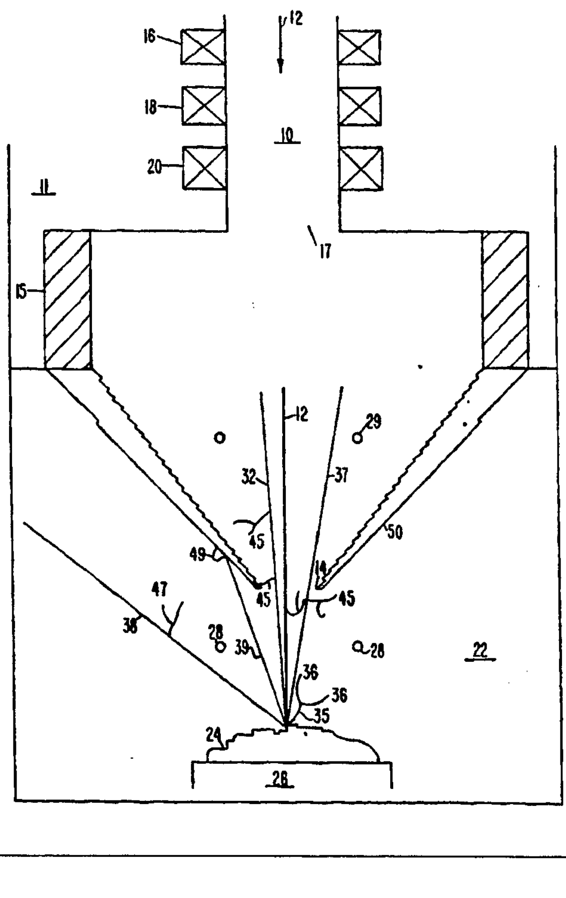
(54) Title: IMPROVED ENVIRONMENTAL SCANNING ELECTRON MICROSCOPE

(57) Abstract

An environmental scanning electron microscope which achieves image resolution comparable to that of a conventional SEM is disclosed. A biased ring electrode (28) detects secondary electrons from the specimen and a biased pressure limiting aperture electron detector (50) is also provided to reduce signals emanating from backscattered electrons and to reduce signal noise generated by the electron beam. An optical window system is provided which allows the user to easily switch between the normal environmental SEM electron image (limited to 0.5 mm in diameter) to an optical light view of the sample that covers a field-of-view of up to about 7 to 10 mm. Moreover, the construction of this environmental SEM provides for a take-off angle for the X-ray detectors (EDX detectors) (102) which is comparable to the take-off angle for an EDX detector in a conventional SEM.



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IMPROVED ENVIRONMENTAL SCANNING ELECTRON MICROSCOPE

BACKGROUND OF THE INVENTION

This invention relates to the field of environmental scanning electron microscopes, and more particularly, to an environmental scanning electron microscope which achieves standard SEM resolution performance in a gaseous environment.

As background, the advantages of an environmental scanning electron microscope over standard scanning electron microscopes (SEM) lie in its ability to produce high-resolution electron images of moist or non-conductive specimen (e.g., biological materials, plastics, ceramics, fibers) which are extremely difficult to image in the usual vacuum environment of the SEM. The environmental scanning electron microscope allows the specimen to be maintained in its "natural" state without subjecting it to the distortions caused by drying, freezing, or vacuum coating normally required for high-vacuum electron beam observation. Also, the relatively high gas pressure easily tolerated in the environmental scanning electron microscope specimen chamber acts effectively to dissipate the surface charge that would normally build up on a non-conductive specimen, blocking high quality image acquisition. The environmental scanning electron microscope also permits direct, real-time observation of liquid transport, chemical reaction, solution, hydration, crystallization, and other processes occurring at relatively high vapor pressures far above those can be permitted in the normal SEM specimen chamber.

As stated in U.S. Patent 4,992,662, the original concept of an environmental scanning electron microscope, as suggested in U.S. Patent 4,596,928, was to maintain the specimen chamber in a gaseous environment such that the gaseous environment acted as a conditioning medium in order to maintain the specimen in a liquid or natural state. In addition, the utilization of the gaseous environment of the specimen chamber as a medium for amplification of the secondary electron signals is described in U.S. Patent 4,785,182.

In the environmental SEM of U.S. Patent 4,824,006, electron beam observation of unprepared, full-sized specimens at high vacuum pressures was made possible due to the combination of pressure control and signal detection means, housed entirely within the magnetic objective lens of the electron beam column. The environmental SEM design of U.S. Patent 4,823,006 satisfied the simultaneous requirements for pressure control, electron beam focusing, and signal amplification, while providing no practical limitations on specimen handling or microscopic resolving power. A limitation of the environmental SEM of U.S. Patent 4,824,006, however, is that the field-of-view of the sample is limited by the final pressure limiting aperture. The pressure limiting aperture is necessary to prevent the gas from the specimen chamber affecting the operation of the electron column and absorbing the primary electron beam. This pressure limiting aperture is typically 0.5 millimeters in diameter. This also limits the field-of-view to about a 0.5 millimeter diameter. This limited field-of-view makes it difficult for the operator to know where he or she is on the sample and the location of the desired area of examination.

It is therefore desirable to provide an environmental scanning electron microscope having an optical window system which allows the operator to switch between the normal environmental scanning electron microscope electron image (limited to approximately 0.5 millimeters in diameter) to an optical light view of the sample that covers a field-of-view of about 7 to 10 mm which is comparable with typical field-of-view capabilities of an SEM.

U.S. Patent 4,897,545 describes a more complex detector arrangement than that disclosed in U.S. Patent

4,824,006 which allows for the detection of other signals (i.e., backscattered electrons) in the gas, utilizing a set of differently biased electrodes. U.S. Patent 4,897,545 discusses that various electrodes can be used to collect different signals from the specimen chamber, but fails to discuss how the signal from one electrode might be optimized by a suitable bias on another electrode. In addition, in U.S. Patent 4,897,545, there is no mention of the concept of using an electrode as a collector of unwanted signals or using an electrode to reduce signal noise produced by the primary beam. It would therefore be desirable to provide an environmental SEM which improves secondary electron detection by reducing the backscattered electron component of the signal and the signal noise produced by the primary beam.

In comparison to the environmental SEMs of U.S. Patent Nos. 4,824,006 and 4,897,545, it has also been found desirable to provide an environmental SEM which optimizes signal amplification following detection of the desired secondary electrons such that the detector noise is reduced below the noise in the signal itself, while still maintaining an overall signal bandwidth that is suitable for setting up the image.

Most modern SEMs utilize a method to enable an electron beam to be scanned over the sample in order to construct an image of the sample, or to collect other information from the sample, such as X-ray data. These methods allow a large part of the sample to be scanned with acceptably low geometric distortion of the image of the sample. In a typical SEM, the electron gun generates a relatively large (20 micrometer) source of electrons which must be demagnified to the small size required to image small details on the sample. This de-magnification is typically produced by three electron lenses in the optical vacuum column. Only a small proportion of the electrons reach the sample as the final beam is conveniently referred to as a "pencil beam" (see reference numeral 2 in Figure 1).

As is shown in Figure 2, in order to scan the primary beam along the length of the vacuum column, scanning coils, such as 3 and 4, are positioned in the objective lens assembly 5. If a current is passed through the two sets of scanning coils 3 and 4, the pencil beam will be deflected as shown in Figure 2.

In the previous environmental SEM of Figure 3, two pressure limiting apertures 6 and 7 allow high pressure in the specimen chamber 8 (e.g., approximately 5 Torr) while maintaining a high vacuum (e.g., approximately 0.0001 Torr) in the region of the scanning coils 9a and 9b. As these pressure limiting apertures are normally 0.3 mm to 0.5 mm in diameter, they limit the field-of-view of the specimen, as aforementioned, to about 0.5 mm in diameter. In contrast, a typical SEM will allow at least ten times this amount under comparable working conditions. It is therefore desirable to provide a scanning coil deflection system for an environmental scanning electron microscope having at least two pressure limiting apertures which has an enhanced field-of-view.

Moreover, in the prior environmental SEM, such as the environmental SEM of U.S. Patent No. 4,824,006, the take-off angle of the X-ray detector (EDX detector) is not comparable to the take-off angle of the EDX detectors of conventional SEMs. As is shown in Figure 4, in a conventional SEM, the conical base 201 of the objective lens 202 allows the energy dispersive X-ray detector (EDX) 203 to collect X-rays emanating from the surface of the sample at a take-off angle of approximately 30%, without the bulk of the EDX detector intruding into the sample space.

In environmental SEMs, however, as is shown in Figure 5, the objective lens 204 with a flat lower pole piece 205 and the gas manifolds 206 and 207 (used to withdraw the gas that passes through the pressure limiting aperture) are at the same level. Since the working distance between the specimen and the data acquisition devices in an environmental SEM must be kept as short as possible, the space that the EDX detector can occupy in the specimen chamber is restricted. Thus, in order to limit this working distance, the design of the environmental SEM of Figure 5 limits the take-off angle of the EDX detector 208 in the specimen chamber to approximately 20°. It is therefore desirable to provide an environmental SEM which provides for a take-off angle of the EDX detector which is comparable with the take-off angle of EDX detectors in conventional SEMs.

OBJECTS OF THE INVENTION

Therefore, it is an object of the present invention to provide an improved environmental scanning electron microscope which avoids the aforementioned deficiencies of the prior art.

It is also an object of this invention to provide an improved environmental scanning electron microscope which permits direct real-time observation of liquid transfer, chemical reactions, solutions, hydration, crystallization and other processes occurring at relatively high vapor pressures.

It is another object of this invention to provide an environmental scanning electron microscope which satisfies the simultaneous requirements for pressure control, electron beam focusing and signal amplification while placing no practical limitations on specimen handling or microscope resolving power.

It is a further object of the invention to provide an improved environmental scanning electron microscope which achieves standard SEM resolution in a gaseous environment.

It is a further object of this invention to provide an improved environmental scanning electron microscope having an improved secondary electron detector which reduces the backscattered electron component of the signal emanating from the specimen and reduces the signal noise produced by the primary beam.

It is yet another object of this invention to provide an improved environmental scanning electron microscope which allows the electron beam to strike a greater surface area of the specimen, and thus, provides for an enhanced field-of-view of the specimen comparable to that of a standard SEM.

It is a still further object of this invention to provide an improved environmental scanning electron microscope which has an improved amplifier for the signal received by the secondary electron detector.

It is still a further object of this invention to provide an improved environmental scanning electron microscope which has an improved method of observing large samples.

It is still a further object of this invention to provide a scanning electron microscope which allows an optical view of the sample while simultaneously utilizing a gaseous detector.

It is still a further object of this invention to provide an improved environmental scanning electron microscope which has an enhanced take-off angle for an EDX detector which is comparable with the take-off angle for an EDX detector of a standard SEM.

It is still a further object of this invention to provide an electrode detector assembly for an environmental scanning electron microscope wherein the electrodes are supported mechanically.

It is still a further object of this invention to provide an electrode detector assembly for an environmental scanning electron microscope wherein each of the signals received by the electrode detectors are insulated from the signals received by the other electrode detectors of the electrode detector assembly.

It is still a further object of this invention to provide an electrode detector assembly for an environmental scanning electron microscope which provides for electrostatic screening to reduce pick-up of electronic noise.

It is still a further object of this invention to provide an electrode detector assembly for an environmental scanning electron microscope which insulates the pressure limiting aperture but the insulators in the support structure are "hidden" to avoid disturbing the primary beam.

It is still a further object of this invention to provide an electrode detector assembly for an environmental scanning electron microscope wherein the support structure for the electrodes is electrically isolated so that the various signals collected by the electrodes are not interconnected.

It is yet a further object of the present invention to provide an electrode detector assembly for an environmental scanning electron microscope wherein the electrode structure is robust, (i.e. strong enough to minimize mechanical damage caused by hitting it with the sample or by the requirements to claim it).

It is still a further object of this invention to provide an electrode detector assembly for an environmental scanning electron microscope which is easily cleanable to thereby remove the results of experiments carried out on wet or dirty samples.

It is still a further object of this invention to provide an electrode detector assembly for an environmental scanning electron microscope which is relatively inexpensive to replace.

Various other objects, advantages and features of the present invention will become readily apparent from the ensuing detailed description and the novel features will be particularly pointed out in the appended claims.

SUMMARY OF THE INVENTION

This invention relates to an improved environmental scanning electron microscope which achieves standard SEM resolution performance in a gaseous environment.

In a preferred embodiment thereof, the electron microscope includes an electron gun for generating and directing an electron beam towards a specimen to be examined. In the objective lens assembly of this environmental scanning electron microscope, the electron beam passes through an electron optical column until it reaches a differentially pumped aperture column. In the differentially pumped aperture column, the electron beam is focused and scanned across the diameter of the final pressure limiting aperture.

A specimen chamber is positioned below the objective lens assembly and is capable of maintaining the specimen enveloped in gas in registration with the pressure limiting aperture such that a surface of the specimen may be exposed to the focused beam of electrons. A specimen mount is located within the specimen chamber and is positioned for supporting the specimen approximately 1 to 25 mm below the pressure limiting aperture so as to allow the focused beam of electrons to interact with the specimen.

In accordance with one of the general objects of the present invention, this environmental SEM includes an electron detector configuration which reduces the backscattered electron component of the signal emanating from the surface of the sample and reduces the signal noise produced by the primary electron beam. More specifically, this configuration includes a biased pressure limiting aperture electrode detector formed integrally with the pressure limiting aperture and a biased ring electrode provided at or just below the final pressure limiting aperture within the specimen chamber and above the surface of the specimen. This ring electrode assembly is formed of a thin ring structure having a thickness of approximately 50 to 1000 microns and is made of an electrically conductive material, such as metal, pyrolytic graphite, etc. The ring electrode is suitably biased such that desired signals from secondary electrons emanating from the surface of the sample are collected thereon.

In this environmental SEM, the pressure limiting aperture detector electrode is suitably biased such that the undesired secondary electrons, including (1) secondary electrons generated by collisions between the primary beam and the gas in the specimen chamber, (2) secondary electrons generated by collisions between backscattered electrons that pass through the pressure limiting aperture and the gas in the specimen chamber, (3) secondary electrons generated by collisions between backscattered electrons which pass through the gas between the sample and the rest of the specimen chamber, and (4) secondary electrons produced by backscattered electrons striking the pressure limiting aperture, are intercepted and collected by the pressure limiting aperture electrode. Accordingly, these undesirable secondary electron signal components are not collected by the ring electrode, and the secondary electron image derived from the ring electrode is a more pure secondary electron image which also exhibits a lower noise level.

In accordance with another general object of the present invention, this environmental SEM includes an improved amplifier for amplifying the signals collected by ring electrode. This amplifier floats at the bias voltage of the ring electrode and the output of the amplifier is supplied to a video display. The amplifier has a feedback mechanism including a resistor having a resistance value of R. The output signal of the amplifier is amplified to restore the high frequency signal lost due to the effect of R. In addition, the amplifier is operated in a so-called virtual earth or ground mode.

Advantageously, this amplifier maintains the voltage on the ring electrode to be very close to V1. With this design, noise at the output of the amplifier is also reduced such that the dominant source of noise in this environmental SEM is from the shot noise in the beam. In order to achieve this reduction, the resistor R is at least 1M ohm.

The environmental SEM of the present invention also permits the operator to easily switch between a normal environmental scanning electron microscope electron image (typically limited to 0.5 mm in diameter) to an optical light view of the sample that covers a field-of-view of up to approximately 7 to 10 mm. The optical windowing system of this environmental scanning electron microscope includes (1) an optical image production system to illuminate the specimen from a light source and reflects the image of the specimen to provide a continuous optical view thereof, and (2) an optical display system that allows the optical image to be shown on an environmental SEM display and control screen.

