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[54] **HOT SUB-STAGE FOR A SCANNING ELECTRON MICROSCOPE**

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[51] **Int. Cl.²** **H01J 37/20**

[58] **Field of Search** 250/443, 439, 311, 306, 250/307, 309, 310

[56] **References Cited**

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[57] **ABSTRACT**

The present invention relates to a hot sub-stage for a scanning electron microscope characterized by a minimum heated mass, easy outgassing and capable of operation at temperatures in the vicinity of 2500°K. The hot sub-stage employs a boat for holding the sample, formed of a flexible, reflective, refractory conductive foil, through which heating current passes. The sample is enfolded in the boat and disposed so that image forming secondary electrons may pursue both rectilinear and curved paths from the sample through a thermionic electron suppression grid to the secondary electron collection means. This geometry provides excellent discrimination against unwanted thermionic electrons and yet minimizes velocity selection of the more energetic secondary electrons. Heater magnetic field neutralization for avoiding beam offset is also provided.

3 Claims, 3 Drawing Figures

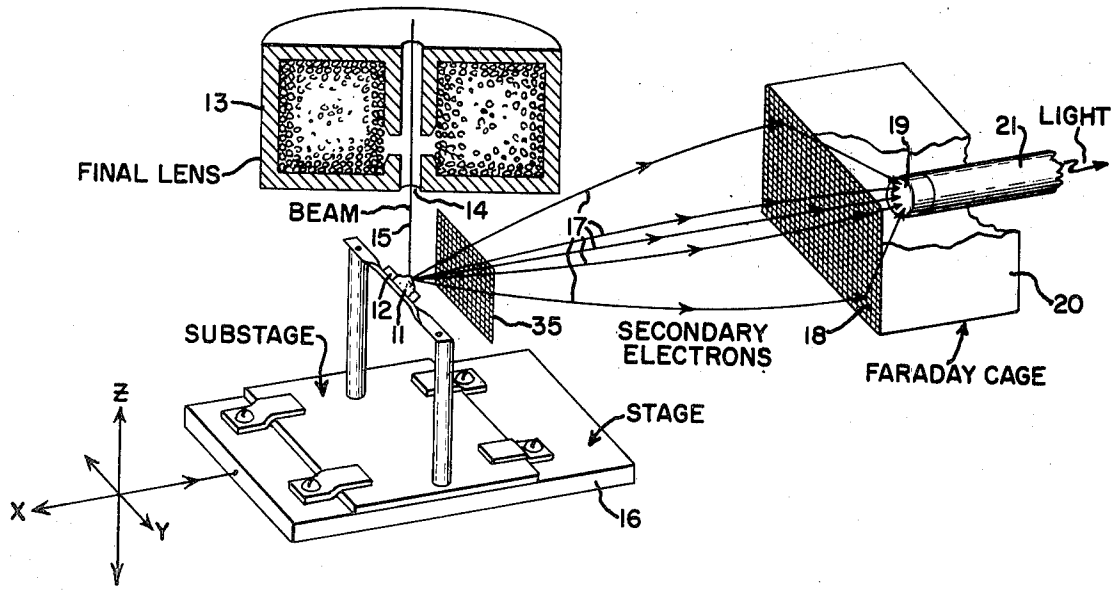
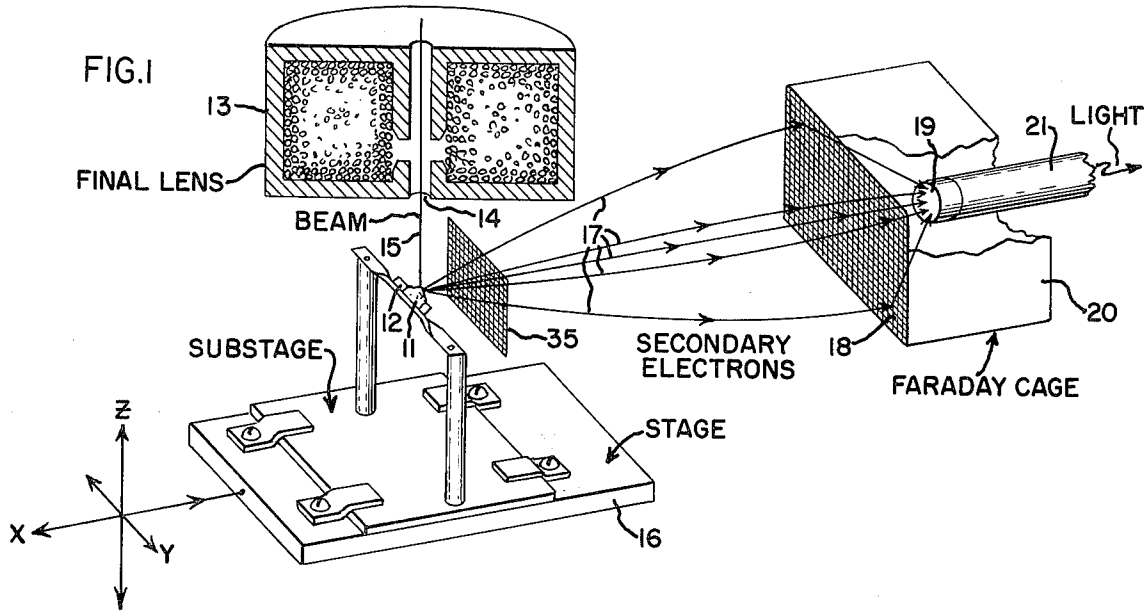


