Jan. 9, 1951 C. F. MILLER 2,537,150

ELECTRON MULTIPLIER TUBE

Filed Feb. 25, 1949

Fig. 1.

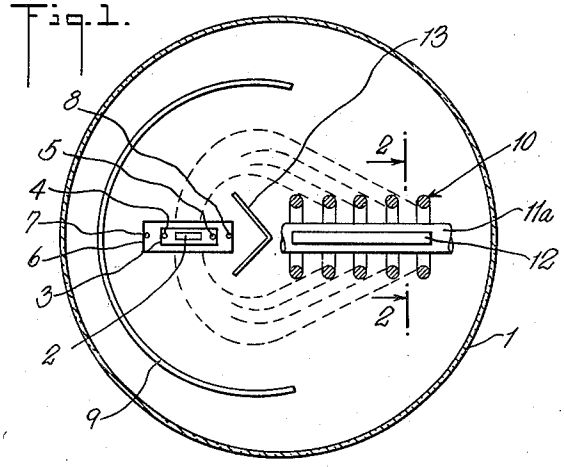
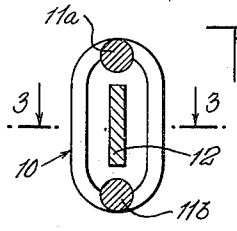


Fig. 2.



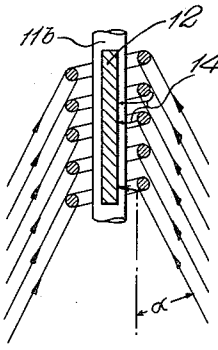
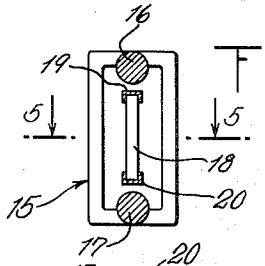


Fig. 3.

Fig. 4.



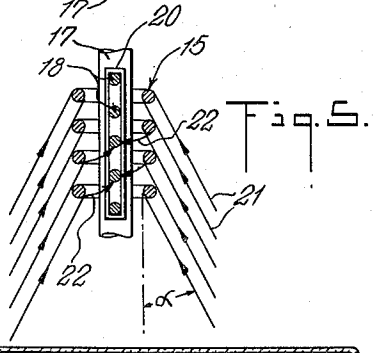


Fig. 5.

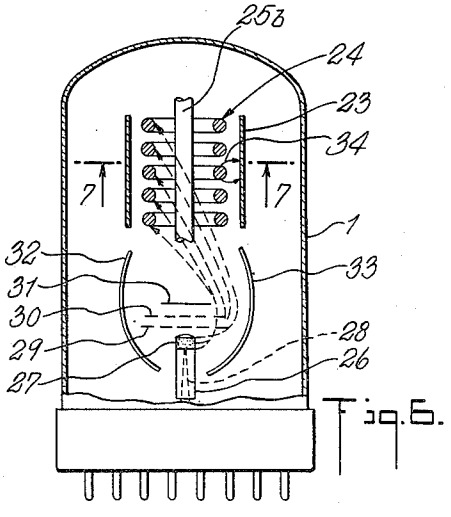


Fig. 6.

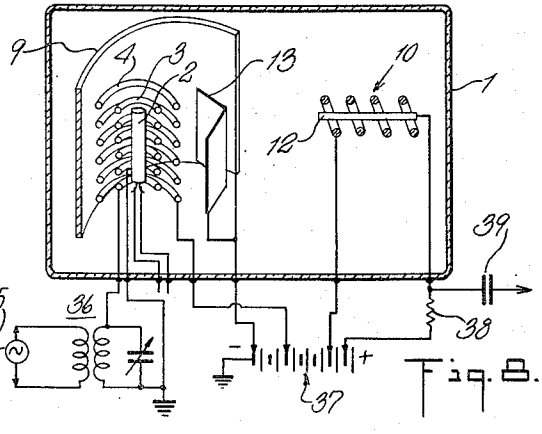


Fig. 8.

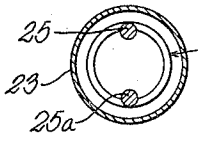


Fig. 7.

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ELECTRON MULTIPLIER TUBE

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12 Claims. (Cl. 250—174)

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This invention relates to electron discharge tubes, and more particularly to electron multiplier tubes utilizing a secondary electron-emissive electrode or dynode.

