BROAD BEAM ELECTRON GUN

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ABSTRACT

A high intensity electron accelerator for irradiating large surface areas is provided with a plurality of cathodes having control grids to achieve a uniform current distribution on the irradiated surface.

5 Claims, 12 Drawing Figures
BACKGROUND OF THE INVENTION

This invention relates generally to particle accelerators and in particular to high intensity electron guns or accelerators having a large area beam cross-section.

In general, the electron guns of the prior art utilized single electron emitting cathodes which either provided a diffusely distributed beam of electrons or, through various electromagnetic or electrostatic means, formed the electrons into a highly concentrated narrow beam which was manipulated back and forth over the irradiated surface for a period of time until the total irradiated dose was sufficient to secure the desired result.

In such devices, the dose rate is necessarily small because of the momentary irradiation of the points on the irradiated surface.

Where other prior art devices attempted to use multiple cathodes, their beam output was not uniform across the beam resulting in inefficient utilization of the emitted electrons.

SUMMARY OF THE INVENTION

The apparatus of the present invention provides a uniform current density, large area electron beam by using a plurality of cathodes spaced apart from a generally electron transparent anode between which are disposed means for controlling the flow of electrons emitted by each cathode.

It is, therefore, an object of the present invention to provide a broad beam electron accelerator in which the electron intensity at the irradiated surface is uniform.

It is another object of the present invention to provide a broad beam electron accelerator having a plurality of cathodes in which means are provided at each cathode for controlling the electron optics of the accelerator.

It is a further object of the present invention to provide a broad beam electron gun in which a control grid is provided for each cathode.

It is still another object of the present invention to provide a broad beam electron gun having several means for controlling the trajectory of accelerated electrons so that they strike the irradiated surface along generally parallel paths.

It is still a further object of the present invention to provide a broad beam electron gun in which cathode to anode arcing is reduced.

These and other objects of the present invention will be manifest upon study of the following detailed description when taken together with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partial cut-away isometric view of the electron beam gun of the present invention;

FIG. 2 is a graphic representation of the basic elements of the broad beam electron gun of the present invention;

FIG. 3 is a graphic representation of the basic elements of the broad beam electron gun of the present invention for a larger cathode-cathode spacing;

FIG. 4 is a graphic representation of the basic elements of the broad beam electron gun of the present invention with the addition of a secondary grid;

FIG. 5 is a graphic representation of the basic elements of the broad beam electron gun of the present invention using an anode screen to prevent arcing damage to the anode foil;

FIG. 6 is a graphic representation of the basic elements of the broad beam electron gun of the present invention using a multiple potential control grid;

FIG. 7 is a graph showing the electron intensity across the electron beam of a typical broad beam electron gun of the present invention;

FIG. 8 is a partial sectional elevational view of an embodiment of the cathode assembly of the present invention utilizing the configuration represented in FIG. 4;

FIG. 9 is a cross-sectional elevational view of the cathode assembly of FIG. 8 taken at various places across the view shown in FIG. 8;

FIG. 10 is a partial sectional elevational view of an embodiment of the cathode assembly of the present invention utilizing the configuration represented in FIG. 3; and

FIG. 11 is a cross-sectional elevational view of the cathode assembly of FIG. 10 taken at various places across the view shown in FIG. 10.

FIG. 12 is a graphic representation of the basic elements of the broad beam electron gun of the present invention using an electron reflector to increase utilization of electrons emitted from the cathode.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The term "electron intensity" as used in this disclosure is defined as electron current density or amperes per unit area.

Referring to FIG. 1, there is illustrated an isometric, partial cut-away view of the broad beam electron gun of the present invention which comprises, basically, a vacuum tight housing 10 at the bottom of which is anode support plate 11, and at the top of which is cathode assembly support insulator 12.

Contained within housing 10 is cathode assembly 14 which is attached to support insulator 12 by cathode assembly support arm 15.

Anode support plate 11 comprises a generally rectangular anode window 17 across which are arranged a plurality of parallel spaced-apart anode rib supports 18. A thin electron transparent anode foil 20, such as titanium or aluminum foil approximately 0.001-0.0005 inches thick, is placed in the underside of rib supports 18 and held in vacuum tight sealed relation with anode support plate 11 by foil clamp 21.

Cathode assembly 14 comprises, basically, a cathode assembly housing 23 which encloses a plurality of elongated, parallel, spaced-apart cathode filaments 24 defining a plane which is generally parallel to the plane of anode window 17 and anode foil 20.

About each cathode filament 24 is disposed a generally half-cylindrical primary control grid 25 having its longitudinal axis coincident with the longitudinal axis of cathode filament 24.