FIG.1



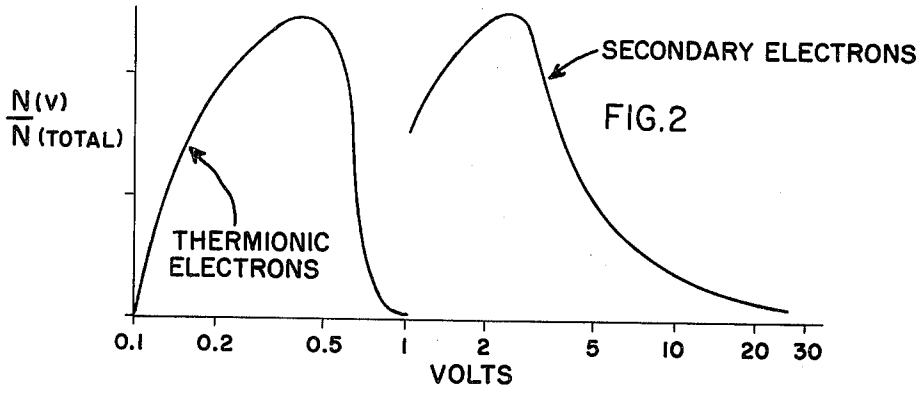
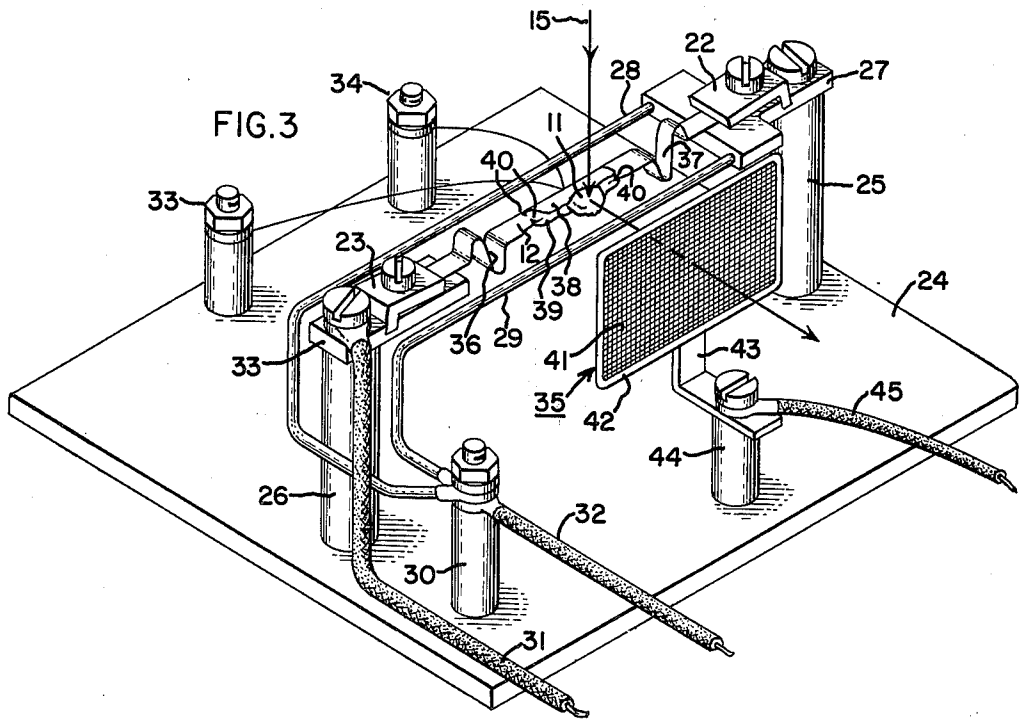


