June 23, 1964 W. SCHEFFELS 3,138,736

ELECTRON BEAM GENERATOR SYSTEM

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Fig.1

PRIOR ART

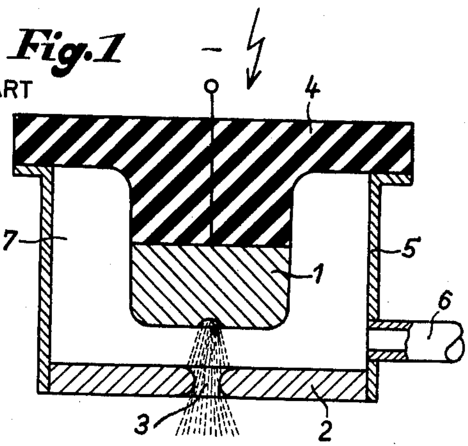


Fig.2a

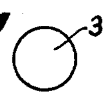
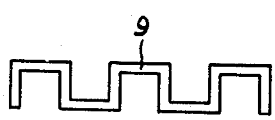


Fig.2b

Fig.2c



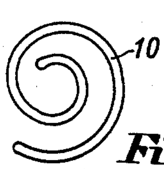


Fig.3

Fig.4

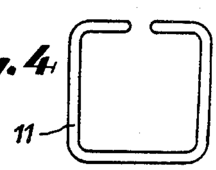
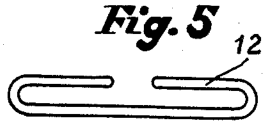


Fig.5



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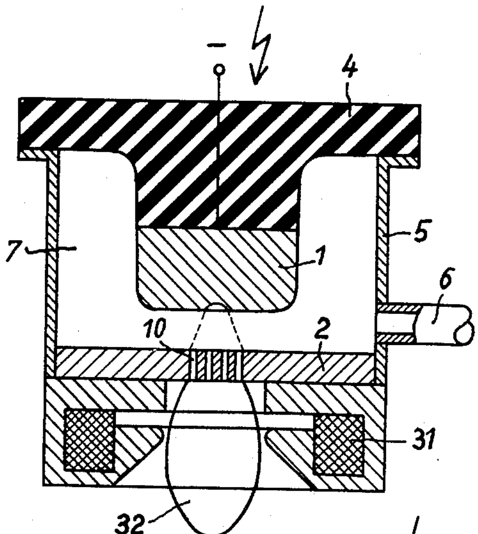

