United States Patent [19]

Tanaka

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[54] **THERMAL EMISSION TYPE ELECTRON GUN**

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Aug. 8, 1972 Japan 47-83891

[52] **U.S. Cl.** .... **315/31 R;** 313/447

[51] **Int. Cl.** **H01j 29/70**

[58] **Field of Search** .... 315/13 CG, 31 R; 313/83 R, 313/DIG.1, DIG. 2, DIG. 3

[56] **References Cited**

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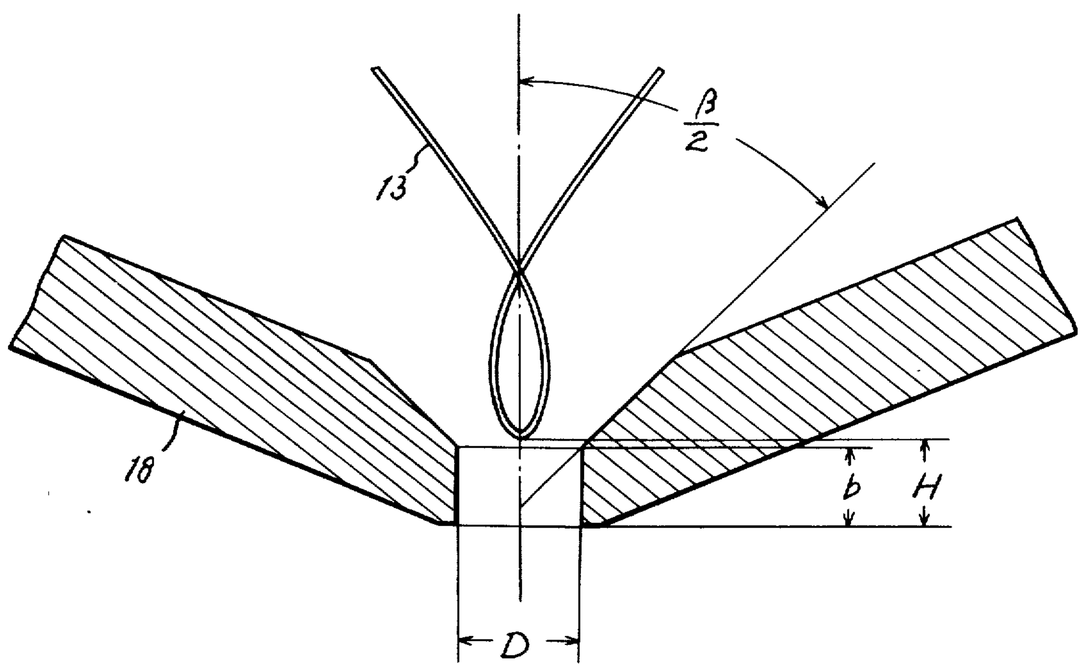
[57] **ABSTRACT**

A thermal emisssion type electron gun of improved design embodying an improved Wehnelt electrode and an improved filament arrangement with respect to the Wehnelt electrode thereby ensuring the generation of an electron beam having a high degree of parallelism, high density and uniformity.