A principal object of the invention is to provide an improved dynode construction for secondary electron-emission tubes.

Another object is to provide an improved secondary electron multiplier tube.

A feature of the invention relates to a dynode for secondary electron-emission tubes, which dynode is of large area and open-work construction, as distinguished from the usual flat-plate-dynode construction.

Another feature relates to a secondary electron-emissive dynode which is in the form of a wire-wound grid having the windings of predetermined pitch and wire thickness, and oriented with respect to the primary electrons so as to translate efficiently incident primary electrons into released secondary electrons.

Another feature relates to a secondary electron-emissive dynode in the form of a wire-wound grid for surrounding the anode or electron collector.

A further feature relates to the combination of a source of primary electrons, a secondary electron collector electrode, and a wire-wound-grid dynode between the said source and collector, the dynode being shaped and dimensioned so as to intercept substantially all the primary electrons before they reach the collector, while allowing the greater part of the released secondary electrons to move to the collector.

A still further feature relates to the novel organization, arrangement, and relative location and proportioning of parts which cooperate to provide an improved electron multiplier tube.

Other features and advantages not specifically enumerated, will be apparent after a consideration of the following detailed descriptions and the appended claims.

In the drawing, which shows certain preferred embodiments,

Fig. 1 is a top plan view, partly sectional, of an electron multiplier tube according to the invention.

Fig. 2 is a cross-sectional view of Fig. 1, taken along the line 2—2 thereof and viewed in the direction of the arrows.

Fig. 3 is a sectional view of Fig. 2, taken along the line 3—3 thereof.

Fig. 4 is a view similar to that of Fig. 2, but showing a modified construction of the dynode and collector electrode.

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Fig. 5 is a sectional view of Fig. 4, taken along the line 5—5 thereof.

Fig. 6 is an elevational view of a modification of the tube of Fig. 1.

Fig. 7 is a cross-sectional view of Fig. 6, taken along the line 7—7 thereof.

Fig. 8 is a composite structural and circuit diagram showing a typical operating circuit for the tube according to the invention.

Referring to Fig. 1, there is shown an evacuated bulb or envelope of any suitable well-known construction.

Mounted within the highly evacuated bulb 1, is an electron-emitting cathode 2 which is adapted to be raised to electron-emitting temperature by any suitable heater element of filament (not shown). Surrounding the cathode 2 is any well-known helically-wound wire grid 3 which is supported by the usual grid side rods 4, 5. Likewise surrounding the control grid 3 is a shield grid 6 which may consist of a helically-wound wire attached to the usual grid side rod supports 7, 8. Surrounding the cathode and two grids is a curved metal plate 9 which acts as a deflector for the primary electrons emitted from the cathode 2, causing them to follow electron trajectories represented by the dotted lines in Fig. 1. Mounted in spaced relation to the cathode and double grid assembly described above, is a dynode consisting of a helically-wound wire grid 10 which is wound around and attached to a pair of grid side rods 11*a* and 11*b*. Suitably mounted within this dynode grid is a flat metal anode 12 which acts to collect the secondary electrons released from the dynode grid 10. Located between the dynode grid and the shield grid 6 is a channeled metal baffle plate 13. As shown in Fig. 1, the plate 13 has its concave side facing the cathode 2, and it is suitably dimensioned and energized by an appropriate potential as is the deflector plate 9, so as to cooperate therewith in constraining the primary electrons from cathode 2 to follow the electron trajectories represented by the dotted lines. The baffle 13 also positively prevents atoms of the cathode coating, e. g., barium or strontium, or other particles emanating from the cathode, from contaminating the coated surface of dynode 10. The bulb 1 has the usual lead-in wires or contact prongs (not shown) connected to the respective electrodes as schematically shown in Fig. 8.

In accordance with one feature of the invention, the dynode grid 10 is formed of comparatively heavy wire stock, and the pitch (i. e., the number of turns per inch) and the wire diameter

of the wire 10 are designed so as to have a predetermined relationship to the angle α. The angle α represents the angle between the trajectories of the primary electrons and the longitudinal axis of the dynode grid, as indicated in Fig. 3. By correlating the said pitch and wire diameter with the angle of approach of the primary electrons, it will be seen that each grid wire acts as a shield for the next adjacent grid wire, in so far as preventing the direct access of the primary electrons to the collector 12 is concerned. In other words, the primary electrons strike the wires 10 at such an angle that substantially all these primary electrons following the trajectories, as shown in the drawing, must strike the dynode 10. The dynode 10 may be formed of a metal which has a high coefficient of release of secondary electrons in response to impinging primary electrons of predetermined velocity. If desired, the wire 10 can be coated with any material well-known in the art which has a high coefficient of secondary electron emission. The released secondary electrons from the individual turns of the dynode grid follow trajectories represented by the arrows 14 (Fig. 3), and since the collector electrode 12 is at a higher positive potential than the dynode grid, these secondary electrons are capable of moving freely to the collector electrode.