FIG.2

FIG.3



HOT SUB-STAGE FOR A SCANNING ELECTRON MICROSCOPE

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates to SEM electron microscope applications technology, and more particularly to the provision of a "hot-stage" for heating a sample in the microscope.

2. Description of the Prior Art:

The utility of hot stages for scanning electron microscopes has been known for some time. The objective of such stages is to permit elevation of the sample temperature to the point where significant physical or chemical changes takes place. In such applications, hot stages with 1100C upper limits are available, but there is a need for equipment capable of higher upper limits. One known experimental apparatus has been proposed for use at 1600C. Such a hot stage was described in a paper by R. M. Fulrath, entitled "Scanning Electron Microscopy to 1600C", presented at the Proceedings of the Fifth Annual Scanning Electron Microscope Symposium, IIT Research Institute, Chicago, Ill., April 1972, p. 17–24 (*Scanning Electron Microscope*/1972 *Part* I). In the paper it was recognized that at higher temperatures, thermionic electrons mixing with secondary electrons would degrade the quality of the image. To prevent this from occurring, a coarse grid was originally instituted and then abandoned in favor of an apertured plate. The sample, in the preferred Fulrath arrangement is installed in a small indirectly heated cup, covered by the apertured plate. Secondary electrons useful in forming the image thus must overcome any field that might occur at the mouth of the aperture, and then enter the electron collection field at right angle trajectories. While higher temperature operation than achieved by others was indicated, at the upper limits of the temperature range, picture quality was degraded. One might conclude that thermionic electrons were entering the collection field and/or that some loss of useful secondaries was taking place at the limiting temperatures.

The practice of using metal foil heaters for vacuum evaporation is known. Such metal foil heaters, sometimes called "boats", are described on pages 118 and 119 of VACUUM DEPOSITION OF THIN FILMS, L. Hollad, F.Inst.P., published by Chapman and Hall, Ltd., 1966.

SUMMARY OF THE INVENTION:

Accordingly, it is an object of the present invention to provide an improved hot sub-stage for a scanning electron microscope.

It is a further object of the present invention to provide a hot sub-stage capable of operating at higher temperatures than prior art devices.

It is still another object of the invention to provide a hot sub-stage wherein improved means are provided favoring the collection of all secondary electrons, including the more energetic ones, and discriminating against the unavoidably generated thermionic electrons.

It is still another object of the present invention to provide an improved hot sub-stage which is readily outgassed and capable of quickly reaching thermal equilibrium at elevated temperatures.

These and other objects of the present invention are achieved in a novel hot sub-stage for supporting and heating a sample in a scanning electron microscope. When such a microscope is used in the emission mode, an electron beam impinges on a sample and secondary electrons emitted from the beam impact area are collected for image formation, the collection means having a field for accelerating electrons from said impact region. In accordance with the invention, the hot sub-stage supports the sample in a position allowing secondary electrons emitted from the impact area to pursue both rectilinear and curved propagation paths to the collection means. The boat is formed of a flexible, reflective, refractory conductive foil, deformable to enclose the sample in a heat confining manner. Folding further avoids any interference with either the beam or the secondaries. The foil is further dimensioned such that its current conducting cross-sections electrically heat the sample. Terminal means are included to provide two-point electrical contact for heating and for mechanically supporting the boat. Thirdly, a conductive grid is provided arranged in close proximity to the boat, and embracing the propagation paths and oriented in a plane perpendicular thereto. The grid is provided with a potential adjusted with respect to the boat potential to prevent thermionically emitted electrons from penetrating the grid and entering the collection field while at the same time permitting secondary electrons, which have higher energies, to enter the collection field.