In the optical image production system, a relatively small mirror is mounted to the magnetic focusing lens and faces the specimen. The sample is illuminated by reflecting light off the mirror (and the underside of the objective lens). The mirror is also used to collect the image of the sample and send it back through a lens onto a charge-coupled device ("CCD") TV camera. The TV signal from the camera is supplied directly into a standard TV monitor to provide a continuous optical view of the sample. With this optical image production system, a view of the sample is obtained which is substantially equivalent to a "top down" view.

The optical display system includes a screen having an image display area and a menu display area for displaying operational and status information for an operator. In the image display area, either the electron images received by the ring electrode or optical images produced by the optical image production system may be displayed. Furthermore, in the image display area, electron images of the sample may be inserted in the optical images as a "picture-in-picture" display and vice versa such that the operator can switch instantly between selected optical and electron images of the sample.

In this environmental SEM, the take-off angle of the X-ray detector (EDX detector) is comparable with the take-off angle of an EDX detector of a conventional SEM. In order to obtain a take-off angle of approximately 30°, the pressure limiting aperture assembly extends downwardly from the final pole piece such that the specimen is positioned approximately 1 to 25 mm below the pressure limiting aperture.

A further advantageous feature of the environmental SEM of the present invention is that the field-of-view of the specimen is enhanced and comparable to the field-of-view of a standard SEM. In order to increase the surface area of the specimen which is impinged by the primary beam, the objective lens assembly includes a scanning assembly which provides for triple deflection of the electron beam through two pressure limiting apertures and a magnetic lens housing of reduced focal length. As a result of this design, the environmental SEM achieves a field-of-view of the specimen of up to approximately 7 to 10 mm.

In accordance with one of the general objects of the present invention, an improved electrode detector assembly for an environmental scanning electron microscope is also provided. In order to provide mechanical rigidity for the electrodes collecting signals emanating from the surface of the specimen under examination, this electron detector assembly is in the form of a printed circuit board. The printed circuit board includes a detector head having collection electrodes thereon for collecting signals emanating from the specimen. In one embodiment, these collection electrodes include a signal ring electrode biased to collect secondary electrons emanating from the surface of the specimen and a biased electrode pad to reduce signals emanating from backscattered and low angle reflected electrons.

In order to prevent electrical leakage between the collection electrodes, the printed circuit board provides for insulation of those signals and carries those signals to edge connectors. These electrical conductors are in the form of electrically conductive tracks which are embedded in the printed circuit board.

In accordance with another general object of the present invention, this electrode detector assembly also provides for electrostatic screening to reduce pickup of electrical noise. In order to achieve electrostatic screening, the top and bottom sides of the printed circuit board includes gold plated copper covers.

In another preferred embodiment, the detector head includes a generally annular electrode assembly having an inner electron detector formed of a signal ring electrode, an intermediate electron detector positioned radially outwardly of the inner electron detector which is formed of a plurality of concentric arc segments, and an outer electron detector positioned radially outwardly of the intermediate electron detector which is formed of the second plurality of concentric arc segments. In this configuration, the signal ring electrode collects predominantly amplified lower energy secondary electrons emanating from the surface of the specimen. The first plurality of concentric arc segments of the intermediate electron detector collect predominantly amplified higher energy backscattered electron signals. The second plurality of concentric arc segments collects predominantly amplified low angle backscattered electron signals.

In the electrode detector assembly of the present invention, the printed circuit board includes both the detector head for the collecting secondary electrons emanating from the surface of the specimen and the final pressure limiting aperture formed integrally thereon. As a result thereof, the pressure limiting aperture is easily interchangeable for different sizes, and moveover, the cost of manufacturing of the pressure limiting aperture/electrode structure is relative inexpensive such that the user can be provided with more than one assembly with different sized pressure limiting apertures.

In accordance with one of the general objects of the present invention, this electrode detector assembly also provides for a gas tight seal between the objective lens assembly and the specimen chamber and means to easily remove the electrode detector assembly from the environmental scanning electron microscope. In order to achieve that result, a vacuum sealing ring extends from the printed circuit board which is matingly engaged with a body detector mounted to the objective lens assembly to provide a gas tight seal between the object lens assembly and the specimen chamber. In addition, this vacuum sealing ring properly positions the printed circuit board, and hence, the integrally formed collection electrodes and pressure limiting aperture of the detector head in the environmental scanning electron microscope.

A printed circuit board connector is also provided in the specimen chamber to receive an end of the printed circuit board remote from the detector head to retain the printed circuit board in its proper position in the environmental scanning electron microscope. In order that the printed circuit board be easily removed from the environmental scanning electron microscope, the printed circuit board is snap-fit into the printed circuit board connector.

BRIEF DESCRIPTION OF THE DRAWINGS

The following detailed description, given by way of example, but not intended to limit the invention solely to the specific embodiments described, may best be understood in conjunction with the accompanying drawings in which:

Figure 1 is a schematic diagram of the electron beam in a typical SEM column.

Figure 2 is a schematic representation of the beam deflection in a typical SEM column.

Figure 3 is a schematic representation of the beam deflection in an environmental scanning electron microscope having two sets of scanning coils and two pressure limiting apertures.

Figure 4 is a schematic representation of an X-ray detector configuration present in modern SEMs.

Figure 5 is a schematic representation of the configuration for an X-ray detector in a prior art environmental scanning electron microscope.

Figure 6 is a schematic representation of an example of electron trajectory paths in an environmental scanning electron microscope.

Figure 7 is a schematic representation of one preferred embodiment of the environmental scanning electron microscope of the present invention illustrating the preferred electron path trajectories.

Figure 8 is a schematic representation of the improved signal amplifier system used in conjunction with the environmental scanning electron microscope of the present invention.

Figure 9 is a top plan view of the optical system provided in the environmental scanning electron microscope of the present invention.

Figure 10 is a side elevational view of the optical system provided in the environmental scanning electron microscope of the present invention.

Figure 11 is an enlarged side elevational view of the optical system of Figure 10.

Figure 12 is a schematic representation of the screen display for the image display system of the environmental scanning electron microscope of the present invention.

Figures 13a-d are schematic representations of four possible image combinations for the screen display of Figure 12.

Figure 14 is a schematic representation of the X-ray detector assembly present in the environmental scanning electron microscope of the present invention.

Figure 15 is a schematic representation of one embodiment of an environmental scanning electron microscope in accordance with the teachings of the present invention wherein the field-of-view of the specimen is increased.

Figure 16 is a bottom plan view of an electrode detector assembly for an environmental scanning electron microscope in accordance with the teachings of the present invention.

Figure 17 is a top plan view of the electrode detector assembly of Figure 16.

Figure 18 is a schematic representation of one preferred embodiment of an environmental scanning electron microscope employing the electrode detector assembly of Figures 16 and 17.

Figure 19 is another schematic representation of an environmental scanning electron microscope employing the electrode detector assembly of Figures 16 and 17.

Figure 20 is an enlarged schematic representation of a portion of the environmental scanning electron microscope of Figure 19 specifically illustrating the sealing between the body detector and the electrode detector assembly of the present invention.

Figure 21 is a top elevational view of an annular electrode detector assembly of U.S. Patent 4,897,545.

Figure 22 is a bottom plan view of another preferred embodiment of a electrode detector assembly for an environmental scanning electron microscope in accordance with the teachings of the present invention.

Figure 23 is a schematic representation of an environmental scanning electron microscope employing the electrode detector assembly of Figure 22.

Figure 24 is another schematic representation of an electrode detector assembly in accordance with the teachings of the present invention being mechanically supported within an environmental scanning electron microscope.

Figures 25 and 26 are schematic representations illustrating the removal of the electrode detector assembly of the present invention from an environmental scanning electron microscope.

Figure 27 is another schematic representation illustrating an electrode detector assembly of the present invention being employed in an environmental scanning electron microscope, and more particularly, to a clearance space for high voltage isolation thereby provided.

Figure 28 is bottom plan view of a electrode detector assembly for an environmental scanning electron microscope in accordance with the teachings of the present invention illustrating a clearance space of high voltage isolation in the electrode detector assembly.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to Figure 6, an environmental scanning electron microscope is illustrated which provides a device for generating, amplifying and detecting secondary and backscattered electrons emanating from a surface of a sample being examined. A beam of electrons 12 is emitted through an electron optical column 10 of the objective lens assembly 11 by an electron gun (not shown). The vacuum optical column 10 includes a final pressure limiting aperture 14 at its lower end thereof. This pressure limiting aperture 14 is formed within the lower end of an aperture carrier 15. This aperture carrier 15 is discussed in U.S. Patent Application Serial Number 07/908,870, filed July 1, 1992, the subject matter of which is incorporated by reference. This aperture carrier includes a second pressure limiting aperture 17 above final pressure limiting aperture 14 which communicates directly with the electron optical column 10. Preferably, the final pressure limiting aperture 14 has a diameter of approximately 500 microns. The electron beam passes through magnetic lenses 16 and 18 which are used to control the intensity of the electron beam. Focusing means 20 located within the objective lens assembly 11 adjacent to the vacuum column and is capable of directing the beam of electrons through the final pressure limiting aperture 14.

The beam is subsequently directed into a specimen chamber 22 through final pressure limiting aperture 14 wherein it impinges upon a specimen 24 supported on a specimen stage 26. The specimen mount or stage 26 is located within the specimen chamber 22 and is positioned for supporting specimen 24 approximately 1 to 25 mm, and preferably 1 to 10 mm, below final pressure limiting aperture 14 so as to allow the beam of electrons to interact with the specimen. The specimen chamber is disposed below the optical vacuum column 10 and is capable of maintaining the sample 24 enveloped in gas, preferably nitrogen or water vapor, at a pressure of approximately between 1 to 50 Torr in registration with the pressure limiting aperture such that a surface of the specimen may be exposed to the charged particle beam emitted from the electron gun and directed through the pressure limiting aperture 14.

As is shown in Figure 6, a ring detector 28 is provided in the specimen chamber between the final pressure limiting aperture 14 and the specimen 24. This ring electrode detector is preferably formed of a thin ring and made of metal. In the preferred embodiment, the wire thickness of the ring detector is approximately 50 to 1000 microns. The diameter of the ring detector 28 is slightly larger than the diameter of the pressure limiting aperture 14 and is placed immediately below and separated therefrom.

When the primary beam 12 strikes the specimen 24, as in Figure 6, secondary electrons 35 and backscattered electrons, such as 37, 38 and 39, are released from the sample. For purposes of illustration, in Figure 6, a bias voltage is applied to ring electrode 28 of approximately +500V. The bullet detector 30 which forms the pressure limiting aperture 14 is unbiased. In this configuration, high positive voltage on the ring electrode 28 causes the secondary electrons 35 emanating from the surface of the sample to be accelerated until they strike gas molecules of the gaseous environment in the specimen chamber 26. Multiple collisions with the gaseous environment cause other electrons to be released which are, as well, accelerated towards the ring electrode 28. Generally, there will be many such collisions and eventually a cloud of hundreds or thousands of electrons will reach the ring electrode 28. The main objective, however, of the ring electrode 28 is to collect the electrons triggered by secondary electrons emanating from the specimen 24.

However, as illustrated in Figure 6, secondary electrons are also generated by gas collisions from other sources; namely:

a) collisions between the primary beam 12 and the gaseous environment of the specimen chamber, these secondary electrons being represented by reference numeral 43 in Figure 6;

b) collisions between the backscattered electrons 37 that pass through the pressure limiting aperture 14 and the gaseous environment of the specimen chamber 22, these secondary electrons being represented heard to by reference numeral 45;

c) collisions between the backscattered electrons 38 which pass through the gaseous environment between the sample 24 and the remainder of the specimen chamber, these secondary electrons being represented by reference numeral 47; and

d) backscattered electrons 39 which strike the pressure limiting aperture 14, and generate secondary electron which are referred to by reference numeral 49.

All of the secondary electrons generated by these collisions are amplified by gas multiplication in the gaseous environment of the specimen chamber and add to the desired secondary electron signal. However, the secondary electrons that derive from the backscattered electrons, such as 43, 45, 47 and 49, add an undesired backscattered component to the secondary electron image being received by the ring detector 28. Furthermore, the secondary electrons 43 created by collisions between the primary beam 12 and the gaseous environment of the specimen chamber cause an undesired background noise component.

Thus, in order to enhance its signal capabilities, the environmental scanning electron microscope of the present invention incorporates an improved secondary electron detector which reduces the backscattered electron component of the signal, such as signals 43, 45, 47 and 49 present in the Figure 6 example, and reduces the signal noise produced by the primary beam, such as signal 43. In the embodiment of the present invention shown in Figure 7, the ring electrode 28 is biased at an electrical potential between approximately 200 and 2000 volts, and preferably 500 volts. Additionally, a pressure limiting aperture electrode 50 is formed integrally with the bullet detector defining the pressure limiting aperture and is biased at an electrical potential between 200 and 2000 volts, and preferably 500 volts. In the preferred embodiment, it has been found desirable to bias the ring electrode 28 and the pressure limiting aperture electrode 50 at the same electrical potential.

As an example, if the ring electrode 28 and pressure limiting aperture electrode 50 are both biased at 500 volts, the desired secondary electrons 35 are accelerated and multiplied in the gaseous environment of the specimen chamber 22 to generate further secondary electrons 36 which are still collected by the ring electrode 28. However, in this configuration, most of the undesired secondary electrons are intercepted by the pressure limiting aperture electrode 50. More specifically, the secondary electrons 45 generated by collisions with the backscattered electrons 37 are attracted to the positive surface of the pressure limiting aperture electrode 50. Further, many of the secondary electrons generated by collisions between the primary beam 12 and the gaseous environment of the specimen chamber 22 are also attracted to the pressure limiting aperture electrode 50. In addition, the secondary electrons 49 generated by collisions between a backscattered electron 39 and the pressure limiting aperture 50 will no longer be accelerated away from the pressure limiting aperture and no gas amplification occurs. Accordingly, most of the undesirable signal components are not collected by the ring electrode 28, and accordingly, the image signal derived from the ring electrode 28 is a more pure secondary electron image having a lower noise level. Thus, it has been found that this design provides for imaging resolution capabilities of the specimen of about 40 nm which is comparable to the resolution quality of a standard SEM.

As an alternate embodiment, in order to collect undesired secondary electrons, a second biased ring electrode 29 may also be positioned above final pressure limiting aperture 14 within the aperture carrier 15 (see Figure 7). This electrode 29 is also formed of a thin ring and made of metal.

As is shown in Figure 8, the environmental scanning electron microscope of the present invention also includes an improved amplifier assembly 52 for the signal emanating from the ring detector electrode 28. In this environmental scanning electron microscope, the signal current from the ring electrode 28 is passed to a current amplifier 54 used in the so-called virtual earth mode. As aforementioned, the ring electrode 28 and the pressure limiting aperture electrode 50 are typically best operated at the same DC bias voltage (V1) (in the example of Figure 7, at approximately at 500V). This voltage is set to the voltage necessary to obtain sufficient gas multiplication in the specimen chamber. The virtual earth amplifier of Figure 8 is operated from a power source which floats relative to the bias voltage applied to the ring electrode 28. The other input of the amplifier (the + input designated at 56) is also connected to the bias voltage. The output of the amplifier as at 58 is translated to be relative to normal ground potential utilizing an optically coupled amplifier system of conventional design (not shown).

This amplifier also includes a feedback system in the form of a resistor 60 having a resistance value of R. As a result thereof, the output of the amplifier 54 is represented by IsR + V1 wherein Is is the current collected by the ring electrode 28 and V1 is the bias voltage applied to the amplifier. As a result thereof, the amplifier 54 maintains the voltage on the ring electrode 28 to be very close to V1.

