June 17, 1941. W. SHOCKLEY 2,245,614

ELECTRON DISCHARGE DEVICE

Filed Nov. 26, 1937

FIG. 1

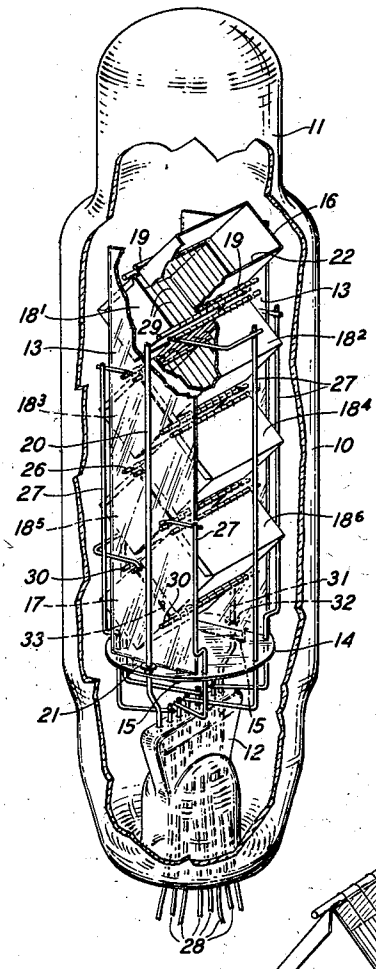


FIG. 2

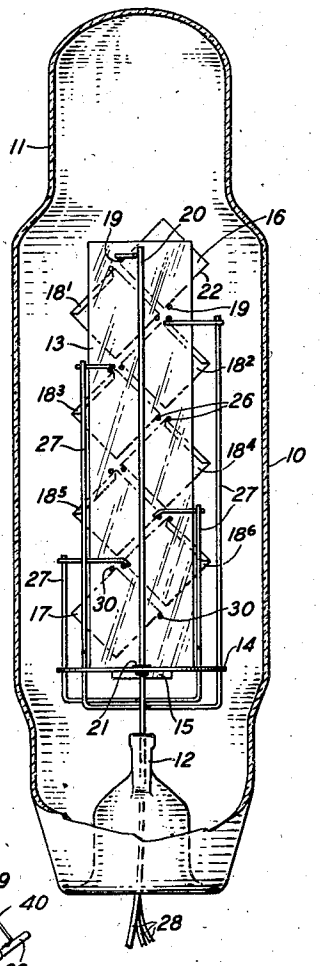


FIG. 3

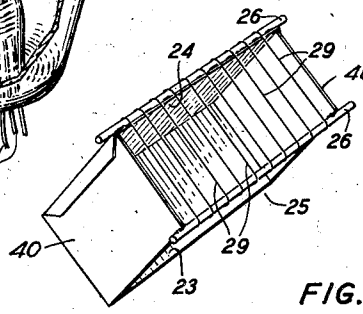


FIG. 4

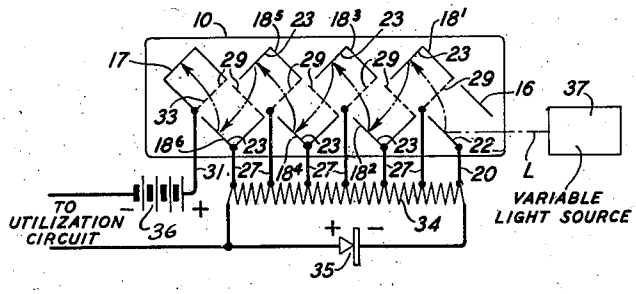
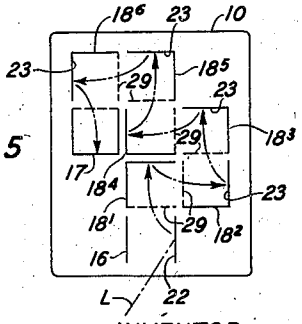


FIG. 5



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ELECTRON DISCHARGE DEVICE

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18 Claims. (Cl. 250—175)

This invention relates to electron discharge devices and more particularly to such devices generally known as electron multipliers.