Fig. 6

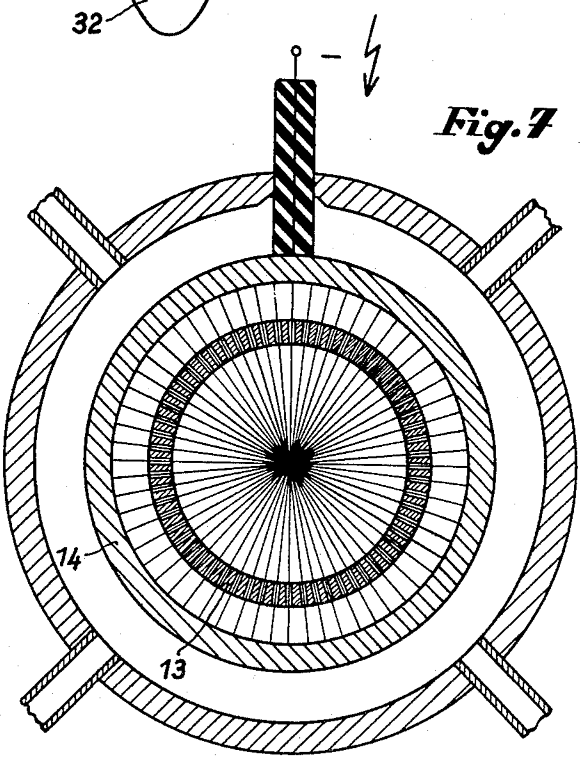

Fig. 7

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Fig. 8

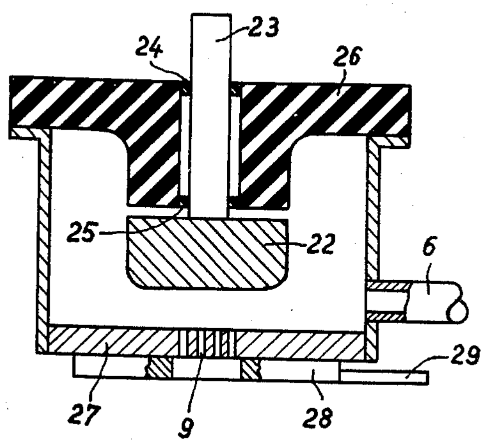
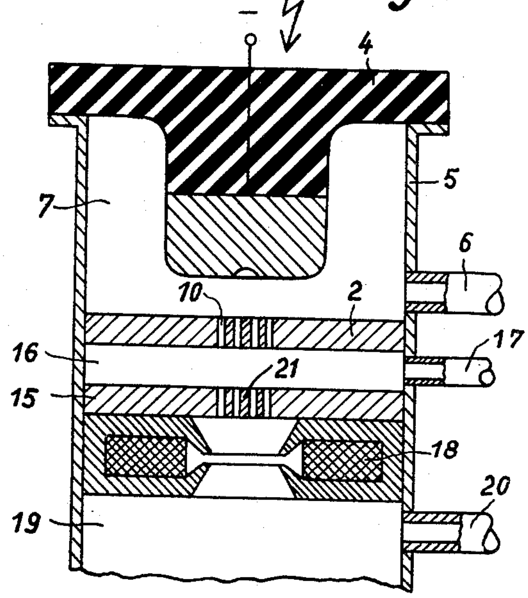


Fig. 9



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ELECTRON BEAM GENERATOR SYSTEM

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11 Claims. (Cl. 315—31)

This invention relates to an electron beam generating system and, more particularly, relates to an improved generator system utilizing secondary emission effects for the irradiation of objects in air by high velocity electrons and for generating electron beams of high velocity and high flux density in a vacuum.

Electron beam generating systems utilizing secondary emission from a cathode under positive ion bombardment are known to the art. In such systems, the electron beam generator consists of a massive metal electrode for a cathode and diaphragm-type anode with a circular aperture therein. The diaphragm forms a part of a beam generating chamber enclosing the cathode.

Thus, the diaphragm separates the generating chamber from the exterior (which may be air or a working chamber) but permits communication between the generating chamber and the exterior through the circular aperture. The generating chamber may be evacuated to the desired working pressure by continuously evacuating the chamber. The pump, of course, works against the gas leakage through the circular aperture and, thus, the aperture must be small to provide the flow resistance necessary to allow the pump to evacuate the chamber to the desired working pressure.

The cathode is biased to a high negative voltage with respect to the diaphragm anode. Thus, as the gas enters the evacuated beam generating chamber, a delayed gas discharge will take place between the diaphragm aperture and the cathode. The ions formed in the discharge will be accelerated towards and will impinge upon the cathode, releasing electrons therefrom. The electrons are accelerated by the electrostatic field betwen the cathode and the diaphragm anode and will pass through the aperture in a beam which can be used to irradiate objects in the beam path.

To obtain large flux densities in the electron beam, the diaphragm must be so shaped that a gas discharge of maximum intensity occurs over a large area of the cathode. However, with a circular aperture discharge over a large area of a cathode has been impossible to obtain. The increasing of the aperture diameter to the desired size for the electrical effect has been precluded by the capacity of the evacuating apparatus. That is, the aperture diameter is limited to relatively small sizes by the capacity of the vacuum pump since the pump must exhaust the chamber while working against entry of gases through the aperture.

The formation of a plurality of small apertures having a total cross sectional area within the limits dictated by the evacuating pumps has been proposed to distribute the gas discharge over the face of the cathode. However, such arrangements have not been satisfactory due to jumping of the beam from place to place over the cathode surface and the resultant non-uniformity of the gas discharge.

Further, the gas discharge between the diaphragm and the cathode results in the erosion of the cathode. If the gas discharge extends over a fairly long period, the erosion will result in holes in the cathode which will become so deep that the resultant electrostatic field causes electron emergence over an undesirably large solid angle.