In addition to the required signal (IsR), noise is also present at the output of the amplifier 54. This noise is produced by a number of sources; namely: (a) shot noise in the signal current Is, (b) noise generated by the amplifier, and (c) Johnson noise from the resistor 60. When the environmental SEM of the present invention is used to obtain the smallest spot size of the sample in order to obtain the best image resolution of the specimen, the image must be scanned at a relatively slow scanning speed to minimize the image noise. Typically, a time of between approximately 1 and 2 minutes is utilized.

In order to minimize the noise from resister R, its value is preferably at least 1M ohm. This high resistance value limits the frequency response of the amplifier 54 so that it is difficult to obtain a suitable image at fast scanning rates. In order to obtain a suitable image, another amplifier (not shown) is utilized with boosted high frequency response, which compensates for the loss at the input. In the previous environmental SEM, the amplifier used a small resistor (50k ohm) in order to obtain suitable high frequency response for fast scanning. This resistor, however, generated undesirable levels of Johnson noise. Accordingly, the amplifier system 52 of Figure 8 has also been designed as set forth above such that the predominant source of noise is from the shot noise in the electron beam 12.

In accordance with another general object of the present invention, the environmental scanning electron microscope of the present invention includes an improved method of observing large samples utilizing a form of an optical microscope. This optical window system allows the user to easily switch between the normal environmental SEM electron image (typically limited to 0.5mm diameter) to an optical light view of the specimen that covers a field-of-view of up to approximately 7 to 10mm to achieve in effect an improved SEM that permits an optical view of the specimen. In addition to showing a significantly larger view of the sample, this optical window system advantageously provides an image of the sample which is a normal optical image in full color. Moreover, as will be explained in more detail below, this optical window system provides for a view of the specimen as if one were looking down into the electron column of the microscope.

This environmental scanning electron microscope exploits the existing characteristics of a gaseous detector (i.e. a detector immersed in the gaseous environment of the specimen chamber), which is that the detector is immune to the effects of light in the specimen chamber 22. In contrast, the standard Everhardt-Thornley detector used for secondary electron imaging in a conventional SEM utilizes a photomultiplier that is sensitive to the visible spectrum, and accordingly, it is impossible to allow visible light into the SEM specimen chamber. Moreover, the backscattered electron detectors utilized in SEMs are similarly light sensitive.

The two major components of the optical window system of this environmental scanning electron microscope are as follows:

(a) an optical image production system for illuminating the specimen from a light source and for reflecting the image of the specimen to a video unit to provide a continuous optical view of the specimen, as is illustrated in Figures 9 through 11; and

(b) a video switching signal or video display system that allows the image from the TV camera to be shown on the normal environmental SEM display and control screen, as is illustrated in Figure 12 and Figures 13a-d.

Referring now to Figures 9 and 10, in this environmental SEM, the specimen 24 is mounted in the specimen chamber 22 on a motorized stage 26 to provide for movement in five axes (XYZ, tilt and rotate). A view port 62 extending through the outer housing 64 of the specimen chamber 22 of the environmental SEM is also provided to allow the operator to directly view the sample during examination.

As is best shown in Figures 10 and 11, the optical image production system of the optical window system includes a relatively small mirror 66 mounted to the underside of the final pole piece 68 of the magnetic focusing lens, or an optically polished reflecting surface of the final pole piece. In this position, the mirror 66 faces the specimen 24. The specimen is illuminated by reflecting light off the mirror 66 (and/or, as will be explained below, the underside of the objective lens 68). The mirror is also utilized to transmit the image of the sample 24 back through a lens assembly onto a relatively small CCD TV camera. The TV signal from the camera can be directly transmitted into a standard TV monitor to provide a continuous optical view of the sample.

More specifically, as shown in Figures 10 and 11, the light source 70 is coupled through an optical fiber bundle 72 and then through a lead glass window 74. The lead glass window 74 provides a vacuum seal and absorbs any X-rays generated by the electron beam 12 emanating from the sample 24. The light is then focused by a lens 76 and reflected off the mirror 66 onto the sample 24. In the preferred embodiment, as shown in Figure 11, the mirror 66 is positioned very close to the gaseous detector 28 of the environmental SEM of the present invention. In a further preferred embodiment, if the underside or final pole piece 77 of objective lens 68 is sufficiently polished, the mirror 66 could be eliminated and the light beam could be reflected off the final pole piece 77 onto the sample.

The image from the sample 24 is reflected by the mirror 66 back through a lens assembly 80. After the image passes through lens 80 on its return path, it passes through two sets of prisms 82 and 84 before reaching the CCD image integrated circuit 86 which provides a video display of the image. As is best shown in Figure 11, the first prism 82 is positioned in the optical system of the present invention such that the image is deflected in a 180° orientation from which it was received. Accordingly, the image is reflected by the prism 82 at two deflection points 82a and 82b. After the image is deflected at deflection point 82b of prism 82, it passes through prism 84 and is deflected only once, at deflection point 84a at a right angle towards the CCD image integrated circuit 86. An even number of reflections between the sample and image CCD ensures a non-reversed image.

Normally, an undesirable oblique view of the sample is obtained utilizing a mirror which is offset from the specimen. In the optical window system of the present invention, the lens 80 and the CCD imaging chip 86 are mounted at an angle from each other in order to obtain a view of the sample that is virtually equivalent to a "top down" view of the sample. In addition, the CCD chip 86 is mounted such that the image formed is as the user would see the sample looking down the electron optical column from the front of the microscope. In the preferred embodiment, the CCD imaging chip 86 is operatively connected to a CCD TV camera with the TV signal from the camera being directly transmitted into a standard TV monitor or video recorder to give a continuous optical view of the specimen.

The video display assembly of the optical window system shown in Figure 12 includes VGA display screen 88 including a menu display area 90 and an image display area 92. The menu display area 90 displays operational and status information for an operator.

As is shown in Figures 13a and 13b, the image display area 92 can display either electron images processed from the ring electrode 28 or optical images produced by the optical image production system as described above. A further advantageous feature of the optical display assembly of the present invention is its ability to insert electron images or optical images in the image display area as a "picture-in-picture" display which allows numerous electron images and optical images of the specimen to be instantaneously viewed. As is shown in Figure 13c, optical images 98 are inserted in the electron images 94 of the image display area as a "picture-in-picture" display. In Figure 13d, electron images 200 are inserted in the optical images 96 of the image display area 92 as a "picture-in-picture" display. Thus, reduced size versions or selected portions of either the optical images 98 in Figure 13c or the electron images 100 in Figure 13d can be displayed in the other image. Electronic circuitry is provided which would be readily appreciated by one skilled in the art to switch the images instantly between the combinations shown in Figures 13a-d.

As is shown in Figure 14, in a preferred embodiment of the environmental SEM of the present invention, the X-ray detector (EDX detector) 102 has a take-off angle for collecting X-rays emitted from the surface of the sample which is comparable with the take-off angle in conventional SEMs of approximately 30°. In order to achieve this desired take-off angle, the pressure limiting aperture assembly 104 is extended downwardly from the final pole piece 106 of the objective lens 108 which separates the vacuum column from the specimen chamber. This extended pressure limiting aperture assembly is utilized to ensure that the gas path length from the pressure limiting aperture 105 to the specimen 103 remains approximately 1 to 25mm, and more preferably 1 to 10 mm. As a result thereof, the distance from the final pole piece 106 of the objective lens 108 to the specimen 103 is increased to allow enough space in the specimen chamber to provide an EDX detector with an increased take-off angle of approximately 30° represented by the angle α in Figure 14.

In the preferred embodiment, the environmental scanning electron microscope of the present invention also provides an enhanced field-of-view of the specimen which is comparable with the field-of-view achieved in a conventional SEM. As is shown more particularly in Figure 15, the enhanced field-of-view is achieved by utilizing three sets of scanning coils 110, 112, and 114 directing the electron beam through two pressure limiting apertures 118 and 120, and a shorter focal length magnetic lens 116. Moreover, the sets of scanning coils 110 and 112 are positioned above pressure limiting aperture 118 and the set of scanning coils 114 is positioned between pressure limiting aperture 118 and final pressure limiting aperture 120.

Without the assistance of the scanning coils or the pressure limiting apertures, electrons emanating from the electron beam are focused onto the sample 24 by the action of the magnetic lens, such as 116. The electrons at the edge of the ray bundle are considerably deflected by the action of the lens. If, however, the focal length of the lens is reduced, as is the magnetic lens 116 of the environmental SEM of Figure 15, by increasing the current through the lens winding, the ray bundle will pass through a point closer to the magnetic lens. The effects of the shorter focal length lens with respect to the environmental scanning electron microscope of Figure 15 will be explained in more detail below.

In operation, the first set of scanning coils 110 deflects the electron beam 12 angularly outwardly as is represented by angle β, toward the second set of scanning coils 112 which are positioned relatively close to the upper pressure limiting aperture 118. The second set of scanning coils 112 deflects the electron beam angularly inwardly, as is represented by the angle Φ, through the upper pressure limiting aperture 118 toward the third set of scanning coils 114. The third set of scanning coils 114 deflects the beam angularly inwardly so that its apparent trajectory is from the image of the electron source. Since the magnetic focusing lens 116 has a short focal length, the lens focusing action will bend the beam as at point 124 to pass the beam through the lower pressure limiting aperture 120. The combination of the three sets of scanning coils 110, 112, and 114 and the magnetic focusing lens 116 of short focal length allows the beam to strike a greater surface area of the specimen 24 (e.g., up to 10mm in diameter) due to its angular displacement. As a result thereof, the field-of-view of the specimen is enhanced and secondary electrons and other available information (such as X-rays, ions, etc.) issuing from a greater surface area of the specimen can be detected.

As a result of the present invention, an environmental scanning electron microscope has been designed which achieves standard SEM resolution performance in a gaseous environment. Thus, applicants have demonstrated that it is possible to use a suitably modified SEM as is set forth herein to observe samples in water vapor without the water vapor producing any significant degradation of the beam spot diameter and have produced a detector and signal processing chain where the image noise is limited only by the shot noise in the electron beam, and not by any instrumentation limitations.

In accordance with another general object of the present invention, an improved electron detector assembly is provided wherein the electrodes are supported mechanically, the electrode structure is robust to minimize damage caused by the structure being hit by the sample, the support structure is electrically isolated so that the various signals emanating from the specimen are not interconnected, and the electrode structure is easily cleanable to remove the results of experiments carried out on wet or dirty specimens.

In accordance therewith, an electron detector assembly has been designed for an environmental scanning electron microscope which includes a detector head formed integrally with the pressure limiting aperture, a support structure which is electrically insulated so that the various signals are not interconnected, and the support structure mechanically supports the electrode detector assembly within the environmental scanning electron microscope.

As is shown in the preferred embodiment of Figure 16, the electrode detector assembly 130 is in the form of a printed circuit board 132 including a detector head 134 having collection electrodes 136 and 138 thereon for collecting signals emanating from the specimen to be examined. In accordance with the principles set forth above, an inner signal ring electrode 136 is suitably biased to collect secondary electrons emanating from the surface of the specimen. This signal ring electrode 136 is supported downwardly from the detector head 134 of the printed cicruit board 132 by preferably three support legs 140a, 140b and 140c. The detector head 134 also includes an appropriately biased electrode pad 138 to reduce signals emanating from backscattered and low angle reflected electrons emanating from the surface of the specimen. The detector head is also beveled downwardly as designated by reference numeral 142 to allow an unobstructed view of the specimen by the optical viewing system, such as is described above.

As is shown in Figure 16, in this electrode detector assembly, the final pressure limiting aperture 144 is formed inwardly of the signal ring electrode 136 of the detector head 134 of the printed circuit board 132. Moreover, as is shown in Figure 17, this final pressure limited aperture is also formed at the end of an inverse conical ring 146, preferably made of copper, provided on the top side of the dectector head. As a result thereof, the collection electrodes, such as the signal ring 136 and electrode pad 138, are formed integrally with the final pressure limiting aperture 144 on the detector head.

The electrode detector assembly of the present invention also provides for electrical connection to the signal ring 136 without the connection wire picking up undesired signals. In order to achieve this result, suitable insulation is provided in the electrode detection assembly of the present invention to prevent electrical leakage between electrodes 136 and 138. As is shown in Figure 16, this insulation is in the form of the printed circuit board support structure itself. A plurality of electrically conductive tracks 148, 150 and 152 are embedded in the printed circuit board 132. In the preferred embodiment, track 148 is connected to the signal ring 134. Track 150 is connected to the electrode pad 138. Track 152 picks-up electrical noise for cancellation purposes as it collects a signal for electronic subtraction from noise interference pickup with the signal. Lastly, track 154 is a ground connection. Each of these tracks 148, 150 and 152 is connected to a respective edge connector 156, 158 and 160. These edge connectors then transmit the signals carried by the tracks to an amplifier (not shown) for amplifying information received by the collection electrodes. In addition, each of these electrically conductive tracks have an exposed portion which is electroplated with gold which protects the copper from attack by harsh gases or oxidation.

The upper and lower surfaces of the printed circuit 132, as shown in Figures 16 and 17, include gold plated copper coverings 164 and 166. This copper covering provides electrical screening to reduce pickup of electronic noise of the signals in the embedded tracks and provides a conductive covering for the insulating circuit board. A standard plated through hole 165 is used to connect coverings 164 and 166 tgether. The two surfaces 164 and 166 are connected to ground via edge connector 162. Additionally, standard plated through holes 182 are provided which connect the copper planes 164 and 166 on both sides of the printed circuit board 132 (see Figure 20).

As is shown in Figure 17, the printed circuit board also includes a "D" shaped insulating ring 168 which is bonded to the printed circuit board to provide a vacuum seal between the objective lens assembly and the specimen chamber to be described in more detail below.

An environmental scanning electron microscope employing an electrode detector assembly employing printed circuit board technology is shown in Figures 18 through 20. As is best shown in Figure 18, the printed circuit board 132 is positioned in the specimen chamber 170 in a generally horizontal manner. The detector body 172 is mounted to the objective lens assembly 174 and provides an path for the electron beam 176 to pass therethrough. This detector body 172 is similar to the aperture carrier described in U.S. Patent 4,823,006, assigned to the common assignee of the application except, that the detector head herein forms the lower portion of the detector body.

As will be described in more detail below, this detector body 172 is threaded into the objective lens 174 to assist in centering the pressure limiting aperture 144 in its proper position. In this configuration, the signal collection ring electrode 136 extends downwardly from the printed circuit board 132 and faces the specimen 178 under examination. As a result thereof, the primary beam 176 passes through the final pressure limiting aperture 144 of the printed circuit board and impinges upon the specimen 178. Secondary electrons emitted from the surface of the specimen are thus collected by the suitably biased signal ring electrode 136.

In order to provide a gas tight seal between the circuit board 132 and by the detector body 172, the vacuum sealing ring 168 is glued to the printed circuit board and mates with a circular flange 180 extending downwardly from the detector body 172. The vacuum sealing ring also assists in properly positioning the pressure limiting aperture 144 in the environmental scanning microscope such that the electron beam 176 can properly impinge upon the specimen 178.

In accordance with another general object of the invention, the insulating surface of the printed circuit board is "hidden" to avoid disturbing the primary beam. As is best shown in Figure 20, the copper ring 171 provided on the top surface of the printed circuit board is of a sufficient width such that it extends outwardly of the pressure limiting aperture 144 to an extent that the primary beam 176 will never strike an insulating surface of the printed circuit board.

Moreover, the inverted conical portion 146 which forms the final pressure limiting aperture 144 can be of varying sizes, such when the printed circuit board is easily removed, as is discussed in more detail below, different size insert, with corresponding varying sized pressure limiting aperture may be provided for different purposes. Thus, the cost of manufacturing the pressure limiting aperture/electrode structure is low enough that the user can be provided with more than one assembly with different sized pressure limiting apertures.