In multistage electron multipliers having a series of auxiliary or secondary cathodes successively arranged between a primary cathode and an anode or collector electrode, a stream of secondary electrons emanates from each of the auxiliary cathodes and some of these electrons flow to and impinge upon the next succeeding electrode. Because of a number of factors, among which are the difference in the velocities of the secondary electrons emanating from the auxiliary cathodes and characteristics inherent in known structures, a divergence of these secondary electron streams occurs. As a result, some of the electrons impinge upon other than desired portions of the next succeeding electrode and other of these electrons may traverse such paths that they do not flow to or impinge upon the desired electrode. Consequently, a relatively low operating efficiency and variable characteristics obtain.

One general object of this invention is to improve the operating efficiency and characteristics of multistage electron multipliers.

More specifically, an object of this invention is to obtain substantial convergence of the secondary electron streams emanating from the secondary or auxiliary cathodes in electron multipliers.

Another object of this invention is to obviate the use of magnetic focussing or concentrating fields in electron multipliers.

A further object of this invention is to segregate effectively each of the secondary or auxiliary cathodes in a multistage electron multiplier from the field of the preceding electrode so that the field at the emitting surface of each of the auxiliary cathodes does not include a component toward this surface.

In accordance with one feature of this invention, the electrodes, particularly the auxiliary electrodes or cathodes, in a multistage electron multiplier are so constructed and arranged that the various electron streams emanating from the cathodes are confined to restricted paths and are substantially converged upon desired portions of the next succeeding electrode.

In accordance with another feature of this invention, reticulated members or screens are provided in cooperative relation with the secondary or auxiliary cathodes, the reticulated members or screens serving to prevent the field of each cathode from producing a component toward the secondary electron emitting surface of a succeeding auxiliary or secondary cathode.

The invention and the foregoing and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing, in which:

Fig. 1 is an elevational view in perspective of an electron multiplier illustrative of one embodiment of this invention, a portion of the enclosing vessel and of the electrode assembly being broken away to show elements of the multiplier more clearly;

Fig. 2 is a side view, partly in section, of the electron multiplier shown in Fig. 1;

Fig. 3 is an enlarged view in perspective illustrating the construction of the auxiliary or secondary cathodes embodied in the electron multiplier shown in Figs. 1 and 2;

Fig. 4 is a circuit diagram illustrating the utilization of an electron multiplier constructed in accordance with this invention in an amplifying system; and

Fig. 5 is a diagrammatic view illustrating the form and arrangement of the electrodes in an electron multiplier illustrative of another embodiment of this invention.

Referring now to the drawing, the electron multiplier illustrated in Figs. 1 and 2 comprises an enclosing vessel 10 having a reduced dome portion 11 at one end and an inwardly extending stem at the other end, the stem terminating in a press 12 from which a unitary electrode assembly is supported. The electrode assembly includes a U-shaped insulating frame having a pair of parallel arms or uprights 13, which may be, for example, mica strips, joined and spaced at one end by an insulating disc 14, which also may be of mica. The disc 14 is provided with parallel slots into which integral tongues 15 of the arms or uprights extend and are frictionally fitted.

Mounted upon the insulating frame 13, 14 are a primary cathode 16, a collector electrode or anode 17, and a plurality of auxiliary or secondary cathodes 18^1 to 18^6 inclusive. As shown clearly in Fig. 2, the various electrodes are arranged in staggered relation and in two rows, one row including the primary cathode 16 and the secondary or auxiliary cathodes 18^2, 18^4 and 18^6, and the other row including the secondary or auxiliary cathodes 18^1, 18^3 and 18^5 and the anode or collector electrode 17.

