ABSTRACT
A scanning electron microscope in which the electron-optical column is formed by a plurality of magnetic coils disposed around a removable tube, an electron beam being directed axially through the tube. The tube is suitably sealed at respective ends to the electron gun and specimen-containing portions of the electron-optical column, and thus functions to contain the vacuum thereon. Preferably, the tube comprises a thin, non-magnetic stainless steel tube having a wall thickness of less than 10 mils, to prevent electrostatic charging while minimizing eddy current losses. Alternatively, the tube may comprise a thin metallic layer or inner tube within an insulating, reinforcing outer tube, to impart strength and rigidity to the tube structure.

15 Claims, 8 Drawing Figures
SCANNING ELECTRON MICROSCOPE
ELECTRON-OPTICAL COLUMN CONSTRUCTION

This application is a continuation-in-part of our earlier copending application Ser. No. 75,899, filed Sept. 28, 1970, entitled "Vacuum Containment in Scanning Electron Microscope," now abandoned.

This invention relates to a scanning electron microscope, and, more particularly, to the construction of the electron-optical column of a scanning electron microscope.

In a scanning electron microscope, a beam of electrons emitted from a cathode are focused upon, and caused to scan, a specimen. The focusing an deflection of the electron beam is usually accomplished by a plurality of magnetic coils which function as lenses and deflection coils, and which are arranged successively along the path of the electron beam to form an electron-optical column. In order to provide appropriate lens-forming magnetic discontinuities between the pole pieces of the various coils, the electron-optical column has heretofore been constructed in sections, the various sections being interconnected and sealed to one another to permit operation in the necessary high vacuum environment.

Such a construction suffers from several important drawbacks and disadvantages. In particular, the provision of a sectional electron-optical column has made it extremely difficult to align and adjust the electron lenses with the high degree of accuracy necessary to achieve precision scanning and high resolution of the electron beam. Furthermore, the numerous seals between sections have created a severe leakage problem. In addition, the prior art electron-optical column construction has often placed the magnetic coils in vacuum, resulting in severe out-gassing and a relatively large volume to be evacuated, thus requiring a long pump-down time. Finally, bombardment of the column parts by the electron beam often causes contamination which coats and electrostatically charges the electron-optical column surfaces. This impairs the operation of the electron microscope, and thus requires that the electron-optical column be frequently disassembled and cleaned, further complicating the alignment and sealing of the electron-optical column, and also creating a possibility of damage to the lens elements during disassembly and reassembly.

In order to overcome some of the drawbacks thus described, it has been proposed that a scanning electron microscope be constructed with a vacuum containing tube, about which the magnet coils are disposed. Specifically, Scanning Electron Microscopy by Thornton suggests that a scanning electron microscope might, in principle, be constructed with a tube interconnecting the electron gun housing and specimen chamber, the coils being disposed about the tube. This suggestion, while overcoming the problems of leakage and outgassing of the electron-optical column, ignores the serious problem of contamination of the interior of the tube. Specifically, Thornton suggests no manner in which the tube may be removable mounted for cleaning and/or replacement. Moreover, use of a tube, as suggested by Thornton, introduces a problem of eddy current losses due to the fluctuating magnetic fields of the deflection coils, which impairs the operation of the microscope.

Miller and Pease, in an article entitled "An Ultra High-Vacuum Surface Electron Microscope," I.E.E.E. 9th Annual Symposium on Electron, Ion and Laser Beam Technology, disclosed a scanning electron microscope having a tube removably disposed interior of the electron-optical column. Once again, the problem of eddy current losses is created, but not solved. Moreover, the tube of Miller and Pease does not extend through the entire electron-optical column, as the final pole piece of the final lens is within vacuum. In order to permit cleaning and/or replacement of the tube, the tube is mounted in a removable manner. However, mounting flanges are employed at both ends of the tube which require manual manipulation. Thus, in order to remove the tube of Miller and Pease, both the specimen chamber and the electron gun housing must be disassembled. Accordingly, while the tube of the Miller and Pease microscope is removable, such removal is a complex and tedious procedure.

The scanning electron microscope's employing tubes, thus described, suffer from an additional drawback in that the inner wall of the tube tends to reflect stray electrons, thereby detrimentally increasing the beam spot size.