In another preferred embodiment, the signals received from the electrode pad 146 may be utilized as an actual backscattered electron signal detector. If the electrode pad 146 is utilized in that manner, the voltage plane that is on the printed circuit board close to the electrode pad 146 will collect backscattered electron signals which are not collected by the secondary electron detector signal ring electrode 144. Thus, in the electrode detector assembly of the present invention, the collection pad 146 may not collect only "undesired backscattered electron signals and primary beam noise".

In U.S. Patent No. 4,897,545, assigned to the common assignee of this application, a gaseous electron detector is improved by placing a number of electrodes close to the sample which pick up different types of electron signals. Figure 21 of this application illustrates such a detector. This detector disclosed in U.S. Patent No. 4,897,545 provided for the separation of different types of electrons, such as low energy secondary electrons (electrode X), higher energy reflected electrons (electrodes C & D), and low angled reflected electrons (electrodes A & B). As is described in that patent, each of these different types of electrons convey different information about the sample.

Figure 22 of this application illustrates an electrode detector assembly 184 employing printed circuit board technology for use in an environmental scanning electron microscope which includes a number of electrodes on the detector head 186 which will pick up a different types of electron signals in a manner similar to the detector disclosed in U.S. Patent No. 4,897,545. As will be discussed in more detail below, this electrode detector assembly of Figure 22 also includes a detector head, suitable insulation, and a support structure as in the embodiment of Figures 16 and 17 of this application.

The detector head 186 of the electrode detector assembly 184 includes three electrodes 190, 192 and 194, preferably formed of copper. The inner electron detector 190 is formed as a signal ring positioned radially outwardly of the pressure limiting aperture 187 formed in the detector head. This signal ring electrode 190 collects amplified low energy secondary electrons emanating from the surface of the sample. The immediate electron detector 192 is positioned radially outwardly of the inner electron detector 190 and is formed of a first plurality of concentric split generally flat arc segments, such as 192a and 192b. The intermediate electron detector collects predominantly an amplified mix of higher energy secondary and backscattered electron signals emanating from the surface of the specimen. The relative strength of the signals in the mix depends on the parameters of pressure, specimen distance and electrode bias used. The outer electron detector 194 is positioned radially outwardly of the intermediate electron detector 192 and is formed of a second plurality of concentric split generally flat arc segments 194a and 194b. The outer electron detector 194 collects amplified low angled backscattered reflected signals which show the topography of the sample.

As is shown in Figure 22, in order to provide a broader spectrum of imaging capabilities, such as topography, the concentric arc segments 192a and 192b of intermediate annular electron detector 192 and the concentric arc segments 194a and 194b of outer electron detector 194 are preferably in a generally normal orientation with one another. By electronically subtracting the output of one half of the arc segments from the output of the other half, topographic shading by Z-contrast suppression can be effected in a manner usually associated with typical backscattered electron detectors.

Electric conductors are also embedded in the printed circuit board such that the support structure is electrically insulated so that the various signals are not interconnected. As is shown in Figure 22, electrically conductive tracks 196, 198, 200, 202 and 204 carry the signals received by the collection electrodes 190, 192 and 194 to respective edge connectors such as 206, 208, 210, 212 and 214. In the preferred embodiment, track 200 is connected to the signal ring electrode 190. Tracks 198 and 204 are respectively connected to concentric arc segments 192a and 192b of the intermediate electron detector 192. Tracks 196 and 202 are connected to concentric arc segments 194a and 194b of the outer electron detector 194.

As is shown in Figure 23, secondary electron signals 216 emanating from the surface of the sample 217 impinge upon the signal ring electrode 190 wherein the high angle reflected electrons 220 impinge upon either concentric arc segment 192a or 192b of the intermediate electron detector. The low angle reflected electrons 220 will impinge upon the concentric arc segments 194a and 194b of the outer electron detector 194.

Electrode detector assemblies, such as 130 (Fig. 15) and 184 (Fig. 22), are mechanically supported in the environmental scanning electron microscope as shown in Figures 24 through 26 of this application. As aforementioned, the vacuum sealing ring 168 extends upwardly from the printed circuit board and is matingly engaged with the body connector or aperture carrier 172 to provide a gas tight seal and to properly position the pressure limiting aperture 144. The end of the printed circuit board 230 remote from the signal head is snap-fit into a printed circuit board connector, such as 232, provided in the specimen chamber 170. In the printed circuit board connector 232, the edge connectors such as 156, 158, 160 or 162 (Figure 16) or 206, 208, 210, 212 and 214 (Figure 22), are connected to suitable connections which carry the signals to amplifiers (not shown) for amplifying information received by the collection electrodes. The printed circuit board connector 232 is supported from lens 174 and connected through specimen chamber 170 by cable connections 234 and 236. In order to retain the vacuum characteristics of the specimen chamber, a vacuum sealing connector 238 is also provided between the connection cables 234 and 236. Thus, in this manner, sealing ring 171 and PCB connector 232 both cooperate to mechanically support the printed circuit board in its desired orientation within the environment scanning electron microscope.

The removal of the printed circuit board detector from the environmental scanning electron microscope is shown in Figures 25 and 26. In Figure 25, the printed circuit board 132 is initially swung in the direction of arrow a such that the vacuum sealing ring 171 is disengaged from the lower extending flange 180 of the body detector or aperture carrier 172. The printed circuit board 132 is then unsnapped from the printed circuit connector 232 to release the printed circuit board therefrom such that the printed circuit board can be moved in the direction of arrow b and removed from the environmental scanning electron microscope. As a result thereof, the pressure limiting aperture is easily interchangeable for different sizes and the cost of manufacturing the pressure limiting aperture/electrode structure is low enough that the user can be provided with more than one assembly with different sized pressure limiting apertures.

Figures 27 and 28 specifically illustrate the clearance space for high voltage isolation provided by the printed circuit board detector of the present application. As the result of the mating configuration of the printed circuit board 132 and the body detector 180, a clearance space is provided (see height c and length d in Figure 27) for high voltage isolation. This voltage isolation is also reflected in Figure 28 and is designated as reference numeral 240. The inverted portion 146 and copper ring 171 are biased at high voltage, and the detector body 180 is biased at approximately zero volts.

As a result of the materials employed in this electrode detector assembly, outgassing is minimized in the vacuum environment, the electrode structure is resistant to high temperatures for hot experiments and is mechanically stable, and any metal surfaces are resistant to the gas environments used in the environmental scanning electron microscope. Moreover, the printed circuit board can be machined extremely accurately and utilized at elevated temperatures.

Further, in the preferred embodiment, the printed circuit board is formed primarily of fiberglass and epoxy. However, the fiberglass and epoxy could be replaced by a multi-layered ceramic substrate.

As a result of the design of this electrode detector assembly of the present invention, a relatively inexpensive printed circuit board construction is utilized, the electrodes are supported mechanically, buried tracks are provided for signal collection, no insulator is exposed to the primary electron beam, the support structure is robust to minimize damage caused by hitting it with the sample, the structure is easily cleanable, and inexpensive to replace.

Although the invention has been particularly shown and described with reference to certain preferred embodiments, it will be readily appreciated by those of ordinary skill in the art that various changes and modifications may be made therein without departing from the spirit and scope of the invention. It is intended that the appended claims be interpreted as including the foregoing as well as various other such changes and modifications.

WHAT IS CLAIMED IS:

1. An environmental scanning electron microscope comprising:

(a) means for generating and directing an electron beam towards a specimen;

(b) means for detecting secondary electron signals emanating from the surface of the specimen; and

(c) means for reducing signals emanating from backscattered electrons and means for reducing signal noise generated by said electron beam.

2. The environmental scanning electron microscope of claim 1 wherein said means for detecting secondary electrons signal emanating from the surface of the specimen is formed of a thin ring electrode.

3. The environmental scanning electron microscope of claim 2 wherein said thin ring electrode is a wire having a wire thickness of approximately 50 to 1000 microns.

4. The environmental scanning electron microscope of claim 2 wherein said ring electrode is made of an electrically conductive material.

5. The environmental scanning electron microscope of claim 2 wherein said ring electrode is biased at between 200 and 2000 volts.

6. The environmental scanning electron microscope of claim 5 wherein said ring electrode is biased at approximately 500 volts.

7. The environmental scanning electron microscope of claim 1 wherein said electron beam is directed through a pressure limiting aperture at a lower end of a vacuum column and said means for reducing signals emanating from backscattered electrons and means for reducing signal noise generated by said electron beam is a biased electrode formed integrally with said pressure limiting aperture.

8. The environmental scanning electron microscope of claim 7 wherein said pressure limiting aperture electrode is biased at approximately 200 to 2000 volts.

9. The environmental scanning electron microscope of claim 8 wherein said pressure limiting aperture electrode is biased at approximately 500 volts.

10. An environmental scanning electron microscope comprising:

(a) a vacuum column having a pressure limiting aperture at the lower end thereof;

(b) a charged particle beam source located within the vacuum column which emits a charged particle beam;

(c) focusing means located within the vacuum column which directs a charged particle beam emitted by the charged particle beam source through said pressure limiting aperture;

(d) a specimen chamber, positioned below said pressure limiting aperture, which maintains the specimen enveloped in gas at a pressure of approximately 1 to 50 Torr in registration with the pressure limiting aperture such that a surface of the sample may be exposed to a charged particle beam emitted from the charged particle beam source and directed through said pressure limiting aperture;

(e) a biased ring detector disposed between said specimen and said pressure limiting aperture to detect secondary electron signals emanating from the surface of the specimen; and

(f) a biased pressure limiting aperture detector formed integrally with said pressure limiting aperture to reduce signals emanating from backscattered electrons and to reduce noise generated by said electron beam.

11. The environmental scanning electron microscope of claim 10 wherein said ring electrode is a metal wire having a wire thickness of approximately 50 to 1000 microns.

12. The environmental scanning electron microscope of claim 10 wherein said ring electrode and said pressure limiting aperture electrode are biased at the same positive electrical potential.

13. The environmental scanning electron microscope of claim 10 wherein said ring electrode and said pressure limiting aperture electrode are biased at between approximately 200 and 2000 volts.

14. The environmental scanning electron microscope of claim 10 wherein said ring electrode and said pressure limiting aperture electrode are biased at approximately 500 volts.

15. A scanning electron microscope comprising:

(a) means for generating and directing an electron beam towards a specimen;

(b) a specimen chamber which maintains the specimen enveloped in a gaseous environment;

(c) means for detecting secondary electron signals emanating from the surface of the specimen; and

(d) means for reducing signals emanating from backscattered electrons and means for reducing signal noise generated by said electron beam.

16. The scanning electron microscope of claim 15 wherein said means for detecting secondary electrons signal emanating from the surface of the specimen is formed of a thin ring electrode.

17. The scanning electron microscope of claim 16 wherein said thin ring electrode is a wire having a wire thickness of approximately 50 to 1000 microns.

18. The scanning electron microscope of claim 16 wherein said ring electrode is made of an electrically conductive material.

19. The scanning electron microscope of claim 16 wherein said ring electrode is biased at between 200 and 2000 volts.

20. The scanning electron microscope of claim 19 wherein said ring electrode is biased at approximately 500 volts.

21. The scanning electron microscope of claim 15 wherein said electron beam is directed through a pressure limiting aperture at a lower end of a vacuum column and said means for reducing signals emanating from backscattered electrons and means for reducing signal noise generated by said electron beam is a biased electrode formed integrally with said pressure limiting aperture.

22. The scanning electron microscope of claim 21 wherein said pressure limiting aperture electrode is biased at approximately 200 to 2000 volts.

23. The scanning electron microscope of claim 22 wherein said pressure limiting aperture electrode is biased at approximately 500 volts.

24. An environmental scanning electron microscope comprising:

(a) means for generating and directing an electron beam toward a specimen;

(b) means for detecting secondary electron signals emanating from the surface of the specimen which is in the form of a thin biased ring electrode;

(c) means for reducing signals emanating from backscattered electrons and means for reducing signal noise generated by said electron beam; and

(d) means for amplifying signals collected by said ring electrode including an amplifier receiving signals collected at said ring electrode, said amplifier floating at the bias voltage of said ring electrode, and the output of said amplifier being supplied to display means.

25. The environmental scanning electron microscope of claim 24 wherein said amplifier includes feedback means.

26. The environmental scanning electron microscope of claim 25 wherein said feedback means includes a resistor having a resistance value of R, preferably greater than 1M ohm .

27. The environmental scanning electron microscope of claim 26 wherein the output signal of said amplifier is amplified to restore the high frequency signal lost due to the effect of R.

28. The environmental scanning electron microscope of claim 24 wherein said amplifier is operated is a so-called virtual earth mode.

29. An environmental scanning electron microscope which permits a substantial portion of specimen to be examined by the operator comprising:

(a) a vacuum column having a pressure limiting aperture at the lower end thereof;

(b) means for generating and directing an electron means through said pressure limiting aperture toward a specimen;

(c) a specimen chamber, positioned below said pressure limiting aperture, which maintains the specimen enveloped in gas in registration with the pressure limiting aperture;

(d) a magnetic focusing lens separating said vacuum column and said specimen chamber and defining said pressure limiting aperture; and

(e) an optical window system including optical image production means for illuminating said specimen from a light source and for reflecting said image of said specimen to video means to provide a continuous optical view of the specimen.

30. The environmental scanning electron microscope of claim 29 wherein said optical image production means includes mirror means mounted to said magnetic focusing lens and facing said specimen.

31. The environmental scanning electron microscope of claim 30 wherein said video means includes a TV camera which receives the image of the sample from said mirror means and transmits a TV signal to a display monitor to provide a continuous optical view of the specimen.

32. The environmental scanning electron microscope of claim 30 wherein before reaching said mirror means the light of said optical video system is transmitted through an optical fiber bundle and a lead glass window which provides a vacuum seal and absorbs X-rays generated by said electron beam in said specimen.

33. The environmental scanning electron microscope of claim 32 wherein after passing through said lead glass window, the light is focused by a first lens and then reflected off said mirror means onto said specimen.

34. The environmental scanning electron microscope of claim 30 wherein said mirror means reflects the image of the sample through a second lens before reaching said video means.

35. The environmental scanning electron microscope of claim 34 wherein said video means includes a CCD imaging chip.

36. The environmental scanning electron microscope of claim 35 wherein said second lens and said CCD imaging chip are mounted at an angle in order to obtain an image of said sample which is substantially equivalent to a top down view.

37. The environmental scanning electron microscope of claim 34 wherein the image of the sample passes through at least one prism between said second lens and said video means.

38. A scanning electron microscope which allows an optical view of the specimen comprising:

(a) a vacuum column having a pressure limiting aperture at the lower end thereof;

(b) means for generating and directing an electron means through said pressure limiting aperture toward a specimen;

(c) a specimen chamber, positioned below said pressure limiting aperture, which maintains the specimen enveloped in gas in registration with the pressure limiting aperture;

(d) a magnetic focusing lens separating said vacuum column and said specimen chamber and defining said pressure limiting aperture; and

(e) an optical window system including optical image production means for illuminating said specimen from a light source and for reflecting said image of said specimen to video means to provide a continuous optical view of the specimen.

39. The scanning electron microscope of claim 38 wherein said optical image production means includes mirror means mounted to said magnetic focusing lens and facing said specimen.

40. The scanning electron microscope of claim 39 wherein before reaching said mirror means the light of said optical video system is transmitted through an optical fiber bundle and a lead glass window which provides a vacuum seal and absorbs X-rays generated by said electron beam in said specimen.

41. The scanning electron microscope of claim 40 wherein after passing through said lead glass window, the light is focused by a first lens and then reflected off said mirror means onto said specimen.

42. The scanning electron microscope of claim 39 wherein said mirror means reflects the image of the sample through a second lens before reaching said video means.

43. The scanning electron microscope of claim 42 wherein said video means includes a CCD imaging chip.

44. The scanning electron microscope of claim 43 wherein said second lens and said CCD imaging are mounted at an angle in order to obtain an image of said sample which is substantially equivalent to a top down view.

