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Welter

[11] **3,927,321**

[45] **Dec. 16, 1975**

[54] **ELECTRON MICROSCOPE BEAM TUBE**

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[73] Assignee: **American Optical Corporation,**
Southbridge, Mass.

[22] Filed: **Apr. 24, 1974**

[21] Appl. No.: **463,630**

[52] **U.S. Cl.** .... **250/311;** 250/396; 315/382; 315/31 R

[51] **Int. Cl.**^{2} **H01J 37/26**

[58] **Field of Search** ..... 315/31 TV, 31 R, 364, 382; 250/310, 311, 396

[56] **References Cited**

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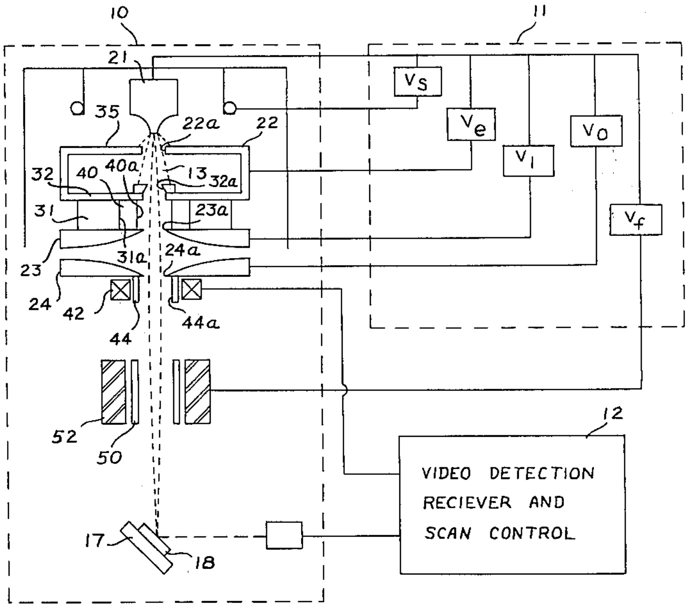
2,234,281	3/1941	Ruska	250/311
3,206,635	9/1965	Phillips	315/31 R
3,223,837	12/1965	Shapiro et al.	250/310
3,760,383	9/1973	Wolfe	315/31 R

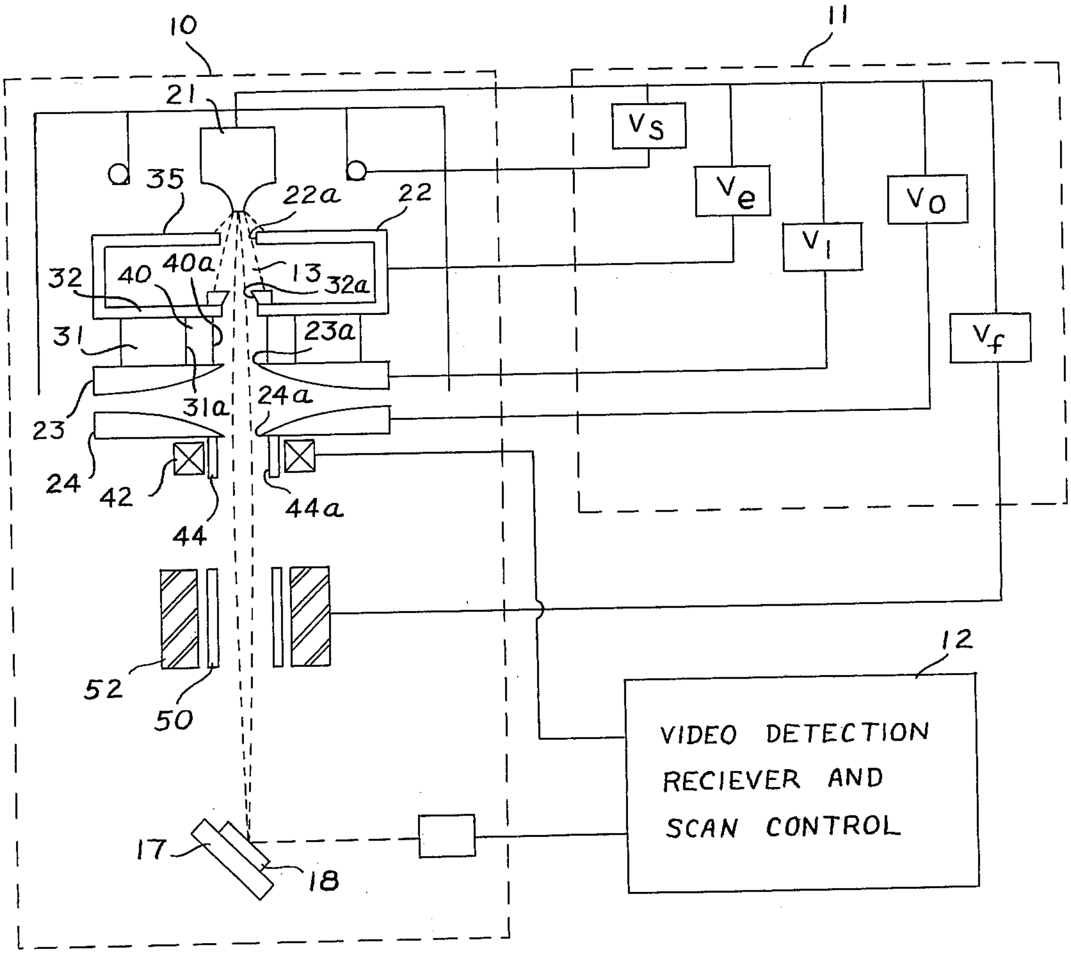
Primary Examiner—T. H. Tubbesing
Attorney, Agent, or Firm—H. R. Berkenstock, Jr.; W. C. Nealon