According to the present invention, there is provided a scanning electron microscope in which the magnetic coils forming the electron lenses and deflection coils are disposed around a removable tube, the electron beam being directed axially through the tube. The tube is demountably sealed at respective ends to the electron gun and specimen-containing portions of the electron-optical column, and thus functions to contain the vacuum. Thus, the magnetic coils are contained outside of the vacuum, thereby minimizing out-gassing. Furthermore, the volume which must be evacuated is reduced, and the number of seals are minimized, thereby reducing the pump-down time and minimizing the possibility of leakage. Moreover, the magnetic pole pieces need no longer be machined for vacuum sealing, thereby reducing manufacturing costs.

According to the present invention, one of the demountable seals at the ends of the tube is adapted for insertion and/or removal without manual manipulation. In this manner, the tube may be removed and reinserted for cleaning and/or replacement by merely disassembling one end of the electron-optical column.

Preferably, the tube comprises a thin wall nonmagnetic stainless steel tube, having a wall thickness of less than ten mils, in order to prevent electrostatic charging, while minimizing eddy current losses due to the dynamic fields of the deflection coils. Since a thin walled metallic tube may lack the necessary strength and rigidity, alternatively, a composite tube having a fiber glass outer tube containing a layer of nonmagnetic stainless steel or inner tube may be provided, the fiber glass serving to reinforce and strengthen the tube structure.

In addition, novel spray apertures may be provided intermediate the tube, to block the path of electrons reflected from the walls of the tube, and to thereby improve the beam spot size. Moreover, the spray apertures tend to increase the vacuum impedance of the tube so as to facilitate differential pumping of the specimen chamber and electron gun housing.

It is thus an object of the present invention to provide a scanning electron microscope employing a vacuum containing tube interior of the electron-optical column, the tube being removably mounted to permit removal.
upon disassembly of only one end of the electron-optical column.

Another object of the present invention is to provide a scanning electron microscope employing a vacuum containing tube interior of the electron-optical column, the tube comprising a thin walled nonmagnetic stainless steel tube having a wall thickness of less than ten mils, in order to minimize eddy current losses while eliminating electrostatic charging.

Yet another object of the present invention is to provide a scanning electron microscope employing a tube interior of the electron-optical column having novel spray apertures interior of the tube.

These and other objects, features and advantages of the present invention will be more readily apparent from the following detailed description of the present invention with reference to the accompanying drawings wherein:

FIG. 1 is a side, cross-sectional view of the electron-optical column of a scanning electron microscope according to the present invention;

FIG. 2 is an enlarged side, cross-sectional view of the upper tube flange portion of the apparatus of FIG. 1;

FIG. 3 is an enlarged side, cross-sectional view of the lower tube end portion of the apparatus of FIG. 1;

FIG. 4 is a side, cross-sectional view, similar to FIG. 3, of an alternative embodiment of the present invention;

FIG. 5 is a side, cross-sectional view, similar to FIG. 3, of another embodiment of the present invention;

FIG. 6 is a side, cross-sectional view, similar to FIG. 3, of still another embodiment of the present invention;

FIG. 7 is a side, cross-sectional view of the spray aperture portion of the apparatus of FIG. 1; and

FIG. 8 is a side, cross-sectional view illustrating the insertion of the spray aperture of FIG. 7.

Referring initially to FIG. 1, there is shown the electron-optical column A of a scanning electron microscope according to the present invention. Electron-optical column A comprises an electron gun housing 10 in which an electron source 11 is disposed. Electron gun housing 10 comprises a substantially cylindrical housing closed at one end, and having an angular groove at the other end adapted to contain an O-ring or seal 12. Electron gun housing 10 includes a pumping port 13 which is employed to evacuate the interior of the electron-optical column, as will be described in greater detail hereinafter.

According to the preferred embodiment of the present invention, electron gun housing 10 is formed of upper and lower halves 10a and 10b, respectively, which are suitably mated by a clamp 14, a seal 15 being disposed therebetween.