45. The scanning electron microscope of claim 42 wherein the image of the sample passes through at least one prism between said second lens and said video means.

46. An environmental scanning electron microscope comprising:

(a) means for generating and directing an electron beam toward a specimen;

(b) means for detecting secondary electron signals emanating from the surface of the specimen to provide electron images of the specimen;

(c) an optical window system including optical image production means for producing optical images of said specimen; and

(d) display means including a screen having an image display area and a menu display area for displaying operational and status information for an operator, and wherein either of said electron images or said optical images may be displayed in said image display area.

47. The environmental scanning electron microscope of claim 46 wherein in said image display area electron images may be inserted in said optical images as a picture-in-picture display.

48. The environmental scanning electron microscope of claim 46 wherein in said image display area optical images may be inserted in said electron images as a picture-in-picture display.

49. A scanning electron microscope comprising:

(a) means for generating and directing an electron beam toward a specimen;

(b) means for detecting secondary electron signals emanating from the surface of the specimen to provide electron images of the specimen;

(c) an optical window system including optical image production means for producing optical images of said specimen; and

(d) display means including a screen having an image display area and a menu display area for displaying operational and status information for an operator, and wherein either of said electron images or said optical images may be displayed in said image display area.

50. The scanning electron microscope of claim 49 wherein in said image display area electron images may be inserted in said optical images as a picture-in-picture display.

51. The scanning electron microscope of claim 49 wherein in said image display area optical images may be inserted in said electron images as a picture-in-picture display.

52. An environmental scanning electron microscope comprising:

(a) means for generating and directing an electron beam towards a specimen;

(b) a vacuum column having a pressure limiting aperture assembly at the lower end thereof;

(c) a specimen chamber in which said specimen is mounted such that a surface of said specimen may be exposed to said electron beam; and

(d) an X-ray detector mounted in said specimen chamber to generate X-ray information from X-ray signals emanating from the surface of said specimen, said X-ray detector having a take-off angle of approximately 30°.

53. The environmental scanning electron microscope of claim 52 wherein said vacuum column and said specimen chamber are separated by a final pole piece of a magnetic focusing lens and said pressure limiting aperture assembly extends downwardly from said final pole piece such that the specimen is positioned approximately 1 to 25mm below said pressure limiting aperture assembly.

54. An environmental scanning electron microscope comprising:

(a) means for generating and directing an electron beam towards a specimen contained in a specimen chamber; and

(b) an objective lens assembly having scanning means for providing triple deflection of said electron beam until said beam impinges on a surface of said specimen and further including a magnetic lens housing of reduced focal length to provide a lens focusing action wherein said scanning means and said magnetic lens housing, in combination, achieve a field-of-view of the specimen of about at least 7 mm.

55. The environmental scanning electron microscope of claim 54 wherein said objective lens assembly includes at least two pressure limiting apertures and said scanning means includes at least three sets of scanning coils with the first and second sets of said scanning coils being positioned above both of said pressure limiting apertures and the third set of said scanning coils being positioned between said pressure limiting apertures.

56. The environmental scanning electron microscope of claim 55 wherein said first set of said scanning coils deflects the electron beam angular outwardly to said second set with said second set redirecting the electron beam angularly inwardly through the first of said pressure limiting apertures to said third set of said scanning coils with the third set in conjunction with the lens focusing action deflecting the electron beam angularly inwardly through the second of said pressure limiting apertures into said specimen chamber such that the electron beam strikes a relatively large surface area of the specimen under examination.

57. An electron detector for an environmental scanning electron microscope comprising a printed circuit board including a detector head having collection electrode means thereon for collecting signals emanating from a specimen to be examined.

58. The electron detector of claim 57 wherein said detector head includes a signal ring electrode biased to collect secondary electrons emanating from the surface of the specimen.

59. The electron detector of claim 57 wherein said detector head includes a biased electrode pad to reduce signals emanating from backscattered and low angle reflected electrons emanating from the surface of the specimen.

60. The electron detector of claim 57 wherein said printed circuit board includes insulation means to prevent electrical leakage between electrodes of said collection electrode means.

61. The electron detector of claim 60 wherein said insulation means includes electrical conductive means embedded in the printed circuit board to carry the signals received by said collection electrode means to edge connector means.

62. The electron detector of claim 61 wherein said electrical conductive means includes a plurality of electrically conductive tracks.

63. The electron detector of claim 62 wherein said electrically conductive tracks have an exposed portion which is electroplated with gold.

64. The electron detector of claim 61 wherein said edge connector means carries the signals to amplifier means for amplifying information received by the collection electrode means.

65. The electron detector of claim 57 and further including electrostatic screening means to reduce pickup of electronic noise.

66. The electron detector of claim 57 wherein said printed circuit board is formed primarily of fiberglass and epoxy.

67. An electron detector for an environmental scanning electron microscope wherein an electron beam impinges upon a specimen to be examined which is supported in a specimen chamber, said electron detector comprising a printed circuit board having:

(a) a detector head having collection electrode means thereon for collecting signals emanating from the specimen;

(b) insulating means to prevent electrical leakage between electrodes of said collection electrode means;

(c) electrostatic screening means to reduce pickup of electronic noise; and

(d) support means for supporting said printed circuit board within the environmental scanning electron microscope.

68. The electron detector of claim 67 and further including noise collection means to collect a signal for electronic subtraction from noise interference pickup with the signal.

69. The electron detector of claim 67 wherein said detector head includes a pressure limiting aperture integrally formed therein to permit the electron beam to pass therethrough.

70. The electron detector of claim 67 wherein said detector head includes means for detecting secondary electron signals emanating from the surface of the specimen and means for reducing signals emanating from backscattered and low angle reflected electrons.

71. The electron detector of claim 70 wherein said means for detecting secondary electron signals is a biased signal ring electrode.

72. The electron detector of claim 70 wherein said means for reducing signals emanating from backscattered and low angle reflected electrons includes a biased electrode pad.

73. The electron detector of claim 70 wherein said insulation means includes electrical conductive means embedded in the printed circuit board to carry the signals received by said collection electrode means to edge connector means.

74. The electron detector of claim 73 wherein said electrical conductive means includes a plurality of electrically conductive tracks.

75. The electron detector of claim 74 wherein at least one of said electrically conductive tracks is connected to said means for detecting secondary electron signals.

76. The electron detector of claim 74 wherein at least one of said electrically conductive tracks is connected to said means for reducing signals emanating from backscattered and low angle reflected electrons.

77. The electron detector of claim 74 wherein at least one of said electrically conductive tracks provides means for pickup of electrical noise for cancellation purposes.

78. The electron detector of claim 74 wherein at least one of said electrically conductive tracks is a ground connection.

79. The electron detector of claim 67 wherein said detector head includes a generally annular electrode assembly having an inner electron detector formed of a signal ring electrode, an intermediate electron detector positioned radially outwardly of said inner electron detector and being formed of a first plurality of concentric arc segments, and an outer electron detector positioned radially outwardly of said intermediate electron detector and being formed of a second plurality of concentric arc segments.

80. The electron detector of claim 79 wherein said signal ring electrode collects predominantly amplified lower energy secondary electrons emanating from the surface of the specimen.

81. The electron detector of claim 79 wherein said first plurality of concentric arc segments of said intermediate electron detector collects predominantly amplified higher energy backscattered electron signals.

82. The electron detector of claim 79 wherein said second plurality of concentric arc segments collect predominantly amplified low angle backscattered reflected signals.

83. The electron detector of claim 79 wherein said first plurality of concentric arc segments is positioned generally normal to said second plurality of concentric arc segments to obtain a directional topography contrast.

84. The electron detector of claim 79 wherein said insulating means includes electrical conductive means embedded in said printed circuit board to carry the signals received by said collection electrode means to edge connector means.

85. The electrode detector of claim 84 wherein said electrical conductive means includes electrically conductive tracks.

86. The electron detector of claim 85 wherein at least one of said electrically conductive tracks is connected to said signal ring electrode.

87. The electron detector of claim 85 wherein at least one of said electrically conductive tracks is connected to said first plurality of concentric arc segments.

88. The electron detector of claim 85 wherein at least one of said electrically conductive tracks is connected to said second plurality of concentric arc segments.

89. The electron detector of claim 67 wherein said support means includes a vacuum sealing ring extending from said printed circuit board, said vacuum sealing ring being matingly engaged with a detector body of the environmental scanning electron microscope to provide a gas tight seal and to properly position the printed circuit board in the environmental scanning electron microscope.

90. An electron detector for an environmental scanning electron microscope comprising a printed circuit board having a detector head for collecting secondary electrons emanating from the surface of the sample and a final pressure limiting aperture formed integrally thereon.

91. The electron detector of claim 90 and further including means for reducing signals emanating from backscattered and low angle reflected electrons formed integrally on said printed circuit board.

92. An environmental scanning electron microscope comprising:

(a) means for generating and directing an electron beam toward a specimen;

(b) a specimen chamber which maintains the specimen enveloped in a gaseous environment; and

(c) a detector assembly comprising a printed circuit board including a detector head having collection electrode means thereon for collecting signals emanating from said specimen.

93. The environmental scanning electron microscope of claim 92 wherein said detector head includes a signal ring electrode biased to collect secondary electrons emanating from the surface of the specimen.

94. The environmental scanning electron microscope of claim 92 wherein said detector head includes a biased electrode pad to reduce signals emanating from backscattered and low angle reflected electrons emanating from the surface of the specimen.

95. The environmental scanning electron microscope of claim 92 wherein said printed circuit board includes insulation means to prevent electrical leakage between electrodes of said collection electrode means.

96. The environmental scanning electron microscope of claim 95 wherein said insulation means includes electrical conductive means embedded in the printed circuit board to carry the signals received by said collection electrode means to edge connector means.

97. The environmental scanning electron microscope of claim 94 wherein said electrical conductive means includes a plurality of electrically conductive tracks.

98. The environmental scanning electron microscope of claim 92 and further including electrostatic screening means to reduce pickup of electronic noise.

99. An environmental scanning electron microscope comprising:

(a) means for generating and directing an electron beam towards a specimen;

(b) a specimen chamber which maintains the specimen enveloped in a gaseous environment; and

(c) an electron detection means comprising a printed circuit board having:

(1) a detector head having collection electrode means there for collecting signals emanating from the specimen;

(2) insulation means to prevent electrical leakage between electrodes of said collection electrode means;

(3) electrostatic screening means to reduce pickup of electronic noice; and

(4) support means for supporting said printed circuit board within the environmental scanning electron microscope.

100. The environmental scanning electron microscope of claim 99 wherein said detector head includes a pressure limiting aperture integrally formed therewith to permit the electron beam to pass therethrough.

101. The environmental scanning electron microscope of claim 99 wherein said detector head includes means for detecting secondary electron signals emanating from the surface of the specimen and means for reducing signals emanating from backscattered and low angle reflected electrons.

102. The environmental scanning electron microscope of claim 101 wherein said means for detecting secondary electron signals is a biased signal ring electrode.

103. The environmental scanning electron microscope of claim 101 wherein said means for reducing signals emanating from backscattered and low angle reflected electrons includes a biased electrode pad.

104. The environmental scanning electron microscope of claim 101 wherein said insulation means includes electrical conductive means embedded in the printed circuit board to carry the signals received by said collection electrode means to edge connector means.

105. The environmental scanning electron microscope to claim 104 wherein said electrical conductive means includes a plurality of electrically conductive tracks.

106. The electron detector of claim 105 wherein at least one of said electrically conductive tracks is connected to said means for detecting secondary electron signals.

107. The electron detector of claim 105 wherein at least one of said electrically conductive tracks is connected to said means for reducing signals emanating from backscattered and low angled reflected electrons.

108. The electron detector of claim 105 wherein at least one of said electrically conductive tracks provides means for pick-up of electrical noise for cancellation purposes.

109. The environmental scanning electron microscope of claim 105 wherein at least one of said electrically conductive tracks is a ground connection.

110. The environmental scanning electron microscope of claim 99 wherein said detector head includes a generally annular electrode assembly having an inner electron detector formed of a signal ring electrode, an intermediate electron detector positioned radially outwardly of said inner electron detector and being formed of a first plurality of concentric arc segments, and an outer electron detector positioned radially outwardly of said intermediate electron detector and being formed of a second plurality of concentric arc segments.

111. The environmental scanning electron microscope of claim 110 wherein said signal ring electrode collects predominantly amplified lower energy secondary electrons emanating from the surface of the specimen.

112. The environmental scanning electron microscope of claim 110 wherein said first plurality of concentric arc segments of said intermediate electron detector collects predominantly amplified higher energy backscattered electron signals.

113. The environmental scanning electron microscope of claim 110 wherein said second plurality of concentric arc segments collects predominantly amplified low angle backscattered reflected signals.

114. The environmental scanning electron microscope of claim 110 wherein said first plurality of concentric arc segments are positioned generally normal to said second plurality of concentric arc segments to obtain a directional topographic contrast.

115. The environmental scanning electron microscope of claim 110 wherein said insulating means includes electrical conductive means embedded in the printed circuit board to carry the signals received by said collection electrode means to edge connector means.

116. The environmental scanning electron microscope of claim 115 wherein said electrical conductive means includes electrically conductive tracks.

117. The environmental scanning electron microscope of claim 116 wherein at least one of said electrically conductive tracks is connected to said signal ring electrode.

118. The environmental scanning electron microscope of claim 116 wherein at least one of said electrically conductive tracks is connected to said first plurality of concentric arc segments.

119. The environmental scanning electron microscope of claim 116 wherein at least one of said electrically conductive tracks is connected to said second plurality of concentric arc segments.

120. The environmental scanning electron microscope of claim 99 and further including an objective lens assembly having a central opening through which the electron beam passes and an aperture carrier being releasable secured within the central opening of the assembly.

121. The environmental scanning electron microscope of claim 120 wherein said support means includes a vacuum sealing ring extending from said printed circuit board, said vacuum sealing ring being matingly engaged with said aperture carrier to provide a gas tight seal between said objective lens assembly and said specimen chamber and to properly position said printed circuit board in the environmental scanning electron microscope.

122. The environmental scanning electron microscope of claim 99 wherein a printed circuit board connector is provided in said specimen chamber to receive an end of said printed circuit board remote from said detector head to retain said printed circuit board in its proper position within the environmental scanning electron microscope; said printed circuit board being snap-fit into said printed circuit board connector to provide easy removal of said printed board from the environmental scanning electron microscope.

123. An environmental scanning electron microscope comprising:

(a) means for generating and directing an electron beam toward a specimen;

(b) a specimen chamber which maintains the specimen enveloped in a gaseous environment; and

(c) a detector assembly formed of a printed circuit board having a detector head for collecting secondary electrons emanating from the surface of the sample and a final pressure limiting aperture formed integrally thereon.

124. The environmental scanning electron microscope of claim 123 and further including means for reducing signals emanating from backscattered and low angle reflected electrons formed integrally on said printed circuit board.