The suppression grid is formed of a fine mesh screen to prevent field penetration by the collection field into the region around the boat. A pair of conductors are provided paralleling the boat and connected to one of the electrical contact points for cancelling the magnetic fields over the sample resulting from heater current so as to reduce any beam offset.

BRIEF DESCRIPTION OF THE DRAWINGS:

The novel and distinctive features of the invention are set forth in the claims appended to the present application. The invention itself, however, together with further objects and advantages thereof may best be understood by reference to the following description and accompanying drawings, in which:

FIG. 1 is a simplified drawing of a sample disposed in a novel hot sub-stage within a scanning electron microscope. The drawing shows the path of the electron beam impinging on the sample and the paths of the secondary electrons emitted from the sample at the impact site and collected to form an image;

FIG. 2 is a graph of electron populations as a function of energy in volts. These populations include the desired secondary electrons collected to form the image and the thermionic electrons which result from heating the sample and whose collection interferes with image formation; and

FIG. 3 is a perspective drawing of a hot sub-stage in accordance with the invention for supporting and heating a sample in the microscope.

DESCRIPTION OF A PREFERRED EMBODIMENT:

The disposition of a sample in a scanning electron microscope is illustrated in FIG. 1. The sample is shown at 11, disposed in a small U-shaped foil boat 12 crimped about it and inclined to the right. The boat is a portion of a hot sub-stage which is shown in a simplified form in FIG. 1. The sample is disposed under the final lens 13,

through the aperture **14** of which the scanning beam **15** passes. The sample is supported by the sub-stage at a position of from 10 to 20 millimeters below the lens and about 1 inches above the platform of the stage **16.** The stage **16** provides X, Y and Z translations to be sub-stage for manipulating the sample in the electron beam.

The electron beam is demagnified to a minimum diameter and has an energy lying in a range of from 1 to 50 kilovolts. Upon passing through the lens aperture **14,** the beam strikes the sample II causing the emission of secondary electrons **17** from the impact site. When the scanning electron microscope is operated in its customary "emissive" mode, the secondary electrons are collected and their rate of generation forms an indication of the nature and configuration of the impact site.

The secondary electron collector is disposed to the right in FIG. **1.** It includes a secondary electron collection screen **18** having a relatively small electron attracting field (100 volts/inch), and a scintillator-photomultiplier-amplifier chain used to detect the secondary electrons collected by the screen. The screen **18** is typically **7.5** centimeters from the sample, 3 centimeters high by 5 centimeters across, and at a 300 volts potential with respect to the sample. The scinitillator **19** of the scintillator-photomultiplier-amplifier chain is installed within a Faraday cage **20** held at the same +300V potential as the screen **18.** The scintillator **19** is installed on the hemispherical end surface of a quartz rod **21** acting as a light pipe. The rod is typically about inch in diameter and 5 inches long and extends through the Faraday cage. The "scintillator" **20** comprises a thin layer of aluminum held at a high positive potential (normally in excess of +10 Kv) and supported over a thin layer of scintillator material. Secondary electrons attracted by the screen **18** and passing through its openings into the cage, are accelerated by the +10 Kv field toward the thin aluminum layer. The electrons are given sufficient energy by this field to penetrate the aluminum layer and to enter the scintillation layer. Upon entering the scintillation layer, the electrons retain adequate energy to create hole-electron pairs. Upon recombination, these hole-electron pairs create photons. The photons which are so created, pass down the light pipe to the photomultiplier (not shown), in which they create large numbers of electrons. The electron current is then amplified by the pre-amplifier and successive amplifiers to a level suitable for use in controlling the amplitude of a CRT beam in the SEM display.

When the electron beam is scanned over the sample, an image of the surface is formed. The deflection coils which are not shown, are normally installed in or above the final (objective) lens **13.** Scanning causes the beam to impact on successive portions of the sample and the customary pattern is a rectangular raster with the sweep lines adjacent to cover an area completely. Since the number of secondary electrons emitted varies according to sample topography and composition, the secondary electron emission levels form a point by point description of the surface. The resolution of detail in this surface description is limited by the size of the beam. It may be focused down to 150A in a typical microscope. The secondary emission current is applied to a synchronously scanned cathode ray tube which uses the information from the individual approximately beam sized points to form a composite image of the area being swept by the electron beam.