Electron gun housing 10 is mounted by a clamp 16 to a first coil housing or pole piece 17, with O-ring 13 abutting housing 17. Housing 17 comprises a hollow cylindrical housing having an interior wall 17a defining an annular chamber and an axial opening. Contained within the annular chamber is a coil 18. Inner wall 17a includes a pair of non-magnetic spacers or gaps 19 at the ends thereof and a non-magnetic spacer or gap 20 approximately in the middle thereof. Coil 18, when appropriately energized, cooperates with housing 17 to form three magnetic lens fields at gaps 19 and 20. These magnetic lens fields serve to focus the beam of electrons emitted by electron source 11.

4

Disposed within the axial opening in housing 17, and extending there beyond, is a tube 21. Tube 21 is attached at one end to a flange 22. As will be described in greater detail hereinafter, flange 22 mounts to the upper surface of housing 17 and functions to mount a vacuum seal tube 21. An apertured cup 23 is mounted on flange 22, the beam of electrons emitted by electron source 11 being directed through the aperture in cup 23 and thence through the bore of tube 21.

Accordingly, the aperture of cup 23 functions as the initial aperture of the electron-optical column, and thus functions, in part, to define the solid angle of the beam of electrons emitted by electron source 11.

Disposed around that portion of tube 21 which protrudes beyond housing 17 are an astigmatism coil 24 and a pair of deflection coils 25. As will be described in greater detail hereinafter, deflection coils 25 are suitably energized to cause the beam of electrons to scan the specimen in the desired manner.

A second housing 26, somewhat similar to housing 17, is disposed around deflection coils 25 and astigmatism coil 24, and is mounted to housing 17 by a clamp 27. In particular, housing 26 comprises a hollow cylindrical housing having an inner wall 26a defining an annular chamber and an axial opening. The axial opening within inner wall 26a substantially encloses astigmatism coil 24 and deflection coils 25, tube 21 thus passing therethrough. Contained within the annular chamber of housing 26 is a coil 28. Inner wall 26a of housing 26 includes a non-magnetic spacer or gap 29 between inner wall 26a and the lower end of wall of housing 26.

When suitably energized, coil 28 cooperates with housing 26 to form a magnetic lens field at gap 29, which magnetic lens field will focus the beam of electrons in a manner to be described in greater detail hereinafter.

Attached to the other or lower end of tube 21 is a flange 30. Flange 30 cooperates with the lower end wall of housing 26 to mount and seal tube 21, in a manner to be described in greater detail hereinafter.

Disposed beneath housing 26 is a specimen chamber 31. Specimen chamber 31 comprises a substantially cylindrical chamber closed at one end, and, at the other end having an annular groove containing an O-ring or seal 32. Specimen chamber 31 is suitably disposed beneath housing 26 so that O-ring 32 abuts the lower end of housing 26, thus forming a vacuum seal between housing 26 and specimen chamber 31. Specimen chamber 31 further includes a pumping port 33, which is employed to evacuate the interior of the electron-optical column.

Disposed within specimen chamber 31 is a stage 34 adapted to support a specimen 35 in a predetermined position relative to the electron beam. An electron collector 36 is disposed adjacent specimen 35 and functions to receive the electrons emitted by, or reflected from, specimen 35 as it is scanned by the electron beam. Electron collector 36 functions in cooperation with electronic circuitry (not shown) to provide a conventional scanning electron microscope display.

Referring now to FIGS. 2 and 3, tube 21 will now be described in greater detail. Specificially, tube 21 is mounted for vacuum-containing sealing at the ends thereof, so that the vacuum contained within the electron-optical column A is confined within tube 21, electron gun housing 10 and specimen chamber 31. Tube 21 may comprise either a metallic or non-metallic tube. However, if a non-metallic or insulating tube is em-
ployed, electrostatic charges may develop in the interior thereof, which charges may result in astigmatism, defocusing or misdirection of the electron beam. If, however, a metal tube 21 is employed, the varying fields produced by deflection coils 25 necessary to appropriately deflect the beam of electrons, will induce eddy currents in tube 21, which currents will unduly limit the useful scanning frequency and otherwise deleteriously affect the operation of scanning electron microscope.

Accordingly, it is preferable that tube 21 comprise a thin-walled non-magnetic metal tube. Specifically, applicants have found that tube 21 may preferably comprise a non-magnetic stainless steel tube having a wall thickness of less than 10 mils, so as to eliminate electrostatic charging, while minimizing eddy current losses. Applicants have found that such a tube 21 may successfully be employed with scanning rates in excess of 15,000 lines per second. It is further apparent that even higher scanning rates may be achieved with a thinner tube 21.