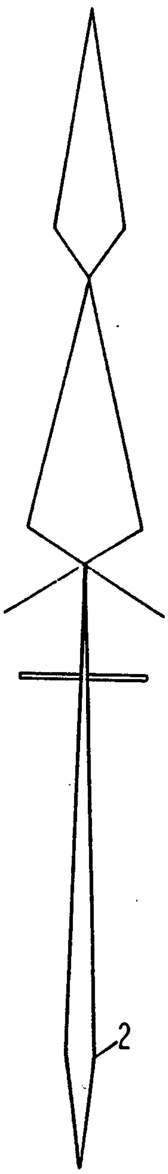

FIG. 1
PRIOR ART

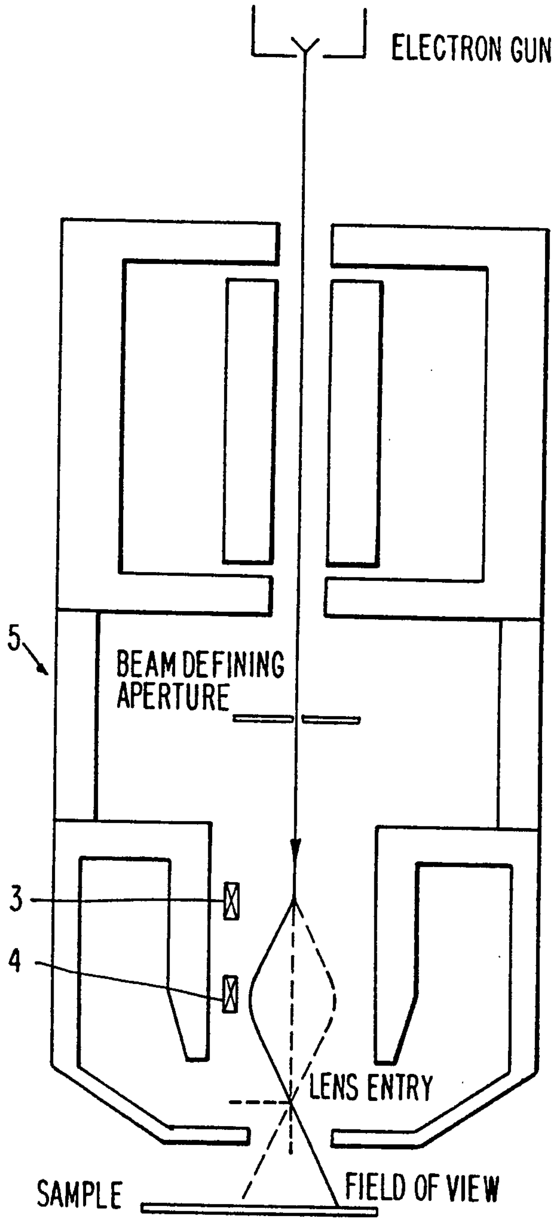

FIG. 2
PRIOR ART

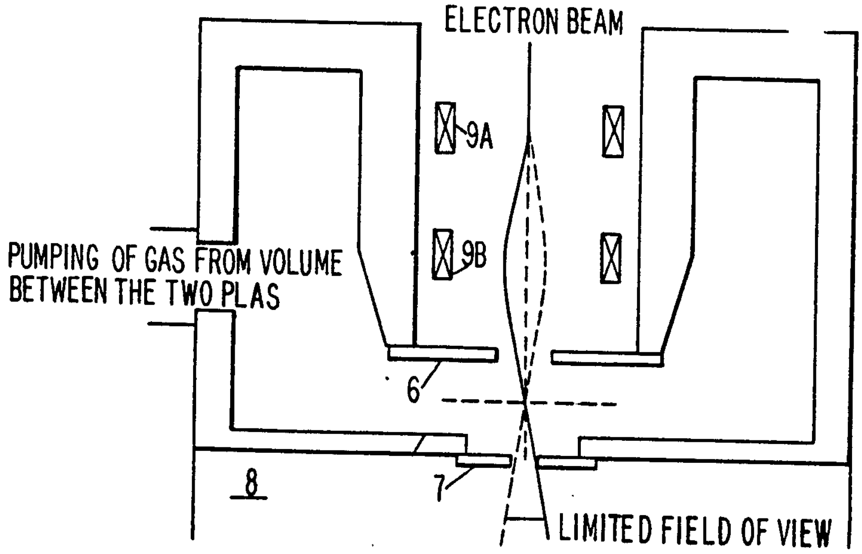

FIG. 3
PRIOR ART

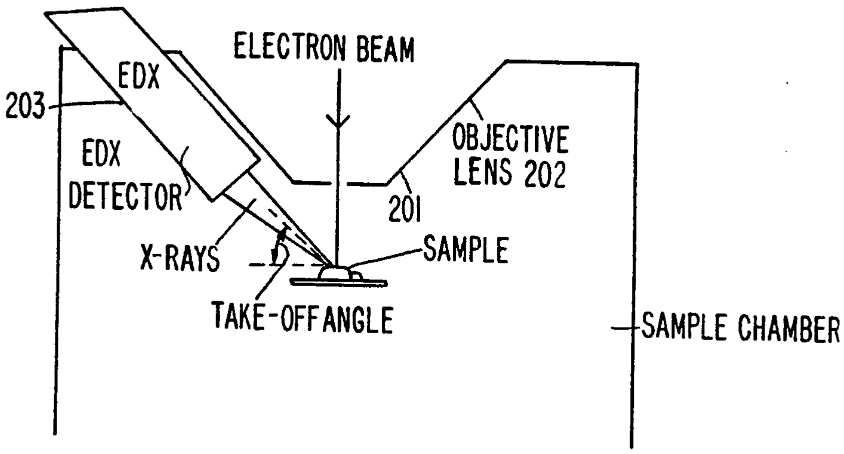

FIG. 4
PRIOR ART

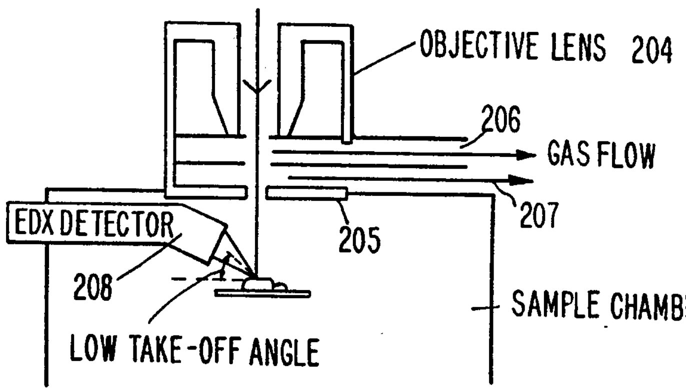

FIG. 5
PRIOR ART

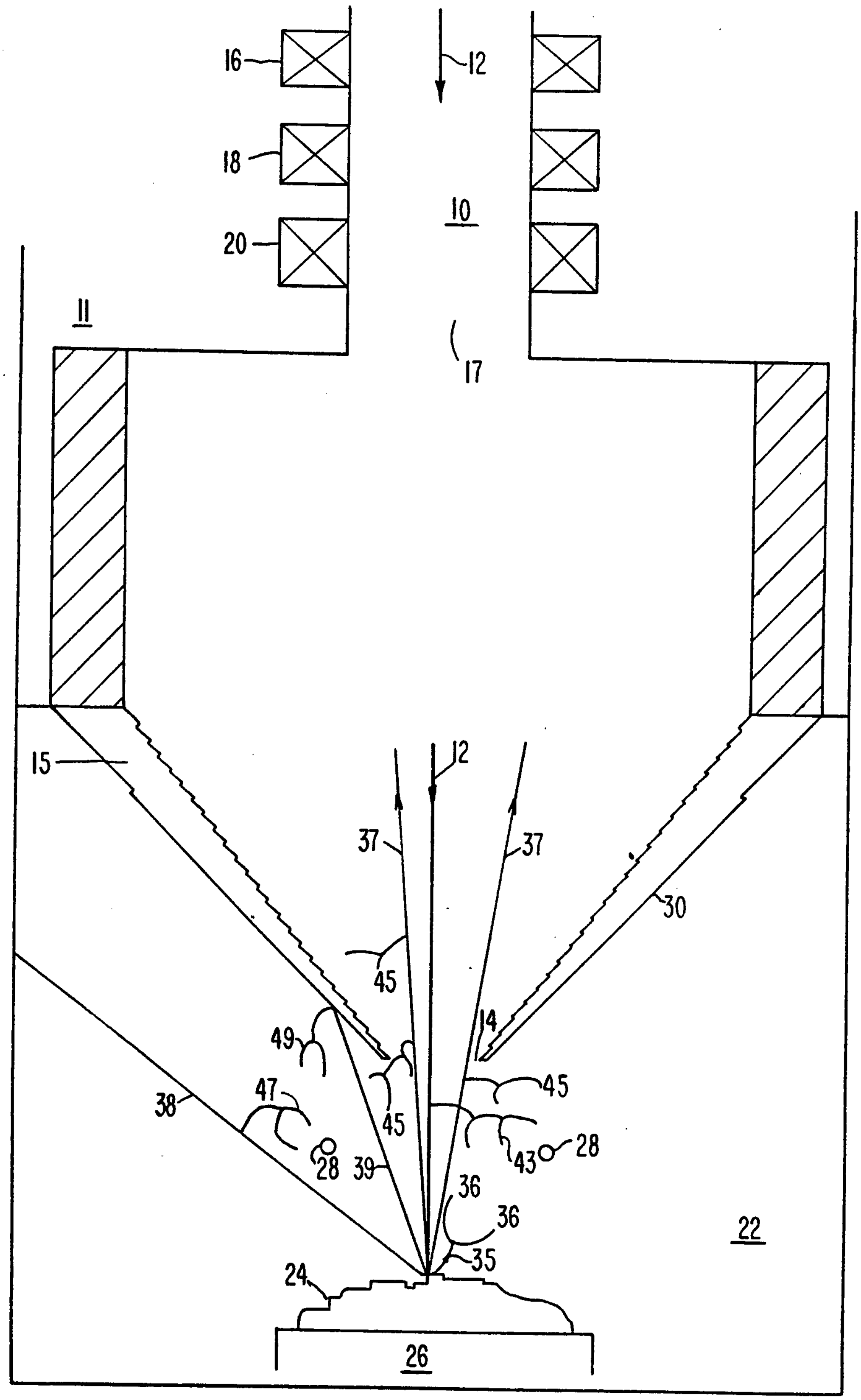
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FIG. 6

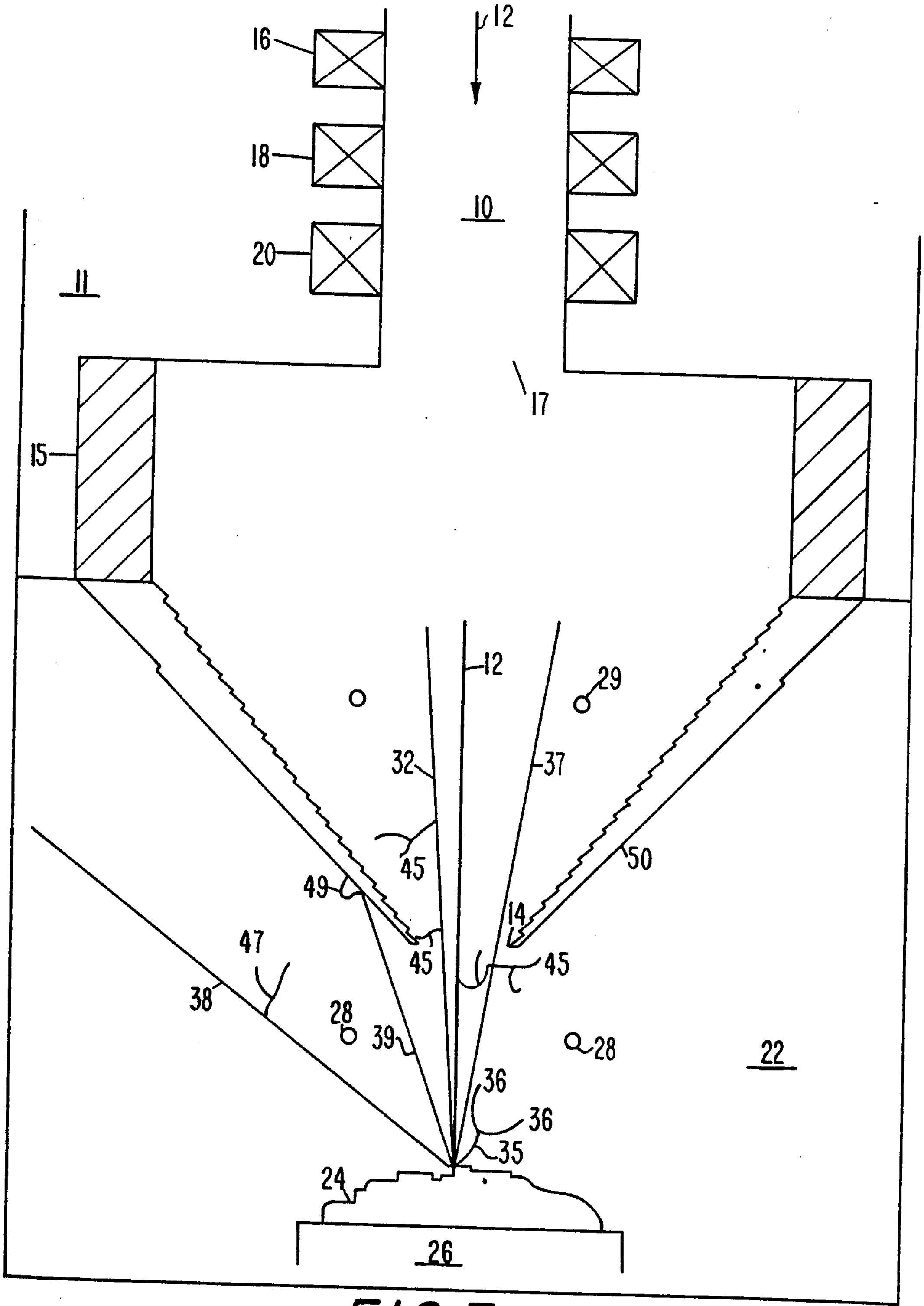
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FIG. 7