[57] **ABSTRACT**

In a charged particle microprobe system having, for example, a housing defining a vacuum chamber, a source of charged particles such as a field emission tip disposed in the chamber for generating charged particles, means for establishing focusing and accelerating fields for forming a beam of said charged particles and including means for either deflecting said beam according to a predetermined program whereby the beam may scan a specimen to be examined or including additional means for focusing the beam, inclusion of an apertured conductive glass cylinder spaced about the charged particle beam path as a non-chargeable, field-free means for maintaining a vacuum chamber around said beam in the region of said deflection coils or magnetic focusing coils.

4 Claims, 5 Drawing Figures

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11
21
Vs
Ve
VO
V1
Vf
35
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32
40
40a
13
32a
31
23a
23
31a
24a
24
42
44
44a
52
50
12
VIDEO DETECTION RECIEVER AND SCAN CONTROL
17
18

FIG. 1

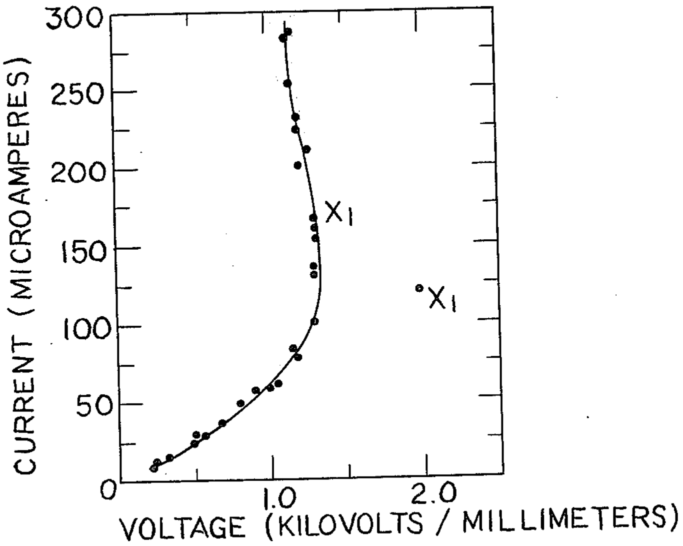
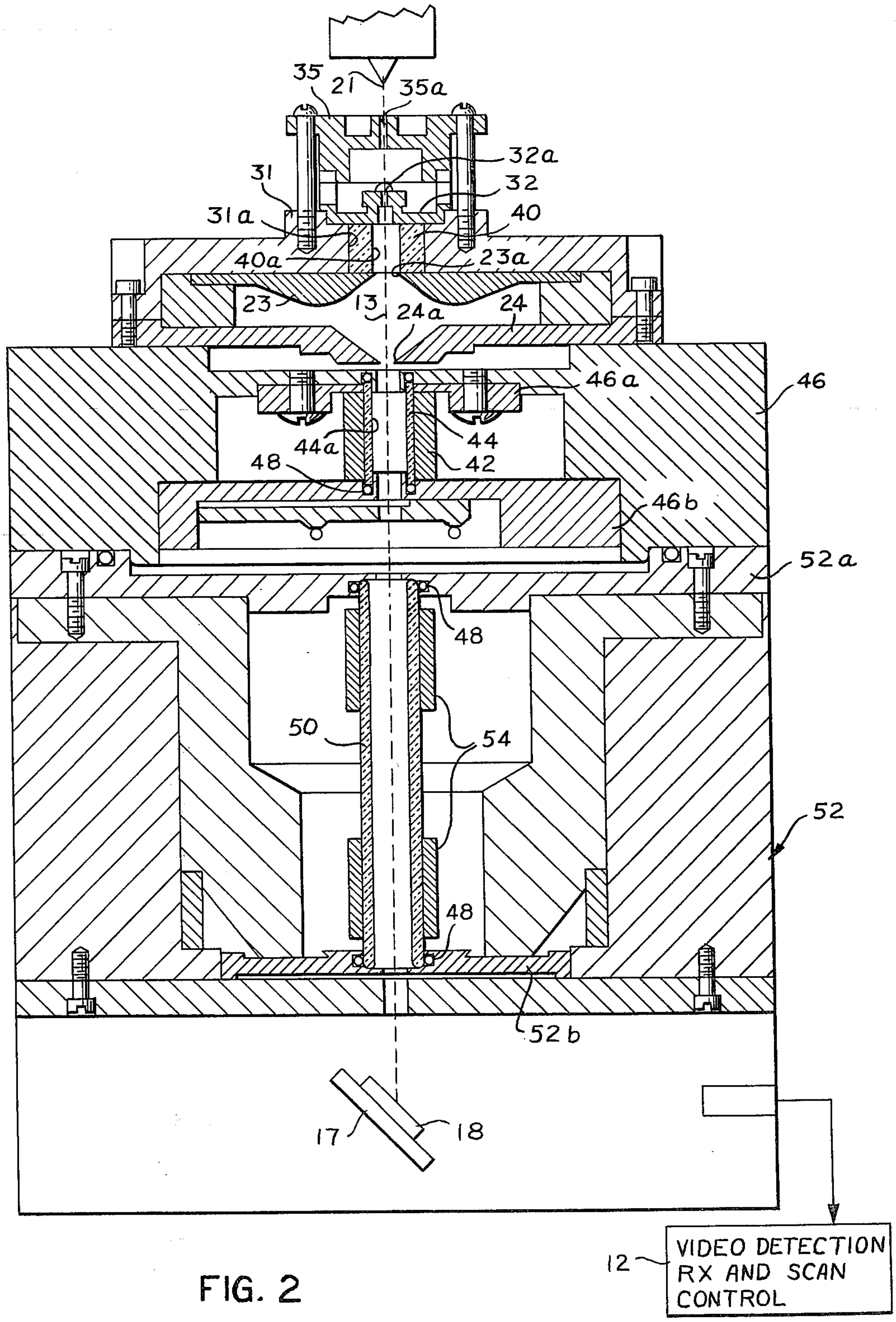