As the wall thickness of tube 21 decreases, it is apparent that the strength and rigidity of tube 21 decreases. Thus, according to an alternative embodiment of the present invention, tube 21 may comprise a composite tube formed by an outer insulating tube encompassing a thin metallic layer or inner tube. In this manner, the problem of electrostatic charging of the inside of tube 21 is eliminated, as the inner metallic tube may be grounded to conduct away the charges, while the eddy current problem is minimized, since the inner tube may be extremely thin. Thus, tube 21 may be a composite formed by a thin, non-magnetic stainless steel inner tube contained within an outer fibreglass tube, which serves to provide the necessary strength and rigidity.

Referring specifically to FIG. 2, the mounting and sealing of tube 21 will now be described in greater detail. As briefly referred to hereinbefore, one end of tube 21 is attached to a flange 22 which is mounted and vacuum sealed against the upper surface of housing 17. Specifically, flange 22 includes a portion having a diameter greater than the aperture in the upper surface of housing 17. The upper surface of housing 17 includes an annular groove containing an O-ring or seal 37. A pair of screws 38, threadably engaging the upper surface of housing 17, urge apertured cup 23 and flange 22 downwardly to secure tube 21 in the electron-optical column A while urging flange 22 into vacuum containing pressure contact with O-ring 37. Accordingly, the upper end of tube 21 is thus vacuum sealed to the upper surface of housing 17 by screws 38 and seal 37. Furthermore, as will be more readily apparent hereinafter, screws 38 cooperate with flange 22 to urge tube 21 downwardly, the downward urging functioning to seal tube 21 to the other end thereof.

Referring specifically to FIG. 3, the mounting and sealing of the lower end of tube 21 will now be described in greater detail. As briefly referred to hereinbefore, the lower end of tube 21 is attached to a flange 30 which is vacuum sealed and mounted to the lower end of housing 26. According to the present invention, the mounting and sealing of lower end of tube 21 is accomplished in a self-sealing manner as to eliminate the need for manual manipulation of the lower end of the tube. In this manner, tube 21 may be removed for cleaning or replacement upon disassembly of only one end of the electron-optical column. Specifically, according to the preferred embodiment of the present invention, only the electron gun housing 10 need be removed from the electron-optical column A in order to remove tube 21. Of course, it is to be expressly understood that the particular end of the electron-optical column through which the tube may be removed can be reversed, and such modification is specifically within the scope of the present invention.

According to the preferred embodiment of the present invention, the non-manipulative for self-sealing mounting of the lower end of tube 21 is accomplished by employing the downward urging from the upper end of tube 21, created by screws 38, to urge insulating flange 30 into vacuum sealing engagement with the lower end of housing 26. Specifically, flange 30 includes an annular groove in the lower surface thereof adapted to contain an O-ring or seal 39. Downward urging of tube 21, caused by the downward pressure at the other end of the tube, urges the lower face of flange 30 into contact with housing 26, thereby compressing O-ring or seal 39, so as to achieve the desired vacuum-containing seal. Accordingly, it is apparent that by so providing a non-manipulative seal at one end of the tube 21, the tube may be removed upon disassembly of only one end of the electron-optical column A.

Flange 30 may additionally function to mount the final aperture for the electron beam. Specifically, flange 30 may include a cylindrical recess in the lower surface thereof, and an apertured disc 40 may be mounted therein. Specifically, a resilient O-ring 41 may be provided to retain disc 40 in the recessing of flange 30. It is thus apparent that the aperture in disc 40 functions to further define the solid angle of the beam of electrons passing therethrough. Of course, the final aperture need not be provided within flange 30, but may be provided in accordance with conventional scanning electron microscope construction.

Referring now to FIG. 4, an alternative non-manipulative self-sealing arrangement for the lower end of tube 21 will now be described in detail. Specifically, according to this alternative embodiment, the lower end of housing 26 is provided with an annular groove containing a seal 42. The lower end of tube 21 is disposed on seal 42 and is urged into vacuum sealing contact therewith by the downward urging of tube 21 from the top thereof. Specifically, as referred to hereinbefore, screws 38 urge tube 21 downwardly, so that the downward pressure from the top end of tube 21 seals the lower end thereof. It is apparent that according to this embodiment of the present invention, no lower flange need be provided for tube 21, as the seal therefore may be located in housing 26 rather than in a lower flange. Of course, a final aperture (not shown) may be provided in accordance with conventional scanning electron microscope construction.