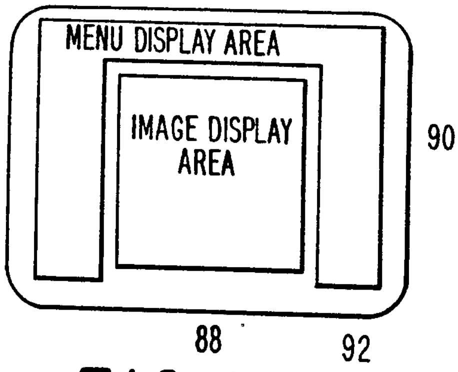

FIG. 12

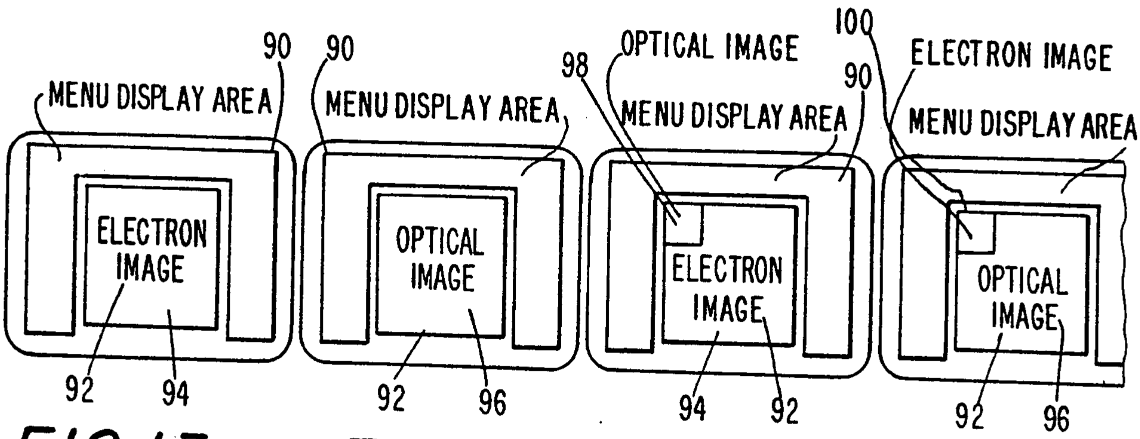

FIG. 13a FIG. 13b FIG. 13c FIG. 13d

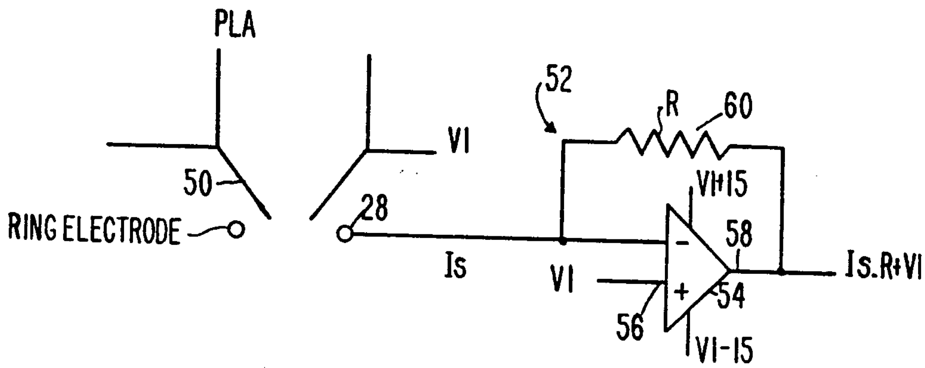

FIG. 8

6/13

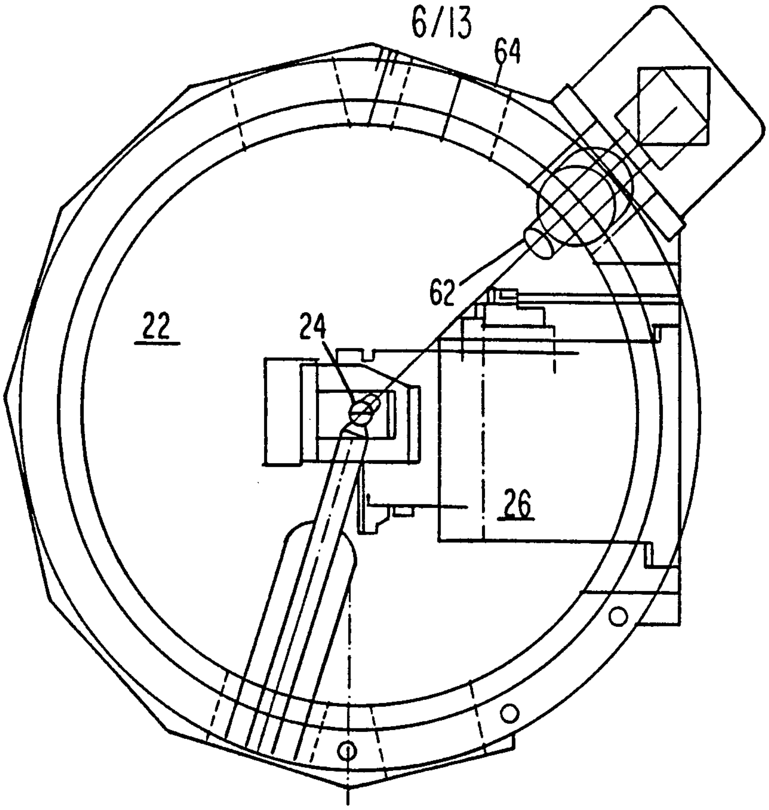

FIG. 9

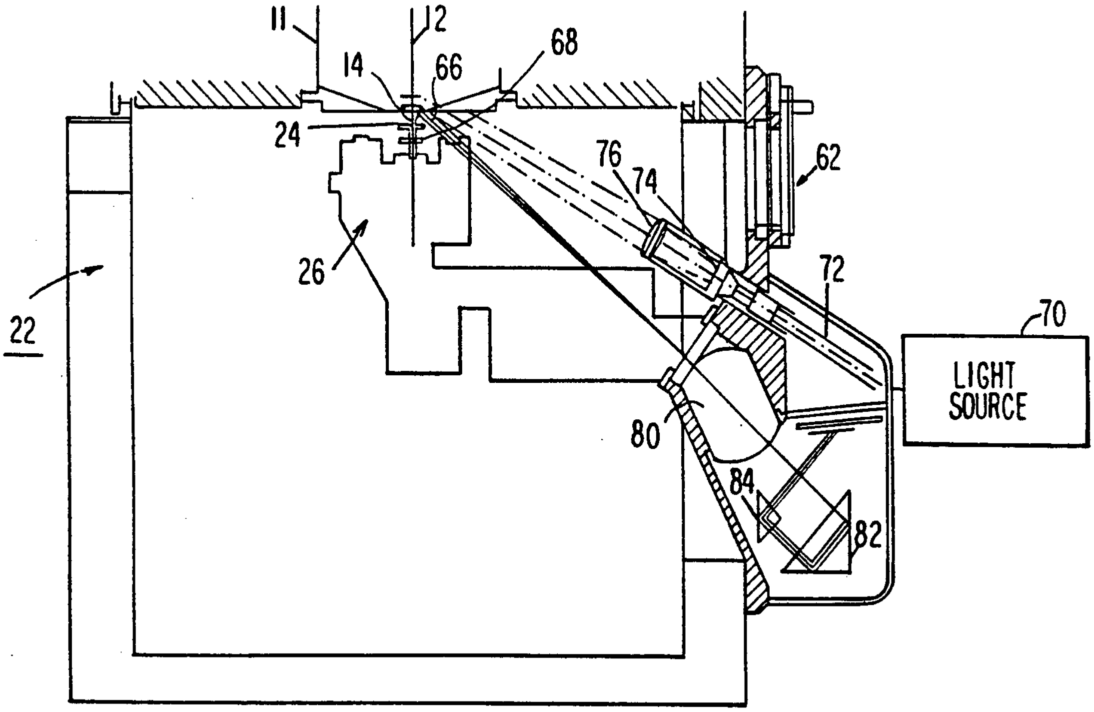

FIG. 10

SUBSTITUTE SHEET (RULE 26)

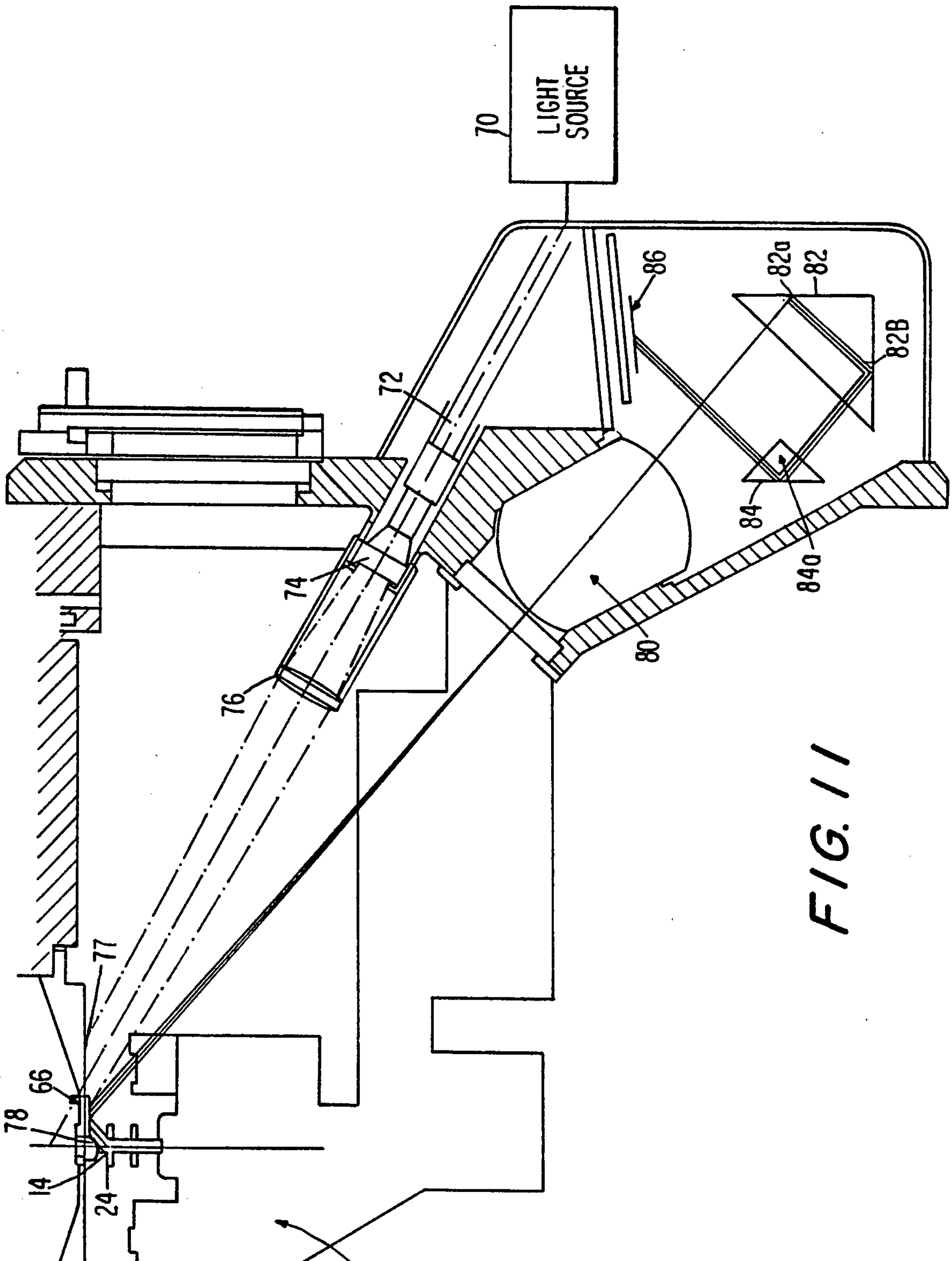

FIG. 11

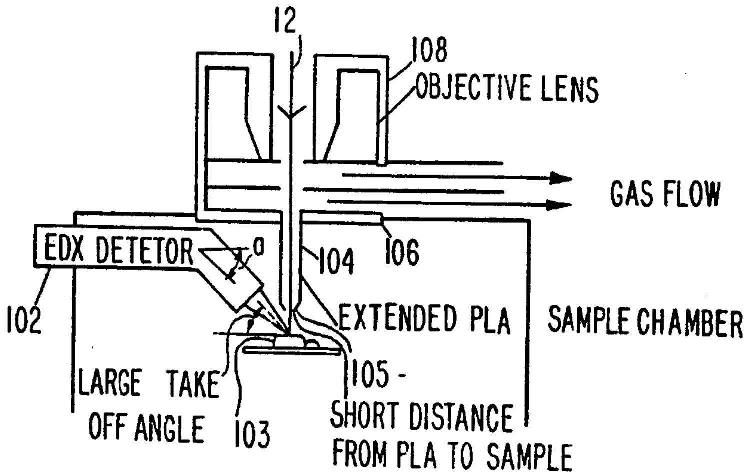
12
108
OBJECTIVE LENS
GAS FLOW
EDX DETETOR
a
104
106
102
EXTENDED PLA
SAMPLE CHAMBER
LARGE TAKE
OFF ANGLE
103
105 -
SHORT DISTANCE
FROM PLA TO SAMPLE

FIG. 14

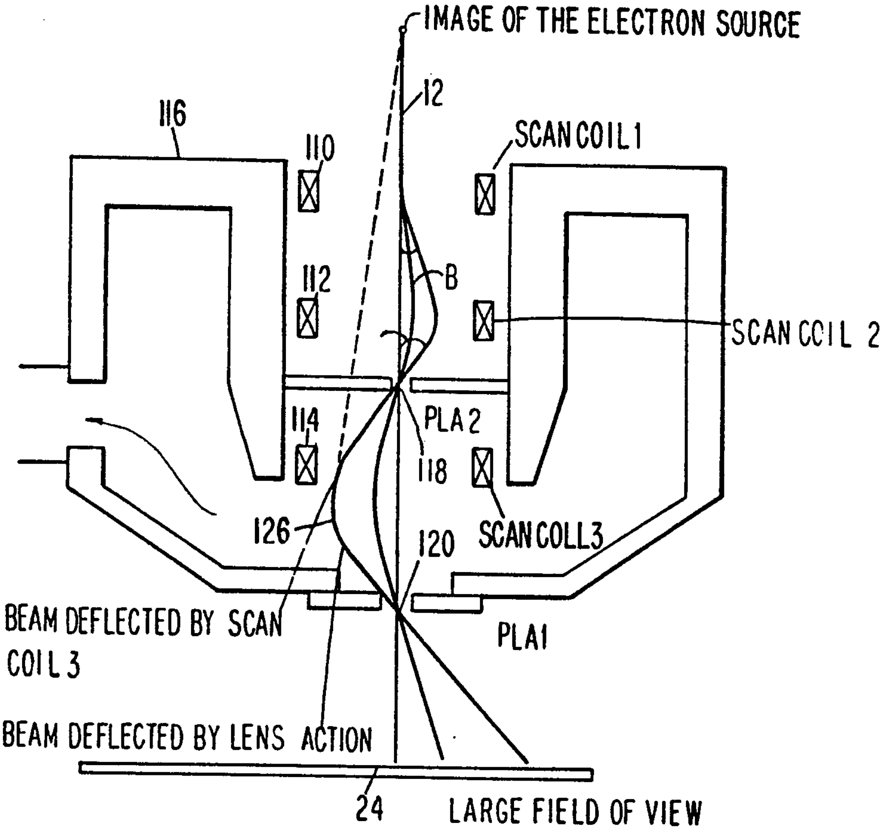
IMAGE OF THE ELECTRON SOURCE
12
116
110
SCAN COIL 1
112
B
SCAN COIL 2
PLA 2
114
118
SCAN COLL3
126
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BEAM DEFLECTED BY SCAN
COIL 3
PLA1
BEAM DEFLECTED BY LENS ACTION
24
LARGE FIELD OF VIEW