The primary cathode 16 is in the form of a metallic frame fabricated, for example, of a strip

or strips of nickel or silver, and is supported at an angle, for example, 45 degrees to the longitudinal axis of the vessel 10 by a pair of rigid wires 19 secured thereto and extending between and through the arms or uprights 13. Electrical connection to the cathode 16 may be established through a rigid metallic rod or support 20 embedded in the press 12, connected to one of the wires 19 and affixed to the disc 14 as by an eyelet 21. The inner surfaces, and preferably only the inner surface of the wall 22 of the cathode 16 may be coated with a photoelectric material. For example, if the cathode is of nickel, the inner surfaces thereof or only the inner surface of the wall 22 may be coated with beryllium. Alternatively, if the cathode or the wall 22 thereof is of silver, the inner surfaces, or only the inner surface of the wall 22, may be treated to form a photoelectrically active coating or matrix including silver, caesium oxide and some free caesium.

As shown clearly in Fig. 3, each of the auxiliary or secondary cathodes 18 is in the form of a rectangular box, which may be fabricated of metal sheets, for example, nickel or silver, having a solid base 23, a solid wall 24 at substantially right angles to the base 23, end walls or field plates 40, an open side 25 and an open top. Secured to each of the secondary or auxiliary cathodes 18 are a pair of rigid metallic supports or wires 26 which extend between, and are fitted in apertures in the insulating uprights or arms 13. The supports or wires 26 mount the cathodes 18 with the base 23 of each at equal angles, for example, 45 degrees, to the longitudinal axis of the enclosing vessel 10. Electrical connection to the secondary cathodes 18 may be established through metallic rods or uprights 27 extending through the disc 14 and connected at one end to the wires 26 and at the other end to leading conductors 28 embedded in the press 12. The inner surfaces of the base and walls of each of the cathodes 18, preferably only the inner surface of the base 23, are treated so that they are rendered capable of emitting relatively large secondary electron currents. For example, these surfaces may be treated to form a coating or matrix thereon of silver, caesium oxide and free caesium. Alternatively, these surfaces may be sensitized with beryllium.

As shown clearly in Fig. 4, the auxiliary or secondary cathodes 18 are mounted so that the open side 25 of each of these cathodes is opposite the base 23 of the next succeeding secondary or auxiliary cathode and the base 23 of each of the secondary cathodes 18^2 to 18^6 is at substantially right angles to the base of the next preceding secondary cathode. The base 23 of the auxiliary or secondary cathode 18^1 is at substantially right angles to the wall 22 of the primary cathode 16.

The top of each of the secondary or auxiliary cathodes 18 has extending thereacross a metallic grid or screen which may be composed of a plurality of thin parallel wires 29 secured at their ends to the supports or rods 26, as by welding.

The anode or collector electrode 17 may be a metallic box, for example, of sheet nickel, having an open top opposite the grid or screen 29 of the secondary or auxiliary cathode 18^6 and having its base at an angle, for example, substantially 90 degrees, to the base 23 of the cathode 18^6. Rigid metallic wires or rods 30 secured to the sides of the anode and having their ends fitted in apertures in the arms or uprights 13 mount the anode upon the insulating frame 13, 14. Electrical connection to the anode or collector electrode may be established through a leading-in conductor 31 connected to one of the wires or rods 30, embedded in the press 12, and affixed to the disc 14 as by an eyelet 32. The top of the anode or collector electrode 17 may be provided with a grid or screen 33, which may be composed of thin parallel wires affixed at their ends to the wires or rods 30.

During operation of the electron multiplier each of the secondary or auxiliary cathodes 18 is maintained at a positive potential with respect to the next preceding cathode. For example, the secondary cathode 18^1 may be maintained at a potential of the order of 100 volts positive with respect to the primary cathode 16 and each of the other secondary or auxiliary cathodes 18 may be maintained at a potential of the order of 100 volts positive with respect to the next preceding one. As shown in Fig. 4, the various potentials for the cathodes may be obtained from a potentiometer or voltage divider including a resistance 34 having a source, such as a rectifier 35, connected to the ends thereof, the cathodes being connected to equally spaced taps on the resistance 34. The anode may be operated at a potential of the order of 100 volts positive with respect to the secondary cathode 18^6, the potential being obtained from a source, such as battery 36.