Referring now to FIG. 5, another alternative non-manipulative self-sealing arrangement for the lower end of tube 21 will now be described in detail. Specifically, the lower end of tube 21 may be seared in a manner which eliminates the need for manual manipulation by employing radial pressure on the seal rather than downward pressure as previously described. To this end, the lower end of housing 26 may include a cylindrical projection 43 extending upwardly into the interior of housing 26. Cylindrical projection 43 has a diameter slightly smaller than the inside diameter of tube 21.
Cylindrical projection 43 includes an annular groove in the outer surface thereof for containing an O-ring or seal 44. As is apparent from FIG. 5, tube 21 is seated on cylindrical projection 43 with seal 44 engaging the inside surface of tube 21 toward the end thereof. Seal 44 has a nominal diameter greater than the inner diameter of tube 21, so that the engagement of tube 21 over cylindrical projection 43 will result in the radial compression of seal 44 thereby resulting in vacuum-containing sealing of the lower end of tube 21. Accordingly, it is apparent that a non-manipulative seal for the lower end of tube 21 employing radial pressure, rather than axial pressure as previously described, may be provided. Once again, a final aperture (not shown) may be provided in accordance with conventional scanning electron microscope construction.

Referring now to FIG. 6, still another alternative embodiment of the non-manipulative self-sealing arrangement of the lower end of tube 21 will now be described in detail. Specifically, the sealing arrangement depicted in FIG. 6 again employs radial pressure to seal the lower end of tube 21. To this end, the lower end of housing 26 is provided with a cylindrical aperture having a diameter slightly greater than the outside diameter of tube 21. An annular groove containing a seal 45 is provided on the inner surface of the cylindrical aperture. Seal 45 is resilient and has a nominal inside diameter slightly smaller than the outside diameter of tube 21. Thus, the lower end of tube 21 is engaged in the cylindrical aperture in housing 26, as depicted in FIG. 6. Tube 21 will thus press outwardly upon seal 45, thereby urging seal 45 into vacuum-containing sealing with the outside of tube 21. Accordingly, it is apparent that a non-manipulative seal for the lower end of tube 21 employing radial pressure on the sealing element may be provided. Once again, a final aperture (not shown) may be provided in accordance with conventional scanning electron microscope construction.

According to a further aspect of the present invention, spray apertures adapted to block the path of electrons reflected off the interior surface of tube 21 may be provided within tube 21. Specifically, applicants have found it desirable to employ a spray aperture within tube 21 at a region slightly before the astigmator and deflection coils 24 and 25, along the path of the electron beam. Applicants have found, however, that the placement of the spray apertures within tubes 21 is not critical, with the exception that the spray apertures should not be located in the region of the deflection coils, since the deflection of the beam might thus be interfered with.

Referring specifically to FIGS. 7 and 8, the spray apertures according to the present invention will now be described in detail. Specifically, according to the present invention, spray apertures are provided in the form of a helical metallic ribbon 46 engaging the interior of tube 21, as depicted in FIG. 7. The helical ribbon 46 presents an inner aperture and an outer metal surface to the electron beam, so that electrons which have diverged from the desired path of the electron beam, including those electrons reflected off the interior surface of tube 21, will impinge upon the metallic surface of helical ribbon 46, while those electrons following the desired beam path will pass through the central aperture unimpeded. As will be more readily apparent hereinafter, use of a helical ribbon 46 as a spray aperture is advantageous in that the helical ribbon 46 may readily be inserted into the tube 21 and will be retained therein due to the resilient urging of the helical ribbon 46 against the inside wall of tube 21. Thus, no independent mounting need be provided for spray apertures in accordance with the present invention. Moreover, the spray aperture 46 in the interior of tube 21 introduces a substantial vacuum impedance into tube 21, so that electron-optical column may readily be differentially pumped in accordance with conventional scanning electron microscope techniques.