3 Claims, 7 Drawing Figures



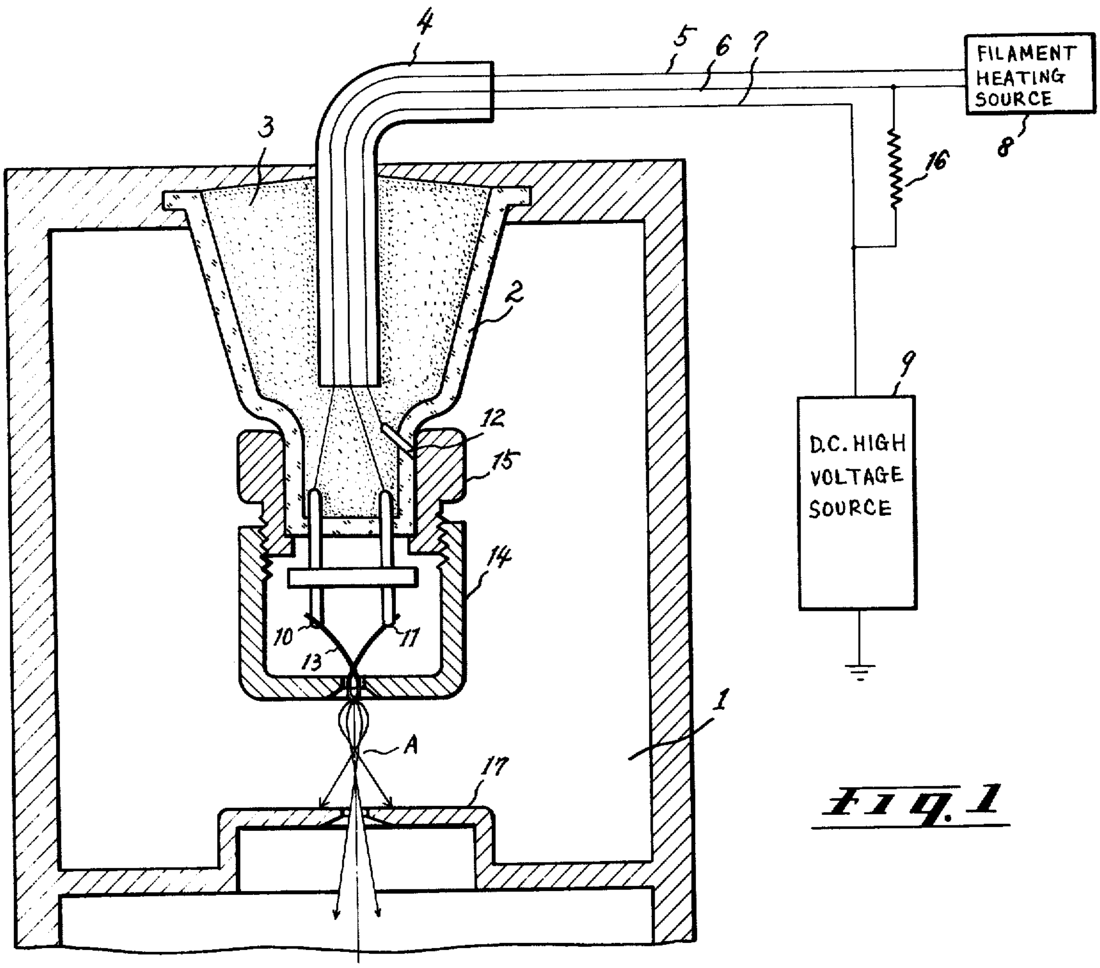


Fig. 1

PRIOR ART

Fig. 2

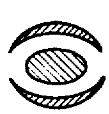


Fig. 6

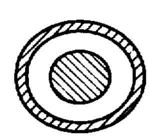


Fig. 3

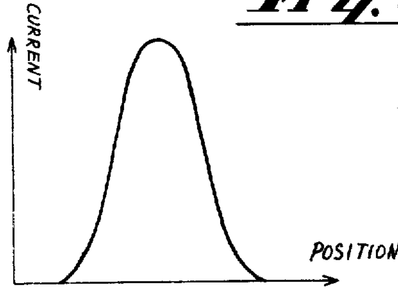
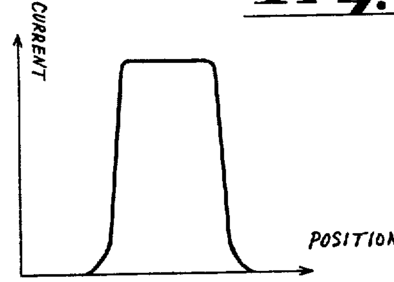