CURRENT (MICROAMPERES)
300
250
200
150
100
50
0
1.0
2.0
VOLTAGE (KILOVOLTS / MILLIMETERS)
X1
X1

FIG. 5


35
21
35a
32a
32
31
31a
40
40a
23a
23
13
24a
24
46a
46
44a
44
48
42
46b
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48
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54
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52b
17
18
12
VIDEO DETECTION RX AND SCAN CONTROL

FIG. 2

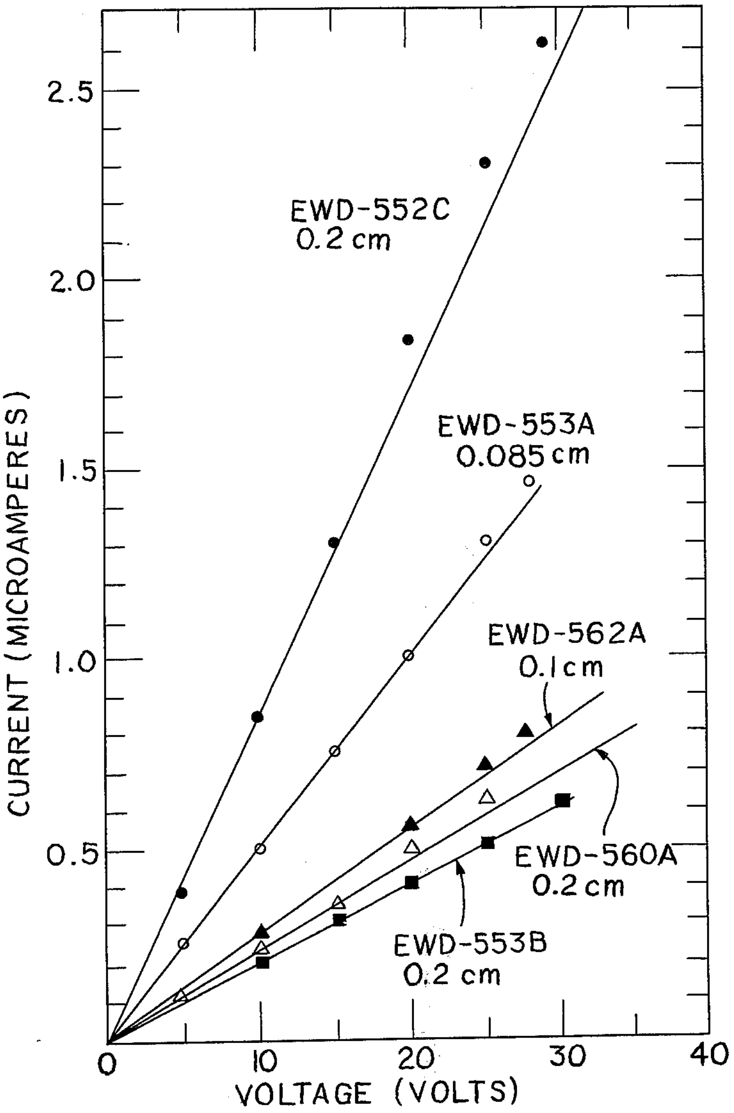
2.5
2.0
1.5
1.0
0.5
CURRENT (MICROAMPERES)
0
10
20
30
40
VOLTAGE (VOLTS)
EWD-552C
0.2 cm
EWD-553A
0.085 cm
EWD-562A
0.1 cm
EWD-560A
0.2 cm
EWD-553B
0.2 cm

FIG. 3

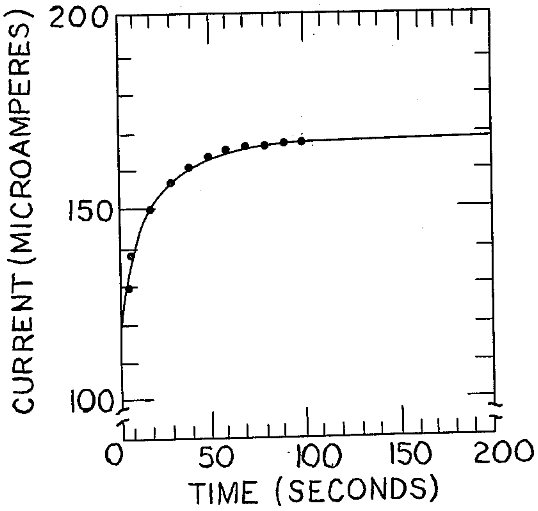
200
150
100
CURRENT (MICROAMPERES)
0
50
100
150
200
TIME (SECONDS)

FIG. 4

ELECTRON MICROSCOPE BEAM TUBE

BACKGROUND OF THE INVENTION

The present invention relates generally to charged particle microprobe systems and the preferred embodiment illustrated relates to a field emission electron optical system as embodied in a scanning electron microscope. By definition herein, references to an electron optical system and a field emission electron optical system shall not be limited solely to those systems wherein charged particles form an electron beam. Rather, reference generally by such terms shall include those systems wherein the emitted charged particles are ions.