Referring specifically to FIG. 8, the insertion of the helical ribbon 46 into the tube 21 will now be described in greater detail. Helical ribbon 46 has a nominal outer diameter slightly greater than the inside diameter of tube 21. In order to insert helical ribbon 46 into tube 21, it is necessary to radially compress the ribbon 46. To this end, a rod 47 having a diameter substantially equal to the bore of helical ribbon 46 may be provided, and ribbon 46 may be disposed about rod 47. Helical spring 48 may then be longitudinally extended which will result in the radial compression thereof. Rod 47 may then be introduced into tube 21 through one of the ends thereof, so as to locate ribbon 46 at its desired location. A second rod 48 having a bend or hook on the end thereof may then be introduced into the tube 21 through the other end thereof and the hook or bend engaged with ribbon 46, as depicted in FIG. 8, while maintaining ribbon 46 in position through the use of rod 48, rod 47 may then be drawn outwardly, leaving helical ribbon in position within tube 21. Rods 47 and 48 may then be manually manipulated to longitudinally compress helical ribbon 46, thereby resulting in the radial expansion thereof. The radial expansion functions to urge the periphery of helical ribbon 46 into resilient engagement with the inner surface of tube 21, and to thereby result in the desired mounting thereof, as depicted in FIG. 7. Accordingly, it is apparent that the spray apertures according to the present invention do not require complex mounting procedures, such as welding, soldering or the like, which would be relatively unfeasible within the interior of tube 21.

In operation, a specimen 35 is introduced into the interior of specimen chamber 31 through a hatch or airlock (not shown), and is suitably attached to stage 34. Vacuum pumps (not shown) are attached to pumping ports 13 and 33, so as to substantially evacuate the interior of specimen chamber 31, tube 21 and electron gun housing 10. A high voltage source of electricity is connected to electron source 11, so as to cause an electron beam to be emitted therefrom. Suitable DC voltages are applied to magnet coils 18 and 28 so as to form magnetic lens fields at gaps 19, 20 and 29, in a conventional manner. Of course, housing 17 and 26 have heretofore been adjusted and are aligned with respect to tube 21, so that the magnetic lens fields will function to focus the beam of electrons emitted from electron source 11 and passing through tube 21.

A suitably varying source of electricity is applied to deflection coils 25, so as to cause the beam of electrons to scan specimen 35 in a raster-like manner. This, in turn, will cause electrons to be emitted by, or reflected from, specimen 35, which electrons are received by electron collector 36. Through suitable electronics (not shown), these electrons are amplified and processed to form a conventional scanning electron microscope display.
As referred hereinbefore, tube 21 may be grounded so as to conduct away electrostatic charges developed thereon. Moreover, the spray aperture of helical ribbon 46 provided within tube 21 will function to collect any stray electrons diverging from the path of the electron beam, such as those which may be reflected off the inner surface of tube 21. Thereby resulting in a relatively precise electron beam. If, during the course of operations, materials are deposited on the interior of tube 21 due to vacuum deposition or evaporation, the tube 21 may be removed for cleaning or replacement by disassembling only the electron gun housing 10 to provide access to screws 38 and flange 22. It is noteworthy that the specimen chamber need not be disassembled, as the lower seal of tube 21 does not require manual manipulation for disassembly. Thus, tube 21 may be withdrawn from the electron-optical column A from the specimen chamber thereof. Thereafter, tube 21 may be cleaned or replaced, with minimal interference with the alignment of the magnetic lenses, and with minimal possibilities of causing damage thereto.

In addition, the foregoing construction of an electron-optical column for a scanning electron microscope is advantageous in that the volume to be evacuated is reduced, and the number of seals are minimized, thereby reducing the pump-down time and minimizing the possibilities of leakage. Furthermore, since the magnetic pole pieces need no longer be machined for vacuum sealing, a substantial manufacturing cost reduction is achieved.

While particular embodiments of the present invention have been shown and described, it is to be understood that modifications or adaptations may be made without departing from the true spirit and scope of the invention, as set forth in the claims.