Fig. 7



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SHEET 2

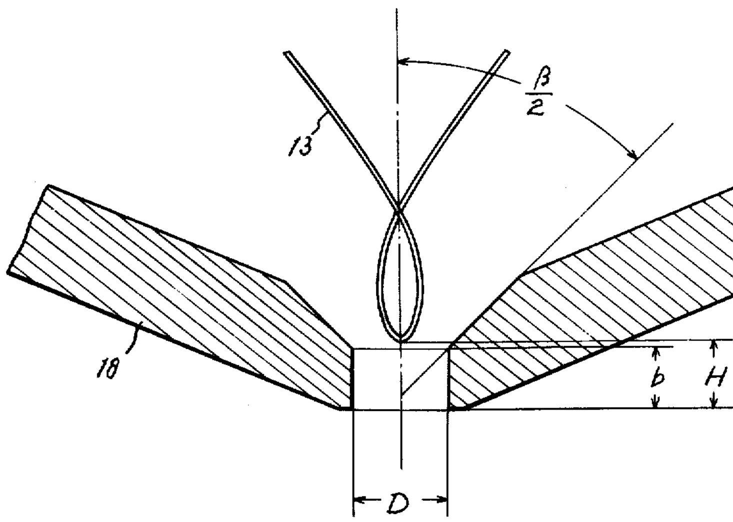

Fig. 4

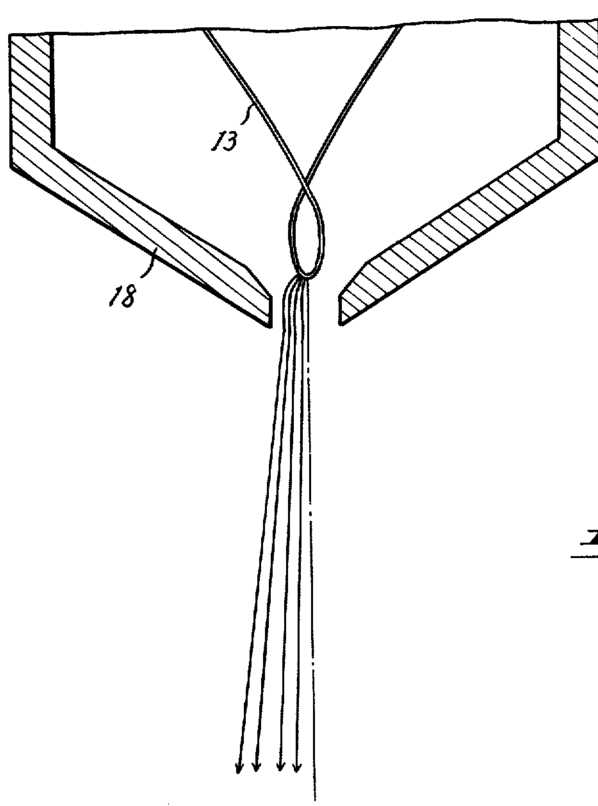

Fig. 5

THERMAL EMISSION TYPE ELECTRON GUN

This invention relates to a thermal emission type electron gun. Electron beam sources used in electron microscopes are required to generate an electron beam having a high order of brightness, a high degree of parallelism, and high density and uniformity, in order to ensure a high quality image.

However, the thermal emission type electron gun presently in use is inescapable of satisfying all the above requirements, hence the quality of the microscope image leaves a lot to be desired. The reason for this, I have found is primarily related to the improper shape of the Wehnelt electrode and the improper position of the filament with respect to the Wehnelt electrode in prior art devices.

An advantage of this invention, therefore, is to provide a thermal emission type electron gun capable of generating an electron beam having the required high degree of parallelism, high density and uniformity by improving the shape of the Wehnelt electrode and rearranging the filament with respect to the Wehnelt electrode.

A further advantage of this invention is to increase the effective working life of the filament.