When it is desired to study samples at a high temperature, the sample is heated in a sub-stage installed in the microscope. Normally, the temperatures at which a material changes in state or exhibits second order phase changes are of greatest interest, and these temperatures are quite high. For such use it is desirable that the sub-stage operate in excess of 1000K and preferably well into the 2000K region. When the temperature of the heater and of any sample reach these elevated temperatures, thermionically emitted electrons are produced. If these thermionic electrons are collected with the secondary electrons which form the image, they create a background noise current which combines with the signal currents and reduces the contrast of the image or destroys it altogether.

FIG. **2** is a graph of energy distributions of secondary electrons and thermionic electrons. The ordinates of the curves are linearly plotted numbers of electrons as fractions of the total in all energy states, while the abscissas correspond to logarithmically plotted energy states in volts. (Thus, the graph in using standardized areas does not disclose the ratio of secondary to thermionically emitted electrons.) The secondary electrons, depending upon the material, have greatest populations in the vicinity of from 1 to 5 volts but a few have higher energies up to 30 or 40 volts. The lower energy portion of the secondary electron curve is generally uncertain and not readily plotted below 1 volt, but does fall rapidly in this region. With respect to thermionic electrons, the curve is temperature dependent. The energy distribution peaks in the range of from 0.4 to 0.6 volt in the temperature range of from 1000K to 2500K, and very few thermal electrons have energies exceeding of a volt. The total numbers of secondary electrons created vary as a function of beam current. Thermionic electrons are produced only after thermionic emission temperatures have been reached, normally at some point well below 1000K. As the temperature is further increased, the total numbers of thermionic electrons increase as a three halves power of the absolute temperature. If the sample has large emissive surfaces, it is not uncommon for the thermionic electrons to be many times more numerous than the secondary electrons. Assuming a beam current in the nanoampere range, and typical production ratios of secondary electrons, the production of secondaries may also be in the range of from several to a few tens of nanoamperes. On the other hand, the production of thermionic electrons for a relatively small metallic surface may be in the fractional milliampere or milliampere range. Thus, the thermionic electrons may be from 10^4 to 10^6 times as numerous as the secondary electrons. However, while the thermionic electrons may exceed the number of secondary electrons, thermionic electrons fall into lower energy levels than secondary electrons. This condition permits their separation from the secondary electrons and prevents them from interfering with image formation.

A hot sub-stage which discriminates against thermionically emitted electrons and which greatly improves the signal to noise ratio when samples are examined at an elevated temperature is shown in FIGS. **1** and **3.** The showing in FIG. **1** is simplified to show the disposition of the hot stage in the scanning electron microscope. The description will now proceed with primary reference to FIG. **3.**

The hot sub-stage is designed to heat a sample to temperatures in the vicinity of 2500K. The boat **12,**

which will be described in greater detail below, is supported at each end by two screw tightened clamps also acting as electrical connectors. The upper jaw **22** of the righthand clamp cooperates with a T-shaped conductive plate **27** forming the lower jaw of the clamp. The plate **27** also forms a connector for current return conductors **28, 29.** The plate **27** is threaded to receive the tightening screw of the clamp and is slotted to receive a small ridge on the back, undersurface of the upper jaw. When the small ridge in the upper jaw engages the slot in the lower jaw, it prevents relative rotation of the two jaws as the screw is tightened. The upper jaw **23** of the lefthand clamp similarly coacts with a lower jaw formed by a small rectangular conductive plate **33.** The plate **33** is threaded to receive the tightening screw of the clamp and is also slotted to prevent relative rotation between the jaws as the screw is tightened. Both the right and the lefthand clamps are supported upon the base plate **24** of the sub-stage by means of ceramic stand-off insulators **25** and **26.**

The conductors **28, 29,** which are supported at the two extremities of the "cross" of the T plate **27** carry oppositely directed heater current in adjacent paralled paths. The conductors **28, 29** lie in approximately the same plane as the bottom of the boat and extend to the left from the plate **27** in a direction generally parallel to the boat and in close proximity to it. The left extremities of the conductors **28, 29** pass adjacent the connector plate **33,** and are bent down to a stand-off insulator and terminal **30.** Heating current to the boat from an external source is provided through the conductors **31** and **32.** The conductor **31** leads to the connector plate **33** while the conductor **32** leads to the terminal **30** and paralleled conductors **28** and **29.** Assuming that current flows into the lead **31,** it will proceed into the lefthand clamp **23** from left to right through the boat **12** to the righthand clamp **22.** At clamp **22** the current path will now reverse and divide equally between conductors **28** and **29.** The divided currents will then continue from right to left to the terminal **30** where the conductors **28** and **29** are joined and the joint return current emerges from the lead **32.**