What is claimed is:

1. A scanning electron microscope comprising an electron source housing, electron source means for emitting a beam of electrons disposed interior of said electron source housing, an electron-optical column including a plurality of magnetic coils having a bore therethrough, said electron source housing being movably mounted to one end of said electron-optical column, a chamber for containing a specimen, said chamber being mounted to the other end of said electron-optical column, detector means for detecting electrons emitted or reflected by said specimen, a unitary tube movably disposed interior of said electron-optical column interconnecting said electron source housing and said chamber, said beam of electrons being directed through said tube to said specimen, mounting means for removable mounting and sealing said tube at one end thereof, self-sealing means for non-manipulatively self-sealing said tube at the other end thereof, said other end of said tube being dimensioned smaller than said bore to permit removal of said tube through said bore without manual manipulation or disassembly at said other end, means for evacuating the interior of said electron source housing and of said tube and of said chamber, and means for energizing said coils for focus and scan said beam of electrons on said specimen.

2. Apparatus according to claim 1 wherein said self-sealing means comprises a resilient seal longitudinally disposed beyond said other end of said tube and wherein said mounting means comprises means longitudinally urged said tube toward said other end for vacuum sealing engagement of said other end and said seal.

3. Apparatus according to claim 2 comprising a flange disposed on said other end of said tube, said flange having a diameter smaller than the bore of said electron-optical column, said flange including an annular groove containing said seal.

4. Apparatus according to claim 1 wherein said self-sealing means comprises a resilient seal radially disposed around said other end of said tube, said seal having a nominal inner diameter smaller than the outer diameter of said tube.

5. Apparatus according to claim 1 wherein said self-sealing means comprises a resilient seal radially disposed interior of the other end of said tube, said seal having a nominal outer diameter greater than the inner diameter of said tube.

6. Apparatus according to claim 1 wherein said one end of said tube is adjacent said electron source housing.

7. Apparatus according to claim 1 comprising a helical metal ribbon having a nominal outer diameter greater than the inner diameter of said tube, disposed in said tube to form a spray aperture.

8. Apparatus according to claim 1 comprising a spray aperture disposed interior of said tube.

9. Apparatus according to claim 8 wherein said spray aperture comprises mounting means resiliently radially urging against the interior of said tube.

10. In a scanning electron microscope having an electron source housing, electron source means for emitting a beam of electrons disposed interior of said electron source housing, an electron-optical column including a plurality of magnetic coils, said electron source housing being removably mounted to one end of said electron-optical column, a chamber for containing a specimen, said chamber being mounted to the other end of said electron-optical column, said beam of electrons being directed through said tube to said specimen, means for evacuating the interior of said electron source housing and of said tube and said chamber, detector means for detecting electrons emitted or reflected by said specimen, the improvement comprising: a spray aperture disposed interior of said tube having mounting means resiliently radially urging against the interior of said tube.

11. Apparatus according to claim 10 wherein said spray aperture comprises a helical metal ribbon having a nominal outer diameter greater than the inner diameter of said tube.

12. In a scanning electron microscope having an electron source housing, electron source means for emitting a beam of electrons disposed interior of said electron source housing, an electron-optical column including a plurality of magnetic coils having a bore therethrough, said electron source housing being removably mounted to one end of said electron-optical column, a chamber for containing a specimen, said chamber being mounted to the other end of said electron-optical column, detector means for detecting electrons emitted or reflected by said specimen, a unitary tube disposed interior of said electron-optical column, said beam of electrons being directed through said tube to said specimen, means for evacuating the interior of said electron source housing and of said tube and of said chamber, the improvement comprising: mounting
means for removably mounting and sealing said tube at one end thereof and self-sealing means for sealing said tube at the other end thereof, said other end of said tube being dimensioned smaller than said bore to permit removal of said tube through said bore without disassembly or manual manipulation at said other end.

13. Apparatus according to claim 12 wherein said self-sealing means comprises a resilient seal longitudinally disposed beyond said other end of said tube and wherein said mounting means comprises means longitudinally urging said tube toward said other end for vacuum sealing engagement of said other end and said seal.

14. Apparatus according to claim 12 wherein said self-sealing means comprises a resilient seal radially disposed around said other end of said tube, said seal having a nominal inner diameter smaller than the outer diameter of said tube.

15. Apparatus according to claim 12 wherein said self-sealing means comprises a resilient seal radially disposed interior of the other end of said tube, said seal having a nominal outer diameter greater than the inner diameter of said tube.