Below and spaced apart from control grid 25 is secondary grid 26 comprising a screen defining a planar surface generally parallel to anode window 17 and anode foil 20. As will be described below, secondary grid 26 is used to prevent the high voltage from affecting electron flow by reducing penetration of high voltage field lines of force into the filament-control grid region, however, the electron gun of the present invention will operate at lower anode to cathode voltage without it.
To energize cathode filament 24, conductors 28a and 28b are connected to each end of filament 24 and pass up through support arm 15 to a power supply (not shown).

Conductor 29 is connected to primary control grid 25 to raise it to its proper control voltage, while conductor 30 is connected to secondary grid 26 to raise it to its proper control voltage, each conductor being connected to an appropriate power supply and control (not shown) common in the art. As will be described below, control grid 25 and secondary grid 26 are normally connected together and held at the same voltage.

Referring to Figs. 2 through 6 and Fig. 12, there is illustrated in graphic form, six configurations of the basic concept of the present invention, the most fundamental of which is shown in Fig. 2.

With reference to Fig. 2, the apparatus of the present invention comprises the same basic elements as shown in Fig. 1, namely, a plurality of cathode filaments 24, in end view, arranged in parallel, spaced-apart relation to define a plane, a plurality of half-cylindrical control grids 25 disposed about each filament 24 having their longitudinal axis coincident with the longitudinal axis of filament 24 and an anode window 17 comprising a plurality of anode rib supports 18 which support anode foil 20 which acts as the barrier between the high vacuum interior of housing 10 and the higher pressure exterior of housing 10 which causes foil 20 to arch inwardly (upwardly) as illustrated in the figures. The entire unit is arranged with the plane of anode window 17 parallel and spaced apart from irradiated surface 22.

The spacing of filaments 24 will depend upon the distance between the plane of filaments 24 and anode foil 20 in order to achieve a relatively uniform electron intensity at foil 20.

Fig. 7 illustrates, for a 40 inch long electron beam gun, the uniformity of intensity achieved by such spacing.

Anode foil 20, in order to withstand the force of atmospheric pressure, should have a high tensile strength yet be generally transparent to electrons. The term "generally transparent" is defined as being "not opaque" to the travel of electrons through the material, it being understood that some electrons will be absorbed and scattered, while others will pass through foil 20 to strike irradiated surface 22. It has been found that titanium foil approximately 0.001-0.0005 inches thick will perform satisfactorily.

With reference to Fig. 3, there is illustrated another configuration similar to Fig. 2, however, filaments 24 and grids 25 are further spaced apart and there is added between each grid 25 and filament 24 combination a beam shaping electrode 40 to shape the high voltage lines of force in the neighborhood of control grids 25 to prevent arcing between control grids 25 and anode foil 20, which also controls the trajectory of electrons leaving grid 25 to achieve a uniform distribution and intensity over the plane of anode window 17 and irradiated surface 22.

With reference to Fig. 4, there is illustrated another configuration similar to Fig. 2 but with the addition of a secondary grid 26 disposed just below grids 25 and parallel to the plane of the plurality of filaments 24.

With reference to Fig. 5, there is illustrated another configuration similar to Fig. 4 but with the addition of an anode screen 27 disposed between secondary grid 26 and anode window 17.

With reference to Fig. 6, there is illustrated another configuration similar to Fig. 1, however, a half-cylindrical grids 25 are now replaced by multiple potential planar control grid 31 comprising individual grid wires 31a through 31d beginning with grid wire 31a directly below filament 24 and grid wire 31d half way between filaments 24 with grid wires 31b and 31c in alphabetical order equally spaced between grid wires 31a and 31d.

With reference to Figs. 8 and 9, there is illustrated an embodiment of the basic configuration of cathode assembly 14 as shown graphically in Fig. 12.

With reference to Fig. 12, there are illustrated the same elements as shown in Fig. 4, however, with the addition of electron reflector plate 42 above and parallel to the plane of cathodes 24.

Although reflector plate 42 can be raised to any potential, satisfactory operation has been found by connecting plate 42 to cathodes 24 to maintain it at the same potential. A typical electron trajectory is shown by the dotted line.

Fig. 9 illustrates a series of sections taken progressively across Fig. 8 at lines 9A, 9B, 9C, 9D and 9E.

With particular reference to Fig. 8, the apparatus illustrated comprises the same elements as shown in Fig. 12, namely, a plurality of cathode filaments 24 around each of which is disposed a half-cylindrical control grid 25, below which is secondary grid 26 and above which is disposed electron reflector plate 46. Since Figs. 8 and 9 illustrate, primarily, cathode assembly 14, anode window 17 and irradiated surface 22 are not shown.