As examples of field emission electron optical systems in which the present invention is useful, reference is made to U.S. Pat. Nos. 3,678,333, 3,766,427, 3,767,926, and 3,784,815 as well as application Ser. No. 225,970, filed Feb. 14, 1972 (being a continuation-in-part application of U.S. Pat. No. 3,678,333), all of the previously mentioned patents and application being commonly assigned to the assignee of the present invention. The electron optical system described in the aforementioned references includes disclosures of systems including a field emission tip for generating charged particles; electrode means for establishing an electrostatic focusing and accelerating field for forming the charged particles into a beam (often referred to as a first and a second anode); a field electrode for establishing an electrostatic field for extracting the charged particles from the field emission tip (often referred to as an extraction electrode or an intermediate electrode, since it is principally disposed intermediate the tip and the first anode); and voltage supply means connected to the tip and the focusing and accelerating electrode means and the field electrode to supply electrical potential between the named elements to establish the requisite operating electric fields.

One of the common objectives of the aforementioned inventions is the protection of the electron beam formed from influences external to the operating structural elements of the microprobe system.

In scanning charged particle microprobes, deflection coils are provided for causing the particle beam to scan a specimen to be examined. These deflection coils are usually magnetic devices producing a magnetic flux by the coil at right angles to the mean path of the electron beam. The action of the magnetic flux as it is generated and allowed to collapse causes the electron beam to be deflected back and forth in a predetermined path. The inclusion of second coil means operative at right angles to the flux produced by the first coil allows deflection in both x and y directions and thus with properly correlated signals can cause the beam to scan, in a regular manner, the surface of the specimen to be examined in a manner much similar to the scan of an electron beam of a cathode ray tube.

When the scanning charged particle microprobe system is a field emission device such as disclosed and described in detail in the references cited above, ultrahigh vacuums are maintained within the vacuum housing wherein the charged particle beam is generated. In keeping with the practice in charged particle microscopy, the specimen chamber which is usually located immediately below the electron gun chamber is usually also maintained in a relatively high vacuum though not necessarily to quite the degree of the field emission producing vacuum electron gun chamber.

It is the usual practice to employ a cylindrical tube to close the vacuum area between the electron gun chamber and the specimen chamber in the region usually occupied by the deflection coils and the focusing coils of the charged particle microprobe system. By such means, these coils may be disposed externally of the vacuum chamber and around these cylindrical tubes. As previously mentioned, care must be taken to insure, in these regions where the electron beam is manipulated, that all external unwanted electrical influences be shielded from the beam. It is usual that the cylindrical tube be positioned around the beam and disposed intermediate the vacuum chamber of the charged particle producing chamber (electron gun) and the specimen chamber and function also as a shielding device. This shielding tube is thus positioned between the deflection or focusing coil and the electron beam path and prevents the coil from being impinged upon by stray electrons. This structural arrangement also further shields the beam from external electrical influences which may exist around the coil. It has been past practice that these shields be made from materials which are recognized as very good insulators or, in the alternative, very good conductors, depending upon the place installation and the influence to be exerted by the surrounding coil.

Problems which have occurred in the past as a result of the conventional materials employed as the particular construction of such shield have included the following description. In the instances where a very good insulating material is employed as an electron tube, the stray electrons which impinge upon the shield from the beam tend to cause the shielding tube to become electrically charged. A localized electron charge may cause further uncontrolled deflection of the electron beam if the charge level builds to a significant value. Such uncontrolled deflection may cause astigmatism and possibly aberrations which can destroy the resolution of the microprobe system. If the charge is sufficient to deflect the beam and cause it to strike microscope structure, there may be further localized charging, and the generation of localized outgassing resulting in contamination of the electron column and/or specimen.

To overcome the above problems of insulating beam tubes, conducting materials have been employed on the tube, the tube being grounded to affect a drain or "bleed off" of any charge which might otherwise built up on the shield and tube. This switch of materials, however, introduces other problems in such installations where it is necessary to scan the beam or cause deflection thereof. In scanning electron microscopy, it is conventional practice to apply a high frequency (e.g. a 15.75 kilohertz) scanning signal to the deflection coils to cause the electron beam to scan at high speeds. This high frequency signal is also conventionally used in the scanning portion of television systems. In the case of the inclusion in the scanning electron microscope employing a conductive shield, a high frequency magnetic flux is produced in the tube. As a result, a high eddy current is introduced into the conductive shield, producing a high frequency magnetic flux which is then applied at right angles to the electron path. This unwanted high frequency flux interferes with the deflection field and the necessary control of the beam during the deflection scanning cycle.