The above disposition of conductors and currents neutralizes the magnetic field over the boat and reduces beam offset. Currents in the boat and in the return conductors **28, 29** are accompanied by the customary encircling, circular magnetic fields. Above the boat, the circular field due to current in the boat is horizontal and will tend to displace the beam from its normal position in proportion to field strength. The deflection will be orthogonal to both the beam path and to the local field, i.e., generally parallel to the axis of the boat. The fields in the return conductors (**28,29**) are half as strong, since the return current is halved between them. Since the current directions are reversed in the return conductors, the circular fields rotate in an opposite direction to the field about the boat. When the field vectors of the return conductors **28, 29** are summed above the boat, their resultants are approximately horizontal and are approximately equal and opposite to the horizontal field due to current in the boat. This approximation becomes better as the distance above the boat increases. Thus, the magnitude of the field directly over the boat is largely cancelled and beam offset is largely eliminated. The lead **29** should be kept below the path of the secondaries emitted from the sample and proceeding toward the secondary electron collector. The positioning of the leads **28, 29** affects the accuracy of the compensation. Some adjustment may be required to provide an optimum correction. The heater currents are direct current to avoid a hum component and normally lie in the range of from 5 to 25 amperes.

A thermocouple is provided since sample temperature is important and since sample temperature cannot easily be observed optically in an SEM. The thermocouple is connected to the terminals **33, 34** and welded to the bottom of the boat **12.** The thermocouple may be of tungsten/tungsten 26% rhenium and is normally calibrated prior to use.

The boat **12** supports the sample, directly heats the sample (as current passes through it), and provides a reflective heat confining enclosure about the sample. The boat **12** is fabricated of a thin flexible foil of refractory, conductive metal such as rhenium. It is desirable for it to retain some resilience at high temperatures. Tantalum, tungsten and molybdenum are also suitable. In its initial form, the boat is in the form of a flat tape with two lateral extensions **38, 39** increasing the width at its mid-section. The two ends of the foil are then curved into S-shaped tabs (**36,37**). The boat is supported by these tabs by connector clamps **23, 22** with the S-shaped tabs under a slight tensile stress. When the temperature is elevated and the foil expands, the resilient take-up at **36, 37** absorbs any slack and reduces the tendency of the boat to rise or fall. This stabilizes the position of the sample in the beam.

The sample is supported in the boat by the two lateral extensions **38, 39.** These extensions are folded up so that a cross-section of the mid-section of the boat takes the form of a U-shaped channel prior to retaining the sample. The width of the sample should be comparable to the width of the channel. When the sample is placed in the channel, the vertical extensions are pressed about the sample to grasp it in a positive manner. This retains a hold on the sample even though the boat may be tipped to one side. The closing of the lateral extensions **38, 39** about the sample causes the foil to fit the sample rather closely and prevents these extensions from interfering either with the impinging electron beam or with the secondaries emitted from the beam impact region. Once the sample is installed in the boat, the boat may be tilted either by rotating the stage or by twisting the boat itself to improve the viewing conditions. This adjustment is designed to maximize secondary electron collection and to allow a clear rectilinear propagation path from the sample to the secondary electron collector.

The cross sections of the foil boat are dimensioned to concentrate the heat upon the sample. The foil is typically of 0.025 mm. rhenium. The width of the rhenium at the mid-section may be 4 mm., while that of the two S-shaped end tabs is 2 mm. The length of the mid-section is about 12 mm., while the end tabs may be from 15 to 35 mm. long. The spacing between the terminal clamps may be from 30 to 50 mm. The central portion of the boat is therefore of greatest total cross section (4 m. ¼ 0.25 mm.) due to the 1 mm. lateral extensions **38, 39.** Since this greater area reduces the I^2R dissipation in the mid-section, notches **40** are provided at both ends of these extensions. These notches reduce the current conducting cross section right at the ends of the extensions and concentrate the current and consequent heating effect at these two points. Since the distance between the notches is small, i.e., 12 mm ., the heating points are close enough so that heat conduction