Since both ends of cathode-grid assembly 43 of Fig. 8 are identical, only the middle, which is shown in section, will be described.

Filament 24 is connected at each end to filament clamp 45 which comprises a generally cylindrical body having a retainer ring 46 at one end and an electrical connection hole 47 adjacent retainer ring 46.

Around the end of filament clamp 45 near the point of attachment of filament 24, is a slidable insulated retainer ring 48, which is, in turn, slideably arranged within control grid end support ring 49.

A filament tension spring 50 is provided between retainer ring 46 and insulated retainer ring 48 and is biased to force retainer ring 46 away from insulated retainer ring 48, thus maintaining a tension on filament 24 to prevent its sagging when hot and also maintaining it in accurate coincidence with the longitudinal axis of control grid 25. The particular configuration of concentric filament clamp 45, insulated retainer ring 48 and control grid end support ring 49 achieves the accurate coincidence of the longitudinal axis of filament 24 and grid 25 for precise control of the electron flow and trajectory.

It can be seen that the voltage applied to grid 25 through control grid support ring 49 from control grid bus bar 52 is isolated from the voltage applied to filament 24 and filament clamp 45 by insulated retainer ring 48.

Control grid 25 also must thermally expand and contract during operation. For this reason, the connection of grid 25 to control grid bus bar 52 must be flexible. Therefore, control grid connection plate 53 is preferably fabricated from a flexible, heat resistant spring material to allow for such movement.
A flexible electrical connection to filament clamp 45 is made by electrical conductors 54 which are attached to filament clamp 45 using machine screws 55 inserted in hole 47 to engage threads in conductor 54.

With particular reference to FIGS. 10 and 11, another embodiment of cathode assembly 14' of the present invention is illustrated utilizing the basic configuration shown graphically in FIG. 3, namely, filament cathode 24, around which is disposed half-cylindrical control grid 25 and between each filament 24-grid 25 combination are disposed beam shaping electrodes 40.

Connecting and supporting all filaments 24 in parallel are filament bus bars 32a and 32b, to which are connected, respectively, filament conductors 28a and 28b.

Connecting and supporting all primary control grids 25 are control grid bus bars 33a and 33b which are, in turn, connected to control grid conductor 29.

Cathode filament bus bars 32a and 32b, and primary control grid bus bars 33a and 33b, are all supported and held in place by bus bar insulator supports 36a and 36b.

Because cathode filaments 24 of FIG. 10 and 11 are spaced relatively far apart, cathode assembly 14' further comprises beam shaping electrodes 40 which are connected to bus bars 41a and 41b and are charged to a voltage to electrostatically assist the shaping of the electron trajectory from cathode filament 24 to achieve a uniform intensity at anode window 17.

Satisfactory results have been achieved when the electrical potential of beam shaping electrode 40 is the same as that of cathode filament 24.

An example of a typical broad beam electron gun of the present invention, Table 1 illustrates typical dimensions and parameters for the apparatus shown in FIG. 1 and 8.

| TABLE 1 |
|----------------|----------------|
| Cathode Filament 24 Radius | = 0.015 inches |
| Cathode Grid 25 Radius | = 0.200 inches |
| Cathode Filament 24 to Anode Foil 20 Distance | = 4.0 inches |
| Cathode Filament 24 to Grid 25 Voltage | = 4,150 volts |
| Cathode Filament 24 to Anode 20 Voltage | = 3.0 K V |
| Cathode Filament 24 to Secondary Grid 26 Distance | = 6.7 inches |
| Cathode Filament 24 to Secondary Grid 26 Voltage | = 4,150 volts |
| Cathode Filament 24 Material | = Thoriated Tungsten |
| Number of Cathode Filaments 24 | = 80 |
| Cathode Filament 24 Spacing | = 0.512 inches |
| Length of Anode Window 17 | = 41 inches |
| Width of Anode Window 17 | = 5.9 inches |
| Output Current at Outside of Anode Window 17 | = 200 ma/cm² |

**OPERATION**

To operate the broad beam electron gun of the present invention, housing 10 (FIG. 1) is evacuated to a high vacuum, typically between 1 × 10⁻⁸ to 1 × 10⁻⁷ torr.

An electrical current is applied to cathode filament 24 to bring it up to operating temperature and a voltage is applied to create a potential difference between cathode filament 24, control grid 25 and anode foil 20.

With particular reference to FIG. 2, a typical electron trajectory is shown in which the voltage of control grid 25 is adjusted to extract electrons from cathode filament 24 with the electrical potential difference between cathodes 24 and anode foil 20 adjusted to accelerate the electrons to the energy level desired.