By this arrangement it is possible therefore, to provide the dynode grid with an efficiently large area, while positively preventing direct bombardment of the collector electrode by the primary electrons. Thus, the dynode and collector electrode are protected against deposition of cathode material thereon, and the baffle 13 and dynode grid can be run at a lower temperature than is possible with prior constructions since both the collector and dynode grid are protected from the direct heat of the cathode. Thus vaporization of the dynode surface coating is greatly reduced as compared with prior constructions.

It will be seen that for larger angles of α, correspondingly large cross-sectional wire should be used for the grid 10, or the pitch of the grid windings of the dynode can be increased so as to prevent the primary electrons from cathode 2 from striking the collector 12. With the foregoing construction, it is possible to have extremely small spacing between the collector 12 and the dynode windings. For example, spacings as little as .002 inch have been found practicable, thus making the electrode 12 a very efficient collector of the secondary electrons, particularly if the direct current positive voltage applied to electrode 12 is high enough to reach through the space between adjacent dynode turns.

In those cases where low electrostatic capacity is required between the dynode and the collector, instead of making the collector in the form of a single sheet or plate as above described, it can be made of individual spaced wires or rods. Thus as shown in Figs. 4 and 5, the dynode 15 may consist of a helically-wound wire attached to a pair of grid supports 16, 17. Fig. 4 shows the dynode grid substantially rectangular in shape, although this is not necessary. The collector electrode consists of a series of spaced wires or rods 18 which are mounted between a pair of parallel channel members 19, 20, to which the wires 18 can be suitably fastened, for example by welding. The wires 18 are preferably inclined so as to have a pitch identical with the pitch of the grid 15, and the wires 18 likewise preferably have a cross-sectional size approximately equal to the spacing between adjacent turns of the grid 15, it being understood that the said wires 18 are located preferably in alignment with the said grid-turn spacings. In this embodiment, the trajectories of the primary electrons are represented by the arrows 21, and the angle of incidence of these primary electrons with respect to the dynode grid turns, is represented by the angle α. The trajectories of the secondary electrons are represented by the curved arrows 22. Here again the cross-sectional size of the wire from which grid 15 is formed, is sufficiently large and the pitch of the grid turns is chosen so that with respect to the trajectory of the primary electrons, each grid turn acts as an efficient barrier to prevent primary electrons from directly reaching the collector.

In both the foregoing embodiments, the collector electrode is shown as being surrounded by the dynode grid. Figs. 6 and 7 show a modification wherein the collector electrode is in the form of a tubular or cylindrical metal plate 23 which surrounds the dynode grid 24. This dynode grid 24 can be similar to grid 10 or grid 15, and is in the form of a wire helically wound around and attached to a pair of grid support rods 25*a*, 25*b*. The remaining electrode elements of Fig. 6 can be identical with those of Fig. 1, and may comprise, for example, a cathode sleeve 26 having its end portion provided with a coating 27 of electron-emissive material. The sleeve 26 may be provided with any suitable heater element 28 for raising it to emitting temperature. A control grid 29 is mounted in spaced relation to the cathode, and a shield grid 30 is mounted in spaced relation to the control grid. An electron baffle 31 is mounted in spaced relation to the shield grid. A pair of electron deflector plates 32, 33, are provided for causing the electrons to follow the desired trajectory towards the dynode 24, as represented by the dotted arrows. The secondary electrons released from the dynode are attracted to the collector 23 along trajectories represented by the curved arrows 34. It will be noted, therefore, that the electron trajectories impinge upon the internal peripheries of the successive turns of the grid 24, and the cross-section of the wire forming the grid 24 is sufficiently large, and the pitch is chosen so that for the desired angular approach or trajectory of the primary electrons, each grid turn effectively shields the succeeding grid turn against the passage of the primary electrons directly to the collector 23.