It is, therefore, one object of this invention to provide an improved beam generating system utilizing secondary

emission from a cathode under positive ion bombardment.

It is a further object of this invention to provide an improved secondary emission electron beam generating system utilizing a diaphragm aperture of such configuration as to provide electric distribution of gas discharges and simultaneously to provide a desired high flow resistance between gases passing through the aperture.

It is a further object of this invention to provide an improved electron beam generating system precluding the erosion of the cathode in undesirably deep holes.

In accordance with these objects, there is provided, in a preferred embodiment of this invention, a cathode contained in an evacuated chamber. A diaphragm forms a portion of a beam generating chamber enclosing the cathode and the diaphragm has an aperture therein communicating between the chamber interior and exterior. The chamber is continuously evacuated by a vacuum pump to maintain the desired pressure in the chamber. As with the prior art, the pump works against the leakage through the aperture.

The aperture is formed in the shape of a long, narrow slit to distribute the gas discharge and the resultant ion bombardment over a large area of the cathode electrode. The slit, however, ensures uniformity of the path of the gas discharge and the discharge will not skip between different places on the cathode surface. Further, the total area of the slit-like aperture may be larger than a circular aperture for the same flow resistance, since, for molecular flow, the flow resistance is proportional to $1/R^3$ where R is the radius of a circular aperture. To further distribute the discharge, the slit may be cut in the shape of a spiral, open loop, or the like.

Thus, the slit aperture provides a large electrical aperture without commensurate decrease in flow resistance and the pressure differential between the chamber and the exterior (whether higher or lower in pressure than the chamber) may be had with conventional pumping equipment. Thus, the chamber may be considered a pressure stage, the flow resistance through the aperture and the delivery capacity of the pump determining the evacuation pressure.

In another embodiment of this invention means are provided to slowly rotate the cathode about its vertical axis thereby to prevent erosion of the cathode surface in deep holes which would result in the emergence of the electrodes over an undesirably large solid angle.

In a still further embodiment of this invention, the cathode and the diaphragm are fabricated as concentric hemispheres, domes or cylinders to allow irradiation of objects over a wide angle without the necessity of providing a plurality of beam generators or the necessity of providing deflection fields for guidance of the electron beam.

The total electron flux density may be controlled by varying the amount of gas entering the beam generating space. In accordance with this invention, such variation may be afforded by an iris positioned over the diaphragm slit which iris may be adjusted to open a variable portion of the diaphragm aperture.

It is advantageous to mill out the diaphragm apertures with the electron beam machining equipment to maintain the dimensions sufficiently small to provide the requisite flow resistance.

In those applications where the diaphragm isolates the generator stage from air at atmospheric pressure, electron scattering by the air molecules will, of course, occur. In such applications, it is often advantageous to provide a focusing system to concentrate the electrons immediately behind the diaphragm.

In those applications in which the irradiation is introduced into a vacuum, a second diaphragm preferably having the same aperture configuration as that of the first diaphragm is provided. The gas for formation of the discharges may then be introduced between the two diaphragms to initiate the gas discharges as the gas flows into the beam generating chamber. Both the generator chamber and the vacuum chamber may be continuously evacuated to the desired pressure. The electron beam will pass through the two diaphragms and into the vacuum.

Alternatively, the gas for the discharge may be introduced into the generator chamber and the vacuum at the exterior maintained by continuous pumping.

By the apparatus of this invention, there is provided means for processing, such as electron beam welding and working, in air and vacuum. Further, irradiation of foils and fibers over large irradiation angles is obtainable directly.

This invention may be more easily understood by reference to the following description taken in combination with the accompanying drawings, of which:

FIG. 1 is a cross sectioned view of an electron beam generator in accordance with the prior art;

FIG. 2 is a plan view of the aperture used in electron beam generators, of which FIG. 2*a* is an aperture in accordance with the prior art and FIGS. 2*b* and 2*c* are apertures in accordance with the present invention;

FIGS. 3–5 are plan views of alternative apertures in accordance with the present invention;

FIG. 6 is a cross sectioned view of one embodiment of an electron beam generating system in accordance with the present invention;

FIG. 7 is a cross sectioned view of another embodiment of an electron beam generating system in accordance with the present invention;

FIG. 8 is a cross sectioned view of still another embodiment of an electron beam generating system in accordance with the present invention; and

FIG. 9 is a cross sectioned view of still another embodiment of the present invention.