through the foil and sample tends to equalize the sample temperature. The supporting S-shaped tabs, on the other hand, are relatively long and present a high thermal impedance. Thus, somewhat over half of the heat generated at the constrictions flows into the sample region and somewhat less than half flows toward the connector clamps. It may be desirable to form the boat from a tape of constant width. In that case, the central portion of the boat remains U-shaped, while the two S-shaped end tabs are formed by initially folding the 1 mm. extensions down flat. This doubles the thickness of the end tabs and reduces the electrical heat dissipation in the tabs fourfold.

A boat, which is formed in the above manner, may be used to carry currents of from 5 to 25 amperes. To reach a sample temperature of 1000C, a power input of approximately 23 watts is required. At 1900C, a typical power input of 43 watts is required. Rhenium has a melting point of 3180C, permitting one to raise the temperature to 2500C without adversely affecting the boat.

The boat acts as a heat confining enclosure having a very small heat capacity, permitting temperature equilibria at high temperatures to be achieved in a very short time. The thermocouple is welded to the boat so that it reads the boat temperature without appreciable delay. The foil, of which the boat is made, is selected to be a reflective, heat and electrically conductive material. It is sufficiently flexible to be folded into intimate contact about the sample without cracking. This enclosure thus forms a reflective barrier reflecting radiant heat back into the sample. At the same time, the intimate surface contact allows thermal conduction through the foil to equalize the temperature over the surface of the sample. Thus, the sample tends to be evenly heated and to quickly assume the temperature of the foil, and the foil temperature is immediately sensed by the thermocouple. The thermal inertia of the heater and its contents are very small, while that of the thermocouple is negligible. The foil boat, which is the principal mass of the heater has a mass of approximately 25 milligrams (assuming rhenium) and the sample is normally of comparable or less thermal capacity. This very small thermal capacity, where up to 40 watts of electrical power is available, permits the temperature to be very quickly raised, stabilized in a sample, and accurately measured.

As previously noted, when the temperature of a material is elevated to a high temperature, thermionic electrons are produced which tend to be collected along with the secondary electrons containing the image information. When this occurs, the quality of the image may be substantially deteriorated or destroyed. The grid **35** illustrated in FIGS. **1** and **3** is provided to prevent the thermionic electrons from reaching the secondary electron collection means.

The grid **35** is arranged adjacent the sample at a distance of from 3 to 5 mm. The field neutralizing conductor **29** lies between the grid and the boat **12,** and the grid is arranged in close proximity to (1 mm.) but not touching the conductor **29.** (For clarity in illustrating what lies behind the grid, the grid separations from the adjacent parts has been exaggerated in the figures.) The frame **42** of the grid is 25 ¼ 35 mm. and arranged so as to lie in a plane perpendincular to a line connecting the sample with the center of the electron collection screen **18.** The frame of the gird is also approximately centered upon this line. The grid uses a fine (90 lines per inch), etched screen **41** of 0.025 mm. nickel. The screen **41** is flat and open (70% transparent) to avoid temperature elevation. The frame **42** of the grid, to which the nickel screen is spot welded, is formed of 0.5 mm. nickel wire. The frame is then attached to a supporting bracket **43.** The bracket **43** is mounted to the base **24** of the sub-stage by a ceramic stand-off insulator **44.** Electrical connections to the grid are provided by means of the lead **45** connected to a bracket mounting screw on the stand-off insulator **44.**

The grid **35** is designed to discriminate against the low velocity thermionic electrons and to permit the passage of the higher energy secondary electrons used to form the image. The grid **35** is made large enough to intercept the trajectories of all electrons including both secondary and thermionic electrons emitted from the sample and from the boat and arriving at the electron collection screen. The grid **25** is provided with a negative bias with respect to the boat which can be varied from a fraction of a volt to several volts. This prevents the collection of any electrons which have less than the amount of energy required to surmount the barrier. Since almost all thermionic electrons have less than 7/10 of a volt of energy, and since the secondary electrons have energies several times higher, with average values between 1 and 5 volts, the potential barrier will sharply discriminate against thermal electrons and favor secondary electrons.