Fig. 8 shows a typical circuit arrangement in which the tubes of the foregoing embodiments may be employed. A suitable input signal source 35 is coupled through a tuned input 36 across the control grid 3 and the cathode 2. The shield grid 4 is connected to any suitable positive direct current potential represented schematically by the battery 37. The deflector 9 can then be connected to a suitable potential tap on the source 37, to cause the primary electrons to follow the desired trajectory. If desired, the baffle 13 can also be connected to this same potential. The dynode grid 10 is connected to a suitable high potential tap on the source 37, and the collector electrode 12 is connected through a resistor 38 to another point on the source 37 which is of higher potential than the point to which the grid 10 is connected. The signal developed across resistor 38 can be coupled through a suitable coupling condenser 39 to any desired load or utilization circuit.

Various changes and modifications may be made in the disclosed embodiments without de-

parting from the spirit and scope of the invention.

What is claimed is:

1. An electron tube, comprising means to develop a beam of primary electrons, a secondary electron collector, and a dynode upon which said primary electrons impinge to release secondary electrons, said dynode being in the form of a wire-wound grid with its central longitudinal axis at an acute angle with respect to the primary electron trajectories.

2. An electron multiplier tube, comprising means to develop a beam of primary electrons, a secondary electron collector, and a dynode upon which said primary electrons impinge to release secondary electrons, said dynode being in the form of a wire-wound grid disposed with its central longitudinal axis at an acute angle with respect to the angle of incidence of the primary electrons, said grid having its wire turns of sufficient cross-section to provide a barrier between the primary electrons and the collector.

3. An electron tube according to claim 1, in which said collector is interior of said dynode.

4. An electron tube according to claim 1, in which said collector is external of said dynode.

5. An electron multiplier tube, comprising a secondary electron collector and a dynode grid in co-axial relation, a cathode for emitting primary electrons mounted in spaced and end-on relation with respect to said dynode and collector, and means in the form of a primary electron deflector located between the cathode and the dynode to cause the primary electrons from said cathode to strike said dynode at an acute angle which is related to the cross-sectional thickness of the dynode grid wires whereby said wires act as a barrier against primary electrons reaching said collector.

6. An electron multiplier tube according to claim 5, in which a baffle member is located between the cathode and dynode grid to protect the dynode grid from the direct heat of the cathode and to protect it against the deposition of particles emanating from the cathode.

7. An electron multiplier tube, comprising a secondary electron collector, a dynode, said dynode having a plurality of spaced wire members, means to develop a beam of primary electrons, and means to cause said primary electrons to impinge upon said members at an acute angle and thereby to shield said collector from said primary electrons, the last-mentioned means including a deflector for the primary electrons.

8. An electron multiplier tube, comprising a secondary electron collector, a dynode, said dynode having a plurality of spaced wire members, means to develop a beam of primary electrons, and means to cause said primary electrons to impinge upon said members at an acute angle and thereby to shield said collector from said primary electrons, the last-mentioned means including an electron baffle and an electron deflector between which the primary electrons are constrained to pass.

9. An electron multiplier tube, comprising a secondary electron collector, a dynode, said dynode having a plurality of spaced wire members, means to develop a beam of primary electrons, and means to cause said primary electrons to impinge upon said members at an acute angle and thereby to shield said collector from said primary electrons, said dynode being in the form of a wire-wound grid having its central longitudinal axis facing the primary electron developing means.

10. An electron multiplier tube, comprising a secondary electron collector, a dynode, said dynode having a plurality of spaced wire members, means to develop a beam of primary electrons, and means to cause said primary electrons to impinge upon said members at an acute angle and thereby to shield said collector from said primary electrons, said dynode being in the form of a helically-wound grid, and said collector being in the form of a metal plate which is surrounded by said grid.

11. An electron multiplier tube, comprising a secondary electron collector, a dynode, said dynode having a plurality of spaced wire members, means to develop a beam of primary electrons, and means to cause said primary electrons to impinge upon said members at an acute angle and thereby to shield said collector from said primary electrons, said dynode being in the form of a helically-wound grid, and said collector being in the form of a tubular conductive member surrounding said grid.

12. An electron multiplier tube, comprising a secondary electron collector, a dynode, said dynode having a plurality of spaced wire members, means to develop a beam of primary electrons, and means to cause said primary electrons to impinge upon said members at an acute angle and thereby to shield said collector from said primary electrons, said collector comprising a series of spaced conductor strips mounted in registry with the spaces between said wire members.

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The following references are of record in the file of this patent:

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