FIG. 15

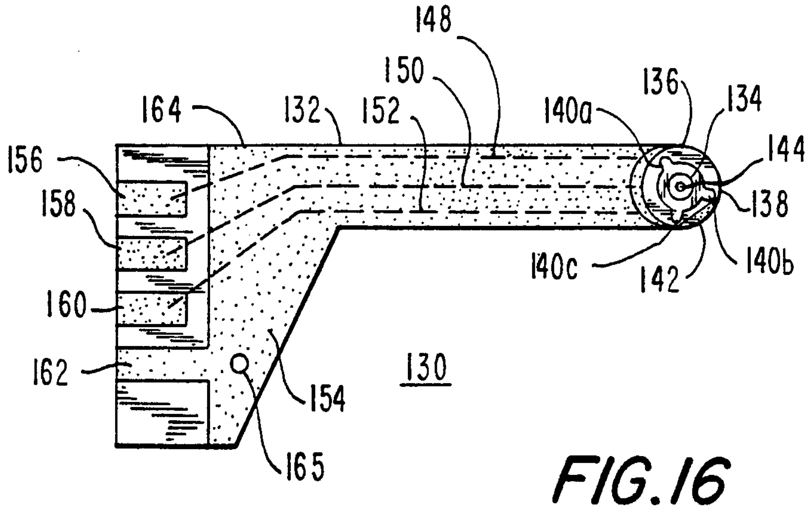


FIG.16

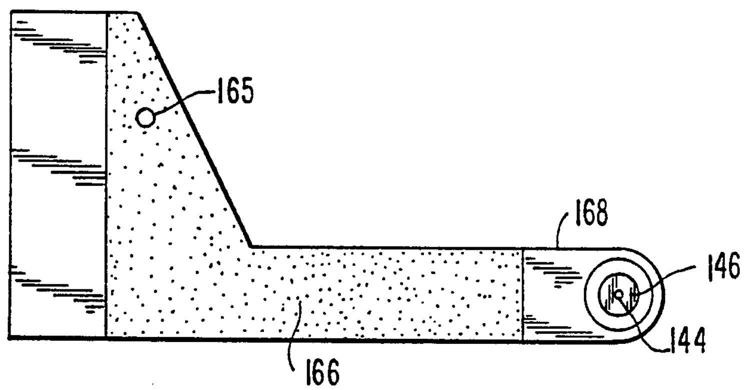


FIG.17

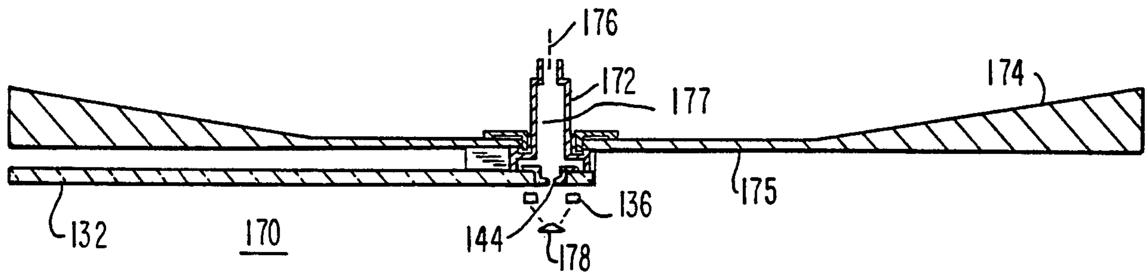
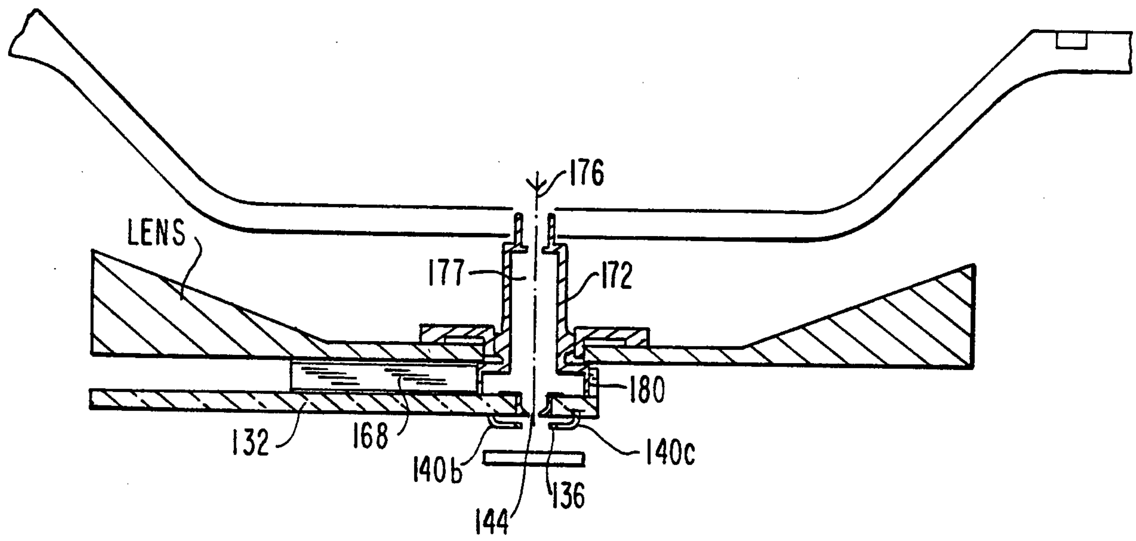


FIG.18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LENS
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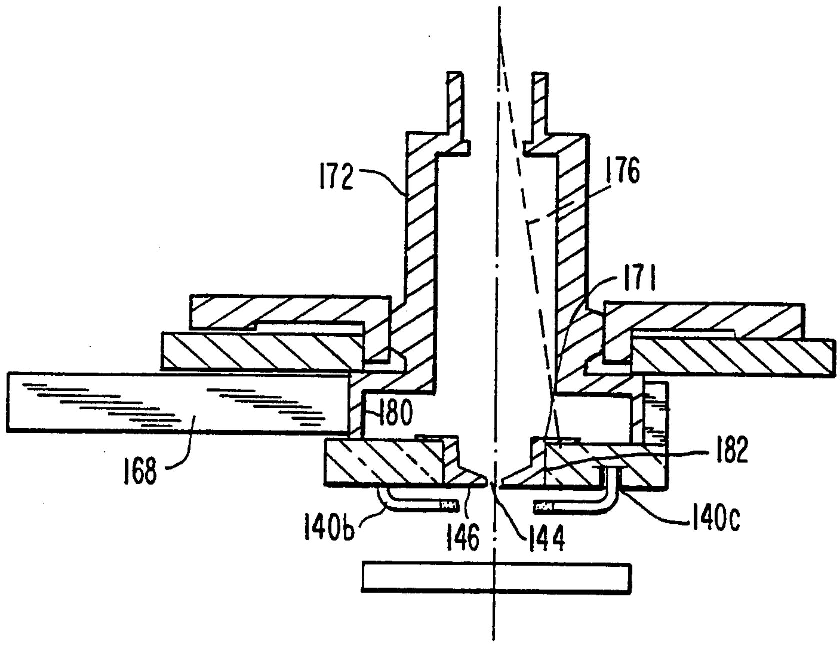
140b
140c
136
144

FIG. 19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140b
146
144
140c

FIG. 20

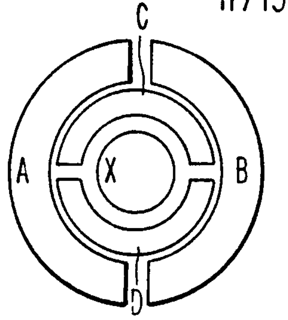

FIG. 21

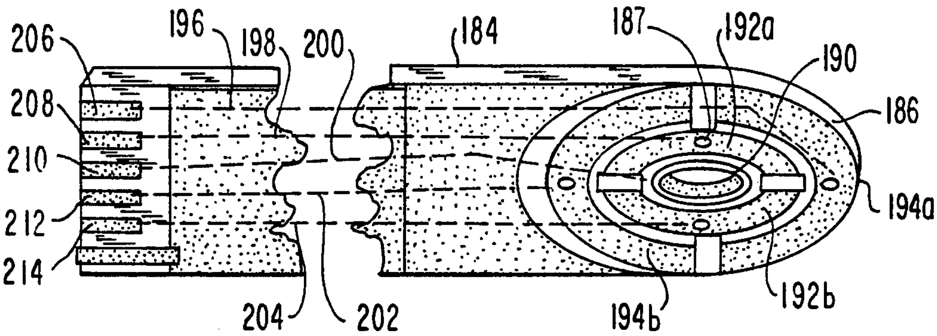

FIG. 22

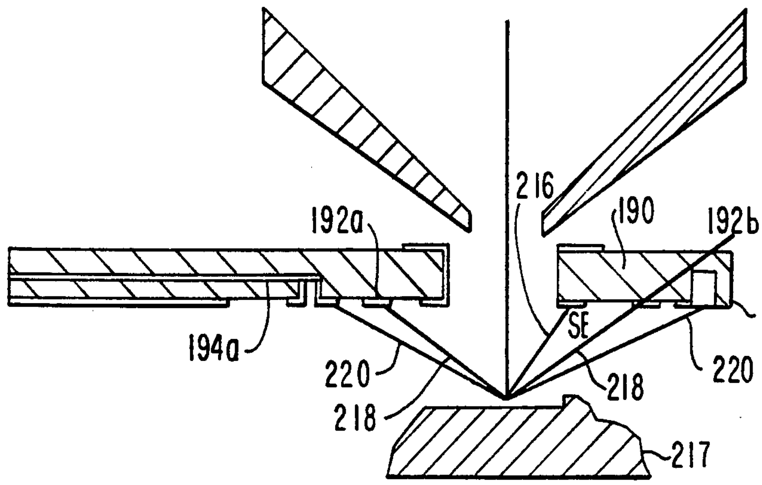

FIG. 23

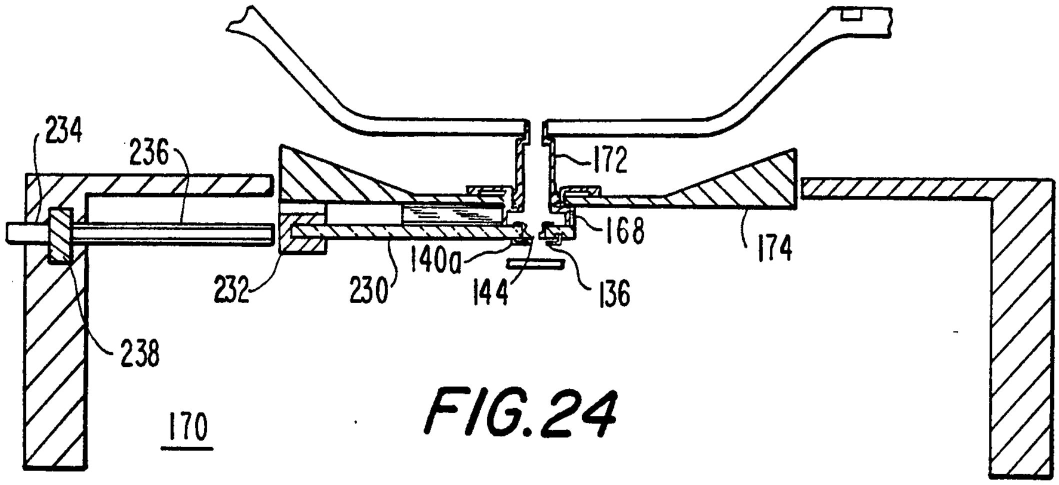

FIG.24

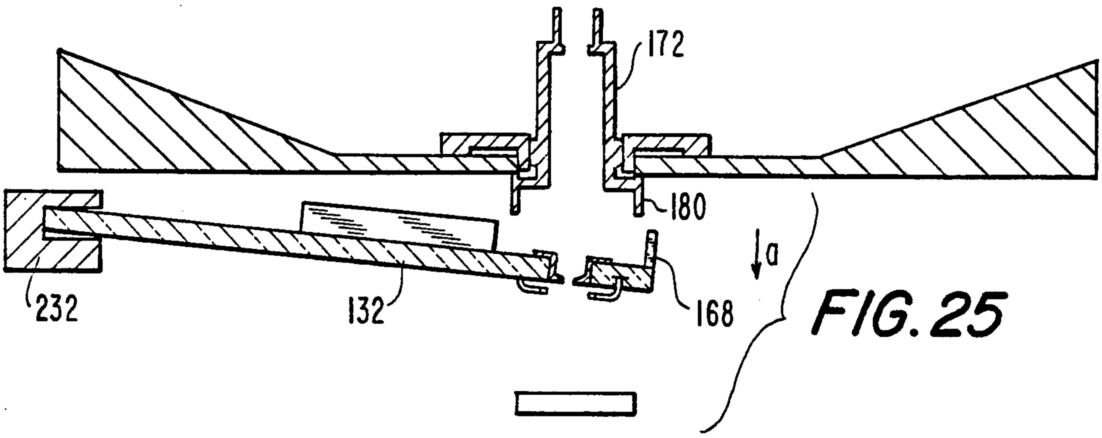

FIG.25

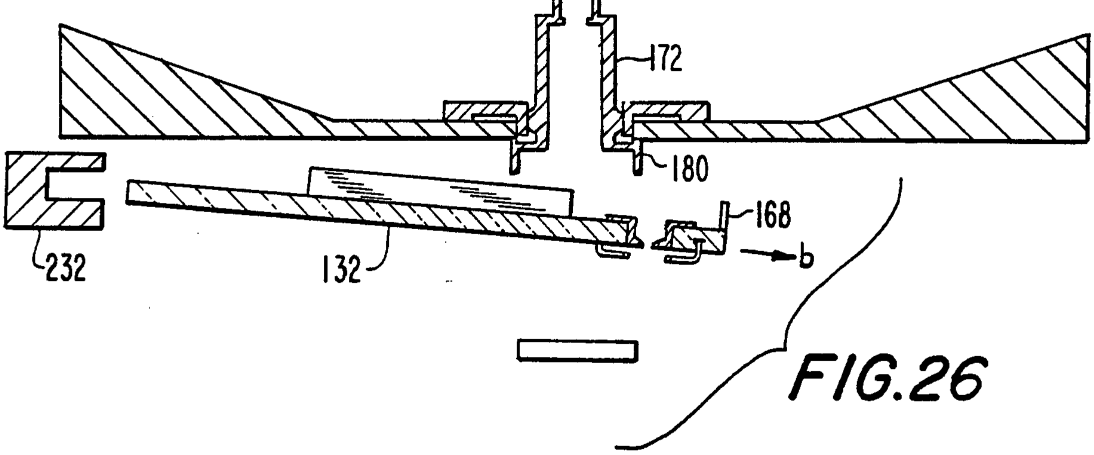

FIG.26

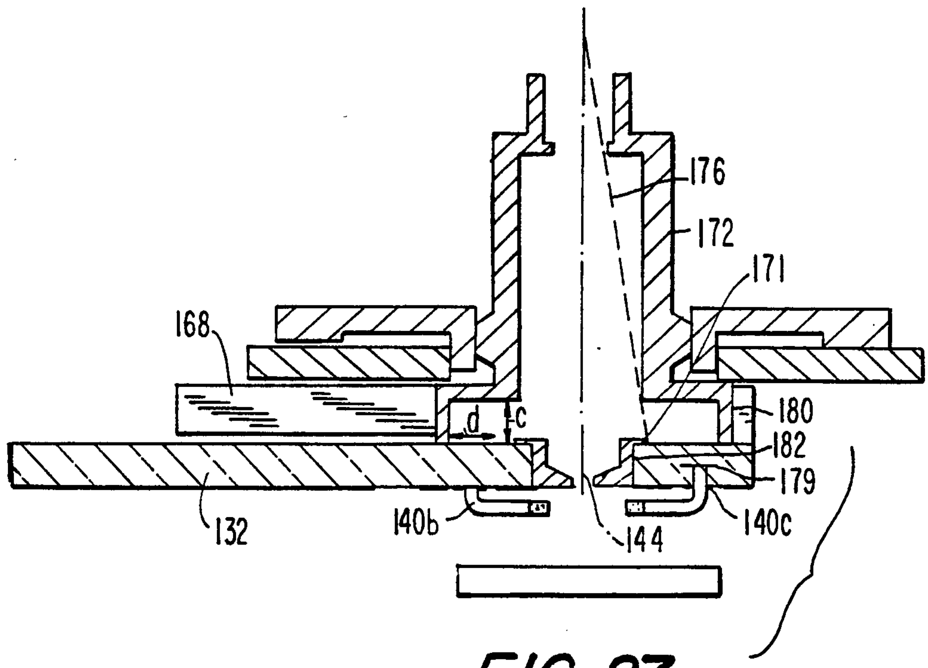

FIG. 27

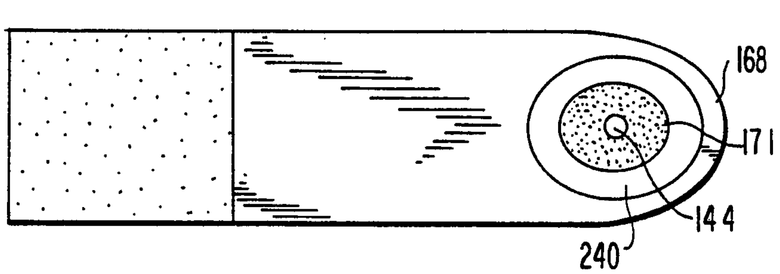

FIG. 28

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/08392

A. CLASSIFICATION OF SUBJECT MATTER
IPC(5) :H01J 37/256, 37/244
US CL : 250/310, 397
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 250/310, 397

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A,4,897,545 (DANILATOS) 30 January 1990	1-124
A	US, A, 4,537,477 (TAKAGI ET AL) 27 August 1985.	29-51
A	US, A, 4,440,475 (COLLIAUX) 03 April 1984.	29-53
A	US, A, 5,122,663 (CHANG ET AL) 16 June 1992.	57-124

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

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