The grid voltage is normally adjusted by viewing the display and maximizing the signal contrast. Thus, a grid voltage is selected at which most of the secondary electrons are passed and substantially all of the thermal electrons rejected. The optimum visual setting corresponds to the maximum signal to noise ratio.

The use of a fine mesh screen in the grid **35** prevents the collection field from penetrating the grid and thus nullifying the suppression field near the surface of the grid. Due to the field screening effect, the region between the suppression grid and the boat is nearly field free except for the weak suppression field. Thus, the collection of electrons emitted becomes dependent on their initial velocities, the repelling field at the surface of the grid, and any space charge that may have developed when thermionic emission has become severe. As conditions change, therefore, the repelling field is readjusted to take into account all three variables and to maximize the signal to noise ratio. Strict field control requires that the potential of the grid be referenced to the boat potential, which is held close to ground potential.

The suppression grid is arranged in a line between the sample and the collection grid to facilitate collection of secondary electrons having the greatest range of energies. This objective is important since additional surface information, very useful in enriching the image, is produced by each energy range of secondary electrons. If a barrier is opposed forcing a curvature of all electron trajectories upon entering the electron collection field, an energy selective effect will occur. If the collector embraces a finite solid angle and the deflection is appreciable, as for instance 90, the more energetic secondary electrons, i.e., those in the 20 to 40 volt region, will bend insufficiently to be collected by such a collector. If on the other hand, a direct linear path is provided, and the sample, though having appreciable surface roughness, is given a generally favorable surface inclination, then the greatest number of high energy electrons will be collected. Normally, a few which are,

emitted at oblique angles to the surface (i.e. orthogonal to the collection field) will have a sufficient velocity to escape the margins of the collector, but the majority will be projected in close enough alignment with the collection field to be collected. Thus, in providing a direct linear path between the sample, the suppression grid, and the collection grid, discrimination against collection of the higher energy secondary electrons is minimized, and the loss of certain types of surface information is minimized.

Heat dissipation from the boat of the hot stage is dissipated without serious thermal side effects within the SEM. (As with all hot stages, some material contamination of the SEM interior will occur.) Because of the massive nature of the metal structures making up the SEM interior, any normal dissipation in the hot stage is dissipated without any appreciable elevation of interior temperature. Thermal conduction to adjacent parts such as the field neutralizing conductors **28, 29** or the electron suppression grid **35** is low and each of these parts are connected by substantial thermal conduction paths to the base **24** of the sub-stage. The base of the sub-stage is intimately fastened to the massive interior surface of the scanning electron microscope which provides an excellent "heat sink" to the assemblage. The radiation coupling between the hot stage and the surrounding metal parts will be appreciable but due to the forementioned heat sinking and due to the openness of the screen **35,** none of these parts will reach thermionic emission temperatures and so any effect upon image quality is precluded. Heat radiation shields are unnecessary within the SEM except in the region of instrumentation. The open structure and low mass of the heated parts in the present hot stage have the advantage of permitting more rapid outgassing than more massive, heat baffled, indirectly heated structures.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A hot sub-stage for supporting and heating a sample in a scanning electron microscope wherein an electron beam impinges on a sample and secondary electrons emitted from the beam impact area are collected for image formation, the collection means having a field for accelerating electrons from said impact region, said hot-stage comprising:

a boat for supporting and heating said sample in a position allowing secondary electrons emitted from said impact area to pursue both rectilinear and curved propagation paths to said collection means, said boat being formed of a flexible, reflective, refractory, conductive foil, deformable to enclose said sample in a heat confining manner while avoiding interference with said beam or said propagation paths, said foil having current conducting cross-sections selected for electrically heating said sample,

terminal means arranged to provide two point electrical contact for heating and mechanically supporting said boat, and

a conductive grid in close proximity to said boat, embracing said propagation paths and oriented in a plane perpendicular thereto, said grid having a potential in respect to said boat which is selected to prevent thermionically emitted electrons from penetrating said grid and entering said collection field while permitting secondary electrons to enter said collection field.

2. A hot sub-stage as set forth in claim **1** wherein said grid is of a fine mesh to prevent field penetration by said collection field.

3. A hot sub-stage as set forth in claim **1** wherein a pair of conductors are provided paralleling said boat and connected to one of said electrical contact points for canceling the electromagnetic fields over said sample resulting from heater current and thereby reducing the amount of beam deflection.

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