Briefly, this invention is characterized in part by the fact that the distance H between the tip of the filament and the lower rim of the Wehnelt electrode opening through which the electron beam passes typically satisfies the relations $0.4D \leq H \leq 0.8D$, where D is the diameter of the Wehnelt electrode opening.

By satisfying the above relation, the distance between the filament and the Wehnelt electrode is large enough to prevent microdischarge, thereby prolonging the effective working life of the filament.

This and other characteristics of this invention, as above mentioned enable the overall performance of electron microscopes to be improved in many ways.

For example, it has been confirmed from my experimental work that a well-paralleled beam enables thick specimens to be observed due to the increased penetrating power. The resultant decrease in electron scatter in the specimen reduces specimen contamination and heat damage. Also, particularly in the case of biological specimens, phase contrast makes it possible to separate the specimen structure image from the image noise, due to increased focal depth.

At the same time, a beam having high density and uniformity enables a low magnification image to be displayed with uniform brightness. It also eliminates the need to adjust the stigmator because beam astigmatism remains almost constant regardless of any change in the accelerating voltage or image magnification.

Further features of this invention will become apparent from the following detailed description considered in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic diagram showing a conventional thermal emission type electron gun;

FIGS. 2 and 3 are schematic diagrams for explaining the characteristics of the electron beam obtained by the electron gun shown in FIG. 1;

FIG. 4 is a drawing showing the essential part of the electron gun according to this invention;

FIGS. 5, 6, and 7 are schematic diagrams for explaining the characteristics of the electron beam obtained by the electron gun according to this invention.

Referring to FIG. 1, an electron gun chamber 1 is mounted upon the microscope column (not shown) and an insulator 2 is filled with insulating pitch 3. A high voltage cable 4 is partially buried in the solidified insulating pitch 3. Lead wires 5, 6, and 7 constitute the electrical conducting path of the high voltage cable 4. One end of said lead wires 5 and 6 and lead wire 7 is connected to a filament heating source 8 and a D.C. high voltage source 9, respectively. The opposite ends of the respective lead wires being connected to rods 10, 11 and 12. A filament 13 is connected to rods 10 and 11, said filament being heated by alternating current generated by the filament heating source 8 which is applied via lead wires 5 and 6 and said rods 10 and 11. A Wehnelt electrode 14 is threadably secured to a member 15 fixed to the insulator 2. The electrode is supplied with a negative high voltage generated by the D.C. high voltage source 9 which is applied via lead wire 7, rod 12 and the member 15. Resistor 16 connected between lead wires 6 and 7 serves as a bias resistor, in order to control the electrons emitted from the filament by varying the bias voltage. A represents the beam crossover point under the condition that the filament tip aligns with the lower rim of the Wehnelt opening, said crossover point being formed by the electrostatic field generated between the filament and an anode 17.

FIG. 2 shows the image of the hairpin filament produced by the prior art thermal emission type electron gun described in FIG. 1 under comparatively low filament temperature conditions. As shown in the figure, the filament image consists of a slightly elliptical bright area at the center and two peripheral bright areas which are more or less crescent shaped. FIG. 3 shows the beam intensity distribution curve of the filament image shown in FIG. 2. As indicated by the curve, the beam intensity is strongest at the center of the image and weakens markedly in the peripheral areas. Accordingly, in order to obtain an electron beam having a high degree of parallelism, high density and uniformity, it is necessary to slice off a large portion of the electron beam by inserting a baffle having small diameter lens aperture therein in the beam path. In so doing, however, a proportional amount of beam current is lost, This, of course, means that if a large beam current is required, it is necessary to rearrange the position of the Wehnelt electrode so as to make the filament protrude from the lower rim of the Wehnelt electrode opening and also to increase the bias voltage between the filament and Wehnelt electrode. However, by so doing, the effective working life of the filament is curtailed due to microdischarge between the filament and the Wehnelt electrode.