As a result of the combined problems, the further progress of the art included the utilization of a shielding device which was substantially an insulating material of cylindrical tubular shapes upon which an electro-conducting coating was supplied. In theory, such a thin conductive coating over the interior surface of the shield provides the advantages recognized with both the prior art non-conductive and conductive shields. Since the interior of the shield is made conductive, the tendency of charge build-up in this region is minimized or eliminated (it tends to bleed off). Further, since the shield conductive coating is to be extremely thin, the bulk of conductive material is not present such that large eddy current producing fluxes are induced.

While this latest advance in the art suggests an operable shielding tube having the requisite operational characteristics, it has also introduced a commercially disadvantageous element of the system which is extremely expensive and difficult to produce. It must be realized that any coating which is to be applied to the shield must be quite uniform throughout the extent of the tube and further of a material which is non-magnetically influenced. The usual coatings are thus foils of gold, silver and aluminum. The tubes must necessarily be electro-conductively coated or sprayed in order to apply the requisite thin conductive coating. There is a problem, however, with such elongated items as cylindrical tubes in producing a uniform coating from one end through the internal portions of the tube to the opposite end. To provide the suggested coatings, very elaborate coating procedures had to be employed. These elaborate procedures plus the inherent expensive material which must be utilized have greatly increased the cost of the coated beam tube shield components.

It is an advantage of the present invention that a relatively low cost, easily produced element may be used. The present invention also provides a tube of uniform, homogeneous structure which provides the desired uniform electrical and physical properties.

SUMMARY OF THE INVENTION

In accordance with certain features of the invention, there is provided an improvement in the charged particle microprobes which conventionally include a housing defining a vacuum chamber, a source of charged particles disposed within the vacuum chamber, and various means such as electro-static or electro-magnetic coils for focusing and/or accelerating the charged particles into a beam as well as for deflecting the formed beam in a predetermined pattern such as a raster for examining a portion of a specimen. The present invention is specifically directed to improvements in shielding tubes which conventionally form part of the vacuum housing and about which the various means for focusing, accelerating or deflecting the beam are disposed. Applicant's improvement is directed to the inclusion of a cylindrical tube which is generally physically and electrically symmetrical about the longitudinal axis of the tube and wherein the tube is disposed within the microprobe system with its axis aligned with the beam. The tube is further in electrical contact with a voltage source (in the preferred embodiment maintained at ground potential) and the shield is formed of a non-magnetic yet conductive material having a substantially uniform cross-sectional conductivity and a predetermined value of resistance over its axial length. In a preferred embodiment, the tube is composed of a conductive glass providing a homogeneous element exhibiting the desired properties of a plurality of prior art devices; however, free of the disadvantages of these prior art devices.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic representation of a microprobe system including the present invention;

FIG. **2** is a partial cross-sectional view of a field emission microprobe including the present invention;

FIG. **3** is a graph showing current versus voltage for a number of semi-conductive glasses according to the present invention;

FIG. **4** is a graph of current versus time for an illustrative semi-conductive glass according to the present invention; and

FIG. **5** is a graph of the equilibrium current plotted against equilibrium voltage for a semi-conductive glass according to the present invention.

DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

Referring now to the drawings and specifically to FIG. **1**, reference numeral **10** indicates a scanning charged particle microprobe such as a field emission scanning electron microscope in which the present invention is illustrated. It is important to note that while the present disclosure speaks illustratively in terms of electron microscopes, it is quite feasible and practical that a preferred embodiment of the invention may be embodied in a variety of charged particle microprobes. To this extent, the source of particles could be of the thermionic or field emission type and productive of either electrons or positively charged ions.

In the present context, most of the voltages producing the extraction fields and the focusing and accelerating fields are illustrative of a field emission microprobe and will be opposite when describing an ion probe. It may be further necessary in the case of an ion probe that an ionizable gas be admitted to the vacuum chamber.

Ancillary to the scanning electron microscope illustrated, there is shown a potential source or voltage means **11** which provides the various levels of operating voltages to the electrodes of the scanning electron microscope **10** which is illustrated.

A second voltage supply unit, the video detection, receiver and scan control **12** supplies the functions to the related detection and scan control for scanning of the specimen by the electron beam **13** and display of the desired view the specimen undergoing interrogation.

In a field emission scanning electron microscope (SEM), the field emission tip constitutes a principal feature of the instrument. The tip **21** produces a highly coherent intensive beam **13** of electrons capable of being readily focused and imaged as a very small spot upon the surface of a specimen **18.** Specimen **18** is shown mounted on a specimen holder **17** which, in conjunction with structure not shown, but well known in the art, positions specimen **18** with respect to the focused beam **13** of charged particles (in the case of the illustrated field emission SEM are electrons). Extractional electrode **22** is disposed in juxtaposition to the field emission tip **21** and when impressed with a voltage from a source (Ve) causes the requisite electrical field to initiate field emission of electrons. Disposed downstream of the extraction electrode **22** are the main focusing and accelerating electrodes (23 and 24) of the field emission system. Electrode 23 serves as the first anode in the SEM and is often maintained at a potential approximately equal to that of the extraction electrode by a voltage source (V_1 which may be a separate or common source to V_e). Operating in conjunction with first anode 23 is a second anode 24. Voltage source V_0 is connected to second anode 24 and applies the main accelerating voltage thereto. In the usual arrangement of the field emission SEM, second anode 24 is maintained generally at ground potential and tip 21 is maintained at a highly negative potential (such as –20KV). Electrode 22 and anode 23 are maintained negative from ground at approximately 13 to 19 kilovolts respectively depending upon the mode of operation of the field emission SEM. Thus, there exists between anode 23 and anode 24 the main focusing and accelerating field produced by relative different potentials upon these two electrodes.