With particular reference to FIG. 3, a typical electron trajectory is shown for a relatively larger cathode filament 24 spacing. The electrical connections and operation are similar to that of FIG. 2, in that the electrical potential between cathode filament 24 and control grid 25 is adjusted to extract electrons from filament 24 while the electrical potential between filament 24 and anode foil 20 is adjusted to accelerate the electrons to the desired energy level. Beam shaping electrodes 40 are shown connected to cathode filaments 24 to maintain them at the same potential as cathode 24 with satisfactory results. Beam shaping electrodes 40 could be connected to be at a different voltage than cathode filament 24 in the event different electrode geometries are used or different electron trajectories are desired.

With particular reference to FIG. 4, when very high cathode to anode accelerating voltages are used, arcing sometimes occurs between the relatively sharp edges of control grid 25 and anode foil 20 causing impairment of the operation of the electron gun of the present invention and the puncturing of anode foil 20.

To prevent such arcing, secondary grid 26 is disposed between grid 25 and anode window 17. Secondary grid 26 is preferably electrically connected to control grid 25 to maintain it at the same potential as grid 25 and, in effect, represents an electron emitting plane parallel to the plane of anode foil 20. Since no portion of secondary grid 26 projects toward anode window 17, the tendency for arcing is substantially reduced.

Where even higher accelerating voltages are used creating a greater tendency for arcing to occur between secondary grid 26 and anode foil 20, an anode screen 27 is installed between secondary grid 26 and anode foil 20 as shown in FIG. 5.

Anode screen 27 comprises a very thin wire mesh or screen such as a molybdenum wire screen which is electrically connected to anode foil 20 and is maintained at the same potential. The space between anode screen 27 and anode foil 20 defines a field free drift space. If arcing should occur, it will be between secondary grid 26 and anode screen 27. Thus, puncturing of anode foil 20 is eliminated so that a high vacuum tight structure is maintained.

With reference to FIG. 6, the same basic elements as shown in FIG. 2 are used, namely, cathode filament 24, anode window 17, anode foil 20 and irradiated surface 22, except that grid 25 is now replaced by multiple potential grid assembly 31 comprising parallel spaced apart grid wires 31a through 31d all arranged in a common plane parallel to anode window 17.
Each grid wire 31a through 31d is connected to a source of voltage (not shown) which can raise each grid wire 31a through 31d to a different voltage relative to the other grid wires depending upon its distance from the nearest cathode filament 24. The average or mean voltage value being established to achieve the desired electron beam intensity.

The voltage difference between grid wires 31a through 31d should be adjusted, depending upon grid wire spacing, until the desired distribution of electrons is achieved at anode foil 20 or irradiated surface 22.

With reference to FIG. 12, electron reflector plate 42 is connected to filaments 24 to maintain plate 24 at the same potential as filament 24. Although only one filament 24 is shown connected to reflector plate 42 in FIG. 12, all filaments 24 are, in fact, connected together.

Reflector plate 42 functions to increase the utilization of electrons emitted by filament 24 by reflecting (deflecting) the electrons emitted from filament 24 in the upper one-half cylindrical portion and directing them down to the lower one-half portion toward irradiated surface 22.

We claim:
1. A broad beam electron gun comprising an anode generally transparent to electrons, a plurality of elongated filament cathodes spaced apart and parallel to each other in a common plane, said plane being generally parallel to said anode, a generally cylindroform control grid disposed about each of said filament cathodes, and means for creating an electrical potential between said anode, said filament cathodes and said control grids whereby electrons emitted from said cathodes are accelerated toward said anode, said beam having both width and depth.
2. The broad beam electron gun as claimed in claim 1 further comprising a beam shaping electrode disposed parallel to and spaced apart between said generally cylindroform control grids, and means for creating an electrical potential between said beam shaping electrodes and said control grids whereby the trajectories of said electrons passing through said control grids achieve a uniform electron intensity at said anode.

3. The broad beam electron gun as claimed in claim 1 further comprising a generally planar secondary grid disposed between said control grids and said anode and parallel thereto, and means for electrically connecting said secondary grid to said control grids.

4. The broad beam electron gun as claimed in claim 1 further comprising a generally planar means for reflecting electrons toward said anode, said reflecting means disposed on the side of said filament cathodes opposite said anode and generally parallel thereto.

5. A broad beam electron gun comprising an anode generally transparent to electrons, a plurality of elongated filament cathodes spaced apart and disposed parallel to each other in a common plane, said plane being generally parallel to said anode, a plurality of parallel spaced apart grid wires disposed between said filament cathodes and said anode, said grid wires spaced apart and having their longitudinal axes parallel to said anode, and means for creating a different electrical potential on each of said grid wires relative to said cathodes and said anode according to the distance from the nearest cathode filament whereby a uniform electron intensity is achieved at said anode.