FIG. 4 is a schematic drawing showing the shape of the Wehnelt electrode and the postition of the filament with respect to the Wehnelt according to this invention. The side of the Wehnelt electrode 18 facing the anode is convex and the distance H between the tip of the filament and the lower rim of the Wehnelt electrode opening satisfies the relation $0.4D \leq H \leq 0.8D$ (0.4D less than or equal to H, H less than or equal to 0.8D) where D is the diameter of the Wehnelt electrode opening.

By satisfying the above condition, excellent results are assured. However, in order to further improve the overall performance of the thermal emission type electron gun with respect to the objectives and claims of this invention, it is necessary to machine the Wehnelt electrode to provide a cylindrical surface for the beam pass-through opening and to make the surface of the Wehnelt electrode near the opening facing the filament substantially cone-shaped (conical). Moreover, the vertical angle β of said cone-shaped position should preferably satisfy the relation $30° \leq \beta \leq 90°$ (beta greater than or equal to 30°, beta less than or equal to 90°) and the height b of the cylindrical surface should preferably satisfy the relation $0.2D \leq b \leq 0.8D$ (b less than or equal to 0.2D, b greater than or equal to 0.8D).

FIG. **5** shows the trajectory of the electron beam emitted from the gun filament according to this invention. It will be noted that the angle of beam diversion beyond the crossover point is minimal thereby ensuring the high degree of parallelism.

FIGS. **6** and **7** show the filament image produced by the thermal emission type gun according to this invention and the corresponding beam intensity distribution curve under comparatively low filament temperature. In this condition, the beam intensity distribution curve is the flat topped curve as shown in FIG. **7**, because the filament image consists of a very slightly elliptical bright area at the center and a ring-shaped bright area as shown in FIG. **6**. Therefore, the electron gun according to this invention generates an electron beam having high density and uniformity.

Having thus set forth my invention as required by the Patent Laws, what is desired by Letters Patent are set forth in the following claims.

I claim:

1. In a thermal emission type electron gun comprising a filament for emitting thermal electrons, an anode arranged to face said filament, a voltage source for supplying high potential difference between said filament and anode, a Wehnelt electrode having an opening therein through which said electrons pass, said Wehnelt electrode arranged between said filament and anode, the side of said Wehnelt electrode facing the anode being convex, and means for supplying a potential to maintain the Wehnelt electrode at a negative potential with respect to the filament, the improvement comprising the distance H between the tip of the filament and the lower rim of the Wehnelt opening satisfying the relation $0.4D \leq H \leq 0.8D$ where D is the diameter of the opening the Wehnelt electrode, and the surface of the Wehnelt electrode near the opening being substantially cylindrical and the surface about the opening facing the filament being substantially cone-shaped and the angle β of said cone-shaped portion with the axis of the cylindrical opening satisfying the relation $30° \leq \beta \leq 90°$.

2. The improvement in a thermal emission type electron gun as set forth in claim **1** in which the height b of said cylindrical surface satisfies the relation $0.2D \leq b \leq 0.8D$.

3. In a thermal emission type electron gun comprising a filament for emitting thermal electrons, an anode arranged to face said filament, a voltage source for supplying high potential different between said filament and anode, a Wehnelt electrode having an opening therein through which said electrons pass, said Wehnelt electrode arranged between said filament and anode, the side of said Wehnelt electrode facing the anode being convex, and means for supplying a potential to maintain the Wehnelt electrode at a negative potential with respect to the filament, the improvement comprising the distance H between the tip of the filament and the lower rim of the Wehnelt opening satisfying the relation $0.4D \leq H \leq 0.8D$ where D is the diameter of the opening in the Wehnelt electrode and the surface of the Wehnelt electrode near the opening being substantially cylindrical and the surface about the opening facing the filament being substantially cone-shaped and the height b of said cylindrical surface satisfying the relation $0.2D \leq b \leq 0.8D$.

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