Electrons (in the illustrated field emission SEM) are extracted from tip 21 in a beam 13 and pass through apertures 22*a*, 23*a* and 24*a* in electrodes 22 and anodes 23 and 24, respectively, to be finally focused upon specimen 18. In the embodiment of the SEM illustrated, extraction electrode 22 includes two main members 32 and 35 (See FIG. 2). Upper member 35 is disposed in juxtaposition to field emission tip 21 and includes a wide angle aperture 35*a* centrally aligned with apertures 23*a* and 24*a*. Lower member 32 is disposed below member 35 and in relatively close position to anode 23. Lower member 32 includes a centrally located aperture 32*a* also aligned with apertures 23*a* and 24*a* as well as aperture 35*a*. As explained in copending application Ser. No. 225,970, aperture 32*a* is of a substantially smaller diameter and serves to define the size of beam 13 which is focused on specimen 18. One of the many purposes of this defining aperture is to minimize the opportunity of beam 13 impinging upon SEM elements downstream.

Continuing with the description of the apparatus as illustrated in FIG. 2, bulk resistor 40 is disposed intermediate lower extraction electrode member 32 and first anode 23. Resistor 40 is geometrically symmetrical about an axis coincident with electron beam 13 and has physical properties of material stability under high vacuum and when bombarded with charged corpuscular particles. Resistor 40 includes an axial centrally aligned aperture 40*a* which is aligned with apertures 22*a*, 23*a*, and 24*a*. Resistor 40 is conveniently disposed in insulator 31 in axial bore 31*a* also generally centrally located therein. Located generally downstream of anodes 23 and 24 is the section of scanning electron microscope which includes the deflection coils 42 which raster the electron beam 13 in the manner previously described. Deflection coils 42 generally surround a beam tube 44 and illustrate one embodiment of the invention herein described.

As shown in greater detail in FIG. 2, beam tube 44 is located physically in the deflection section 46 of the scanning electron microscope and forms the isolating member between the high vacuum portion of the electron microscope and the exterior accessory equipment (such as the deflection coils 42). Beam tube 44 is generally cylindrical in shape and composed of a conductive glass material which is disclosed in patent application Ser. No. 463,628 being filed in the name of E. W. Deeg et al concurrently herewith. Beam tube 44 includes an axial centrally aligned aperture 44*a* aligned with apertures 22*a*, 23*a*, 24*a*, and 40*a*. Beam tube 44 is disposed within the deflection section 46 in conjunction with means 48 such as O-rings for forming a seal between the aperture portion 44*a* of beam tube 44 and the area generally external thereto such as that including deflection coils 42.

As described in the aforementioned patent application Ser. No. 463,628, the resistance of the conductive glass of which the beam tube 44 is made is proportional to the length of the current path which, in the present embodiment, is generally parallel to beam 13 being the path between upper retaining member 46*a* of the deflection section and the lower retaining member 46*b* of the deflection section, and inversely proportional to the cross-sectional area of the current path. In the illustrated embodiment in the scanning electron microscope, the preferred value of resistance is in the range of approximately 10^3 to 10^9 ohms. This value has been found effective to allow the "bleed off" of any charge which might otherwise build upon the beam tube 44, either from the effects of bombardment of the tube by electron beam 13 or by the induced voltage from deflection coils 42. In accordance with the invention, it is desirable that the beam tube be grounded at one or more points throughout its length to insure an adequate path for the "bleed off" of any charge which might otherwise tend to build on beam tube 44. Accordingly, it may be convenient to provide such a grounding contact through O-rings 48, since these, in order to provide an adequate seal for the open high vacuums within the aperture 44*a* are in intimate contact with the conductive material of beam tube 44.

In the embodiment illustrated, beam tube 44 is a bored cylinder having a radius 0.7 cm, a length 2 cm and an internal bore of radius 0.5 cm. The particular glass composition chosen was EWD 553 as disclosed in the aforementioned application being filed concurrently herewith. This particular sample was chosen over the others disclosed because of its characteristics (conductivity, etc.) with respect to the physical preferences of the intended use. It should be pointed out that other conductive glasses such as disclosed in the abovementioned patent application may exhibit more favorable properties for a different embodiment (either in scanning electron microscope or an ion probe) which cause different relative physical or electrical properties related to such as size, or voltage and resistance values. In connection herewith, an additional embodiment of the invention is illustrated including the combination of a conductive glass beam tube 50, hereinafter described, which is disposed in a magnetic lens section 52 of a scanning electron microscope.

Beam tube 50 is also a cylindrically shaped structure, similar to tube 42, having an outer radius of about 0.7 cm, an inner bore of about 0.5 cm and a length of about 5 cm. Tube 50 is disposed in upper plate 52*a* and lower plate 52*b* in deflection section 52 in vacuum-sealed relationship, such as with "O-rings" 48. Magnetic focusing coils 54 are disposed around the outer circumference of tube 50, being electrically connected to a focusing control (not shown). Tube 50 is electrically connected to grounding means, as through O-rings 48 and plates 52*a* and 52*b* to the main frame of the electron probe to enable any electrical charge which might otherwise build locally on tube 50 to be bled off.