In FIG. 1 there is shown an electron beam generating system in accordance with the prior art, comprising a massive metal electrode **1** which serves as a cathode, emitting electrons during bombardment by positive ions. In front of this metal electrode **1** is placed a diaphragm **2**, having a circular aperture **3**. The beam generating chamber **7**, containing the cathode **1**, and defined by the diaphragm **2**, the insulator **4**, and the vessel wall **5**, is continuously evacuated by a vacuum pump (not shown) to which the chamber is connected by pipe **6**. In the example here illustrated, the metal electrode **1** is biased at a potential of, say, −100 kv., while the diaphragm **2** is grounded. Gas under higher pressure enters the beam generating chamber **7** through the circular diaphragm aperture **3**. A delayed gas discharge arises, and ions are formed in it. These ions impinge on the metal electrode **1**, liberating electrons therefrom. These electrons are accelerated towards the diaphragm by the electrostatic field and finally issue through the diaphragm aperture **3** into the space under higher pressure. FIG. 2*a* shows the circular diaphragm aperture of the diaphragm **2**.

However, in accordance with the present invention, the diaphragm aperture is constructed as a long, narrow slit, whose linear extension will be seen from FIG. 2*b*. Comparison of FIGS. 2*a* and 2*b* will show immediately that the area of the slit is greater than that of the circular diaphragm aperture **3**. In spite of this, no more gas enters the beam generating space **7** through the slit **8**, than through the aperture **3**, so that, if the same vacuum is applied, the same pressure will be produced in the chamber **7** in both cases.

The slit **8** shown in FIG. 2*b* may be so shaped that it has, for example, the sinusoid or meandering appearance **9**, as shown in FIG. 2*c*. The end is thereby attained that the slit extends over a larger cathode surface area by comparison with the area of the slit opening.

Instead of slot shape **9**, shown in FIG. 2*c*, the diaphragm opening may also have the shape of a spiral **10**, as shown in FIG. 3. The diaphragm aperture may likewise take the form of an open loop **11** and **12**, as shown in FIGS. 4 and 5, respectively. The slit form shown in FIG. 5 yields a gas discharge more extended in one direction than in the other. On the other hand, the gas discharge is distributed over the largest possible (square) surface when the shape shown in FIG. 4 is employed.

FIG. 6 shows an electron beam generator system in which the diaphragm **2** is provided with a spiral diaphragm aperture **10**. As will be seen at once from this figure, the gas discharge in this case is distributed between electrodes **1** and **2** over a larger area than in the case of the system shown in FIG. 1.

Consequently, the electron flux passing through the aperture of the diaphragm **2** is significantly greater. To focus the electrons issuing from the diaphragm **2**, the electromagnetic focusing system **31** is placed immediately behind this diaphragm. If this system adjoins air under atmospheric pressure, the electron beam generated by the system here shown will have the approximate appearance indicated by **32**.

The diaphragm **2** may, if desired, be provided with means for cooling the diaphragm such as coolant passages.

FIG. 7 shows an electron beam generator system in which the metal electrode **14** is formed of a tube into which the cylindrcal diaphragm **13** projects. The tube **13** is provided with diaphragm apertures, which, for example, have the shape of the sinusoid or meander **9**, shown in FIG. 2*c*. The electron flux issuing from the diaphragm **13** is distributed over a 360° angle. Consequently, with the set-up shown in FIG. 7, foils or fibers, for instance, placed inside the diaphragm tube **13**, may be irradiated with electrons over the entire exposed area. Of course, the electrode and diaphragm may extend over a smaller angle if the 360° irradiation angle is unnecessary.