Tube 50, preferably of a conducting glass such as EWD 553 selected from the group of glasses disclosed by E. W. Deeg et al in Pat. application Ser. No.

463,628, filed concurrently herewith, exhibits the desired homogeniety and uniformity so as to preserve the desired electrical symmetry of a charged particle microprobe. Further, while the material is of generally low conductivity (exhibiting the desired properties of an insulator), it is sufficiently conductive as to prevent the build-up of an electrical charge. Since the electrical characteristics exhibited are that it is non-metallic, eddy currents are not induced which disturb the necessary influence of focusing coils **54.**

The present combination of a conductive glass beam tube disposed either in the deflection section or magnetic lens section exhibits a variety of advantages. Since the beam tubes **44** and **50** are formed of a homogeneous material, this integral element of homogeneous conductive material of the glasses described in the aforementioned patent application, an aspect of overall physical symmetry and homogeneity is attained when the particular beam tubes are included in combination with the scanning charged particle microprobe system.

The included tubes **44** and **50** contribute to the overall symmetry of the electrical characteristics of the microprobe. Uniformity of thickness and length and the homogeneity of the entire material allow the desired electrical properties to be achieved over the full extent of the beam tubes. By controlling these physical properties, the overall symmetry of the environment to which the electron beam **13** is subjected throughout the traverse of the beam through the tubes **44** and **50** can thus be maintained. Further, since the physical properties of the tubes **44** and **50** are uniform throughout, any externally caused influence, such as by coils **42,** will be uniformly received when imposed upon the tubes **44** and **50.** Since the tubes **44** and **50** are likewise uniformly conductive, this external influence may be immediately and uniformly removed. Therefore, the electrical symmetry of the environment of electron beam **13** is continually maintained. Such symmetry becomes increasingly more important as operating voltage and current values of the instrument and/or the beam are increased to provide more versatile microprobes of high resolution. Non-symmetrical elements in the column can induce electrical interference with the flow of electron beam **13** by deviation of some or many of the charged particles causing such as astigmatism, aberration, etc. All of the reasons for such disturbance are not known. However, localized charged ionization field effects are frequencly cited as causes.

While it is contemplated that other materials having the electrical and physical properties found favorable in the foregoing description would be usable for the tubes **42** and **50,** the materials described below constitute a preferred embodiment of the invention.

Glass compositions which are considered to be most favorable in the present invention include those consisting essentially of about 25 to 35 wt.% of V_2O_5, about 35 to 45 wt.% of MoO_3, about 10 to 20 wt.% of P_2O_5, up to about 15 wt.% of BaO, up to about 5 wt.% of Al_2O_3, up to about 10 wt.% Fe_3O_4, up to about 2 wt.% of CaO and up to about 4 wt.% of Co_3O_4. The total of the V_2O_5 plus MoO_3 plus P_2O_5 is equal to about 70 to 90 wt.% of the total glass composition. Generally, the glass compositions will have:

A. About 70 to 90 wt. percent of three essential ingredients consisting of about 27 to 50 wt.% of V_2O_5, about 38 to 65 wt.% of MoO_3, and about 11 to 29 wt.% of P_2O_5;

B. About 2 to 10 wt.% of at least one oxide selected from the group consisting of Fe_3O_4 and Co_3O_4; and

C. About 3 to 20 wt.% of at least one oxide selected from the group consisting of BaO, Al_2O_3, and CaO.

The method of making such glass is described in the application being filed concurrently with this application.

The composition of such other glasses according to the present invention are given below in Table 1.

TABLE 1

R_mO_n	EWD-553 (wt.%)	EWD-552 (wt.%)	EWD-559 (wt.%)	EWD-560 (wt.%)	EWD-562 (wt.%)
V_2O_5	29.00	28.00	32.00	29.00	30.85
MoO_3	37.00	37.00	41.00	37.00	39.36
BaO	8.00	12.98	—	12.00	8.51
Al_2O_3	—	0.58	3.86	—	—
P_2O_5	16.00	14.44	16.14	15.00	17.02
Fe_3O_4	6.00	7.00	7.00	6.00	—
CaO	1.00	—	—	1.00	1.07
Co_3O_4	3.00	—	—	—	3.19

Flat samples for electrical conductivity measurements have been taken from one end of test bars with the plane of the flat faces perpendicular to the long dimension of the bars, the experimental samples being from approximately 0.075 cm to 0.20 cm. in thickness.

For studies of the temperature dependence of the electrical conductivity of the samples, a sample holder, for both the glass specimen and a test circuit, may be placed in a vacuum oven and stabilized to equilibrium at the desired temperature. The conductivity of the sample at that temperature may then be measured. Measurements of conductivity have been made at a number of temperatures over the range of 24°C to 104°C.

Measurements of the electrical conductivity of the samples at low pressure have been made with the sample disposed where the pressure is about 3.5×10^{-5} Torr, such as a bell jar in a vacuum system.

Additional electrical conductivity measurements have been made on annular samples having an inner diameter of about 0.6 cm, an outer diameter of 2.3 cm and a length of 1.1 cm. The electrical conductivity measurements were made at the low electrical field strengths. The methods of testing are disclosed in the aforementioned application being filed concurrently with this application.

The results of the electrical conductivity measurements at low electrical field strengths for the various samples of glass composition illustrated in Table 1 are shown in the graph of **FIG. 3.** The resistances which are calculated for each of the data points shown in **FIG. 3** are given in the Table 2 below. The values of the resistances are given in megohms.

TABLE 2

Composition	Sample Thickness (cm)	Voltage 5V	10V	15V	20V	25V	28V
EWD-552C	0.2	13.2	11.6	11.5	11.0	10.8	10.7
EWD-553A	0.085	20.8	20.0	20.0	20.0	19.2	19.2
EWD-553B	0.2	50.0	52.6	52.0	51.3	50.0	49.3
EWD-560A	0.2	48.0	45.0	44.0	41.0	40.0	—
EWD-562A	0.1	38.4	37.0	41.7	37.8	36.3	36.0

As seen from Table 2 and **FIG. 3**, the resistance property of the samples measured may be non-ohmic in nature. For certain samples such as the sample **EWD-553**, a relatively strong non-linearity in the resistance is observed with increasing voltage up to a threshoid voltage. With increasing voltage, the current is observed to increase by an amount greater than that which is predicted by Ohm's Law. Beyond a specific voltage, the current is observed to rise rapidly to an initial value and, thereafter, is observed to creep slowly up to a final equilibrium value.

The voltage current plot of sample **EWD-553A**, obtained at high electrical field strengths, is shown in **FIG. 5.** The data points correspond to the final equilibrium values observed. A strong non-linearity begins to occur at field strengths which the glass can hold off or sustain is about 13,000V/cm. The data points labelled x_1 and x_f in FIG. **5** correspond to the initial and final values, respectively, of the current and electric field strength for the data shown in FIG. **4.** The resistivities of the samples are calculated from the slopes of the straight lines in the current versus voltage plot shown in **FIG. 3,** in ambient air, at room temperature, and are listed below in Table 3.

TABLE 3

Composition	Resistivity (ohm.cm)	Thickness (cm)
552C	6.0×10^7	0.2
553A	2.5×10^8	0.085
553B	2.8×10^8	0.2
560A	2.2×10^8	0.2
562A	5.1×10^8	0.1

The resistivity of glass sample **EWD-553A**, as measured at a pressure of 3.5×10^{-5} Torr was found to be 2.2×10^8 ohm.cm at 5V DC. This value compares with the value 2.5×10^8 ohm.cm measured for the same sample in ambient air. The small difference observed may be due to measurement errors or differences in temperature of the sample at the time of measurement.

The results of the study of temperature dependence of the resistivity on sample **EWD-553A** are summarized in the aforementioned application.

The resistivities of all the glasses tested are found to be within the range expected for the microprobe application. For the samples of formula **EWD-552,** it is found that the electrical puncture voltage for a **1** mm thick sample was 1.6 kV for several minutes at the voltage. Whereas, a 0.085 centimeter thick specimen of **EWD-553** holds off the same voltage for several minutes. Therefore, **EWD-553** would seem to be advantageous for the application of a leakage resistor for an electron microscope. For this sample, a negative temperature coefficient of resistance of about −2.8%/° C at 25°C is found. In addition, it is found that the resistivity of the samples of formula **EWD-553** are described by the Arrhenius equation over the temperature range of from 22°C to 104°C.

$$P = P_o e^{E=/kT}$$

Where P is a resistivity, P_o is a constant, E* is a so-called activation energy for conduction, *k* is the Boltzmann factor. The activation energy for conduction, E*, is found to be about 0.5eV. The conduction mechanism may be considered to be ionic if 0.7 eV E* 2.4 eV and electronic if E* 0.7 eV. It seems apparent that the primary conduction mechanism in the semiconducting glasses is electronic.

It should be thus recognized that the advance of the present invention has remarkably improved the performance of field emission microprobes. It should also be noted that many embodiments of the present invention may be utilized in microprobes other than the specific embodiment disclosed, but still remaining within the full spirit and scope of the present invention.

Having described my invention, I claim:

1. In a charged particle microprobe system including a housing defining a vacuum chamber;

a source of charged particles disposed in said chamber;

apertured means disposed in said housing for establishing focusing and accelerating fields for forming a beam of said charged particles;

means for deflecting said beam in a predetermined raster pattern;

the improvement comprising a tube, being generally physically and electrically symmetrical about an axis, said tube being disposed in said microprobe with its axis substantially aligned with said beam and in electrical contact with a voltage source, said tube being formed of a non-magnetic material having a substantially uniform cross-sectional conductivity and a predetermined value of resistance of 10^3 to 10^9 ohms/cm over its axial length whereby said tube is electrically conductive yet free of high eddy currents.

2. The improvement of claim **1** wherein said cylindrical tube is formed of a conductive glass material.

3. The improvement of claim **1** wherein said cylinder is connected to a voltage source at ground potential.

4. The improvement according to claim **2** wherein said conductive glass material has a composition consisting essentially of about 70 to 90 weight percent of the essential ingredients V_2O_5, MoO_3, and P_2O_5;

the V_2O_5 being present in an amount ranging from 27.8 to 50 weight percent of the essential ingredients;

the MoO_3 being present in an amount ranging from 38.9 to 64.3 weight percent of the essential ingredients; and

the P_2O_5 being present in an amount ranging from 11.3 to 28.6 weight percent of the essential ingredients;

about 20 to 10 weight percent of at least one modifying oxide selected from the group consisting of Fe_3O_4 and Co_3O_4; and

about 3 to 20 weight percent of at least one modifying oxide selected from the group consisting of BaO, Al_2O_3, and CaO.

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