FIG. 8 shows an electron beam generator system in which the metal electrode **22** is connected to the shaft **23**. This shaft is rotationally mounted between the two sealing rings **24** and **25** in the insulator **26**. The diaphragm **27** is provided with sinusoid aperture **9**. During operation, the metal electrode **22** rotates slowly about its vertical axis, thus avoiding deep penetration of the holes eroded in the electrode **22**.

The slide **28**, placed in front of the diaphragm **27**, serves to control the electron flux. The slide **28** is similar in design to the iris diaphragm currently used in photography, so that the diameter of its aperture can be regulated by moving the lever **29**. According to the position of this lever, a greater or smaller area of the diaphragm aperture **9** will be covered by the slide **28**.

In the embodiment shown in FIG. 9, beneath the diaphragm **2** (seen in the direction of the beam), another diaphragm **15**, is placed, which, with the diaphragm **2**, forms the space **16**. This space is provided with the duct **17** serving to admit gas. This gas passes through the diaphragm aperture **10** into the vacuum space **7**, so that the gas discharge repeatedly hereinabove mentioned takes place. The electrons issuing through the aperture **10** then pass through the aperture **21** of the diaphragm **15**, which, for example, may have the same form as the aperture **10** of the diaphragm **2**, and from there reach the vacuum space **19**. In this space, the electromagnetic focusing system **18** is placed directly beneath the diaphragm **15**. The space **19** is connected by the duct **20** to a vacuum pump, which serves for continuous exhausting of the gas entering the space **19** through the aperture **21**.

The electron generating space may also be fed with gas directly through the duct **6**. In this case, the diaphragm **15** and the space **16** may be omitted.

The diaphragm apertures shown in FIGS. 2*c*, 3, 4 and 5 can be made in particularly simple and accurate manner by means of an electron beam focussed upon the diaphragm and moved along the lines of said apertures.

This invention may be variously embodied and modified within the scope of the subjoined claims.

What is claimed is:

1. An electron beam generator comprising a cold cathode, a diaphragm, means including said diaphragm for enclosing said cathode to form a generator chamber, said diaphragm being provided with a long, narrow slit aperture therethrough, means for continuously maintaining the generator chamber at a desired working pressure against the leakage through the aperture, and means for biasing the cold cathode negatively with respect to said diaphragm to cause a gaseous discharge therebetween and resultant ionic bombardment of the cathode surface, said slit distributing the bombardment over a large area of the cathode surface and simultaneously maintaining a high flow resistance to said leakage through said aperture.

2. An electron beam generator system according to claim 1 in which said slit aperture is developed as a spiral.

3. An electron beam generator system according to claim 1 in which said slit aperture is formed in the shape of an open loop.

4. An electron beam generator system according to claim 1 in which said slit aperture is formed in the shape of a meander or sinusoid.

5. An electron beam generator system according to claim 1 in which said diaphragm and said cathode are both convex in the same direction.

6. An electron beam generator system according to claim 1 which includes means for moving said cathode with respect to said diaphragm.

7. An electron beam generator system according to claim 1 which includes a focusing system, said system being positioned adjacent said diaphragm.

8. An electron beam generator system according to claim 1 which includes a slide positioned adjacent said diaphragm, said slide being movable to selectively cover portions of said slit aperture.

9. An electron beam generator system according to claim 1 in which said diaphragm separates said chamber from an evacuated space and which includes means for introducing gas into said chamber.

10. An electron beam generator system according to claim 1 which includes a second apertured diaphragm positioned near said first diaphragm to define a space therebetween, said second diaphragm separating said space from an evacuated chamber, and means for introducing gas into said defined space.

11. An electron beam generator comprising a cold cathode, a diaphragm, means including said diaphragm for enclosing said cathode to form a generator chamber, said diaphragm being provided with a long narrow slit aperture therethrough, means for continuously maintaining the generator chamber at a desired working pressure against the leakage through the aperture, means for biasing the cold cathode negatively with respect to said diaphragm to cause a gaseous discharge therebetween and resultant ionic bombardment of the cathode surface, said slit distributing the bombardment over a large area of the cathode surface and simultaneously maintaining a high flow resistance to said leakage through said aperture, and focussing means to focus the beam after its passage through the diaphragm into a high intensity beam.

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