The primary cathode 16 may be activated or energized by focussing a light beam, indicated by the line L in Fig. 4, emanating from a suitable source 37 of light of variable intensity, upon the inner surface of the wall 22. When the primary cathode 16 is thus energized or activated, photoelectrons are emitted from the inner surface of the wall 22 and are attracted toward the grid or screen 29 of the secondary or auxiliary cathode 18^1 because of the potential upon this secondary cathode. Most of these electrons pass through the grid or screen and impinge upon the base 23 of the secondary cathode 18^1, the trajectory thereof being represented by the arrow in Fig. 4. Inasmuch as the inner surface of the base 23 of the cathode 18^1 is sensitized as described heretofore, the impinging photoelectrons will cause the emission of secondary electrons from this base 23, the secondary electron current being several times as great as the photoelectric current. Consequently, in effect, an electron multiplication and hence an amplification of the primary or initial current is obtained.

The secondary electrons emanating from the auxiliary or secondary cathode 18^1, under the influence of the potential upon the auxiliary or secondary cathode 18^2, pass through the grid or screen 29 of the latter cathode, as indicated by the arrow in Fig. 4, and impinge upon the base 23 of this cathode to cause the emission of other secondary electrons therefrom. The secondary electron current thus produced is several times as great as the current composed of the impinging electrons so that a further amplification of the initial electron current is obtained.

This phenomenon is repeated at each of the succeeding secondary or auxiliary cathodes at each of which a further electron multiplication and hence effective amplification of the initial current, occurs. The secondary electrons emanating from the secondary or auxiliary cathode 18^6 flow to the anode or collector electrode 17 and constitute the output current of the electron multiplier.

Because of the form and disposition of the electrodes, dispersion of the electrons constituting the various streams between successive electrons is substantially prevented. The end walls **40** of the several cathodes serve as field plates and confine the electron streams laterally, and the solid sides **24** of the auxiliary or secondary cathodes **18** constitute baffle members which assist in converging the electron streams so that they are confined and are directed to only the next succeeding electrode. Hence, a relatively high efficiency and stable operating characteristics are obtained.

Each of the grids or screens **29**, being at the same potential as the corresponding cathode, screens the corresponding base **23** from the adjacent cathodes and thereby prevents the field of the adjacent cathodes, particularly the adjacent cathode in the same row, from producing a component toward the base, which would materially hinder or prevent the emission of secondary electrons therefrom.

It will be noted that in electron multipliers constructed in accordance with this invention the electrons may be acted upon only by electrostatic fields and highly desirable convergence of the electron streams is effected without the use of magnetic fields. Hence, such multipliers may be utilized satisfactorily in instances where magnetic fields are objectionable. For example, devices constructed in accordance with this invention may utilize a thermionic cathode, the electron current from which, not being distorted by a magnetic field, may be controlled readily in accordance with a signal, by a control grid mounted adjacent the primary cathode. Furthermore, fluctuations in over-all voltages applied to the electrodes do not affect the focussing properties of the electrodes.

In the embodiment of this invention illustrated in Fig. 5, the various electrodes, which may be of the same form and construction as the electrodes in the embodiment shown in Figs. 1 and 2, are arranged in somewhat honeycomb fashion so that the dimensions of the multiplier are relatively small and a compact structure is obtained. The multiplier may be connected in circuit and operated in the same manner as that shown in Figs. 1 and 2.

Although specific embodiments of this invention have been shown and described, it will be understood, of course, that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An electron multiplier comprising a primary cathode, an auxiliary cathode in cooperative relation with said primary cathode and having an emissive portion facing toward said primary cathode, a second auxiliary cathode in cooperative relation with said first auxiliary cathode and having an emissive portion at substantially right angles to said first emissive portion, and a collector electrode in cooperative relation with said second auxiliary cathode, said emissive portions being substantially plane and said second auxiliary cathode being offset diagonally with respect to said first auxiliary electrode.

2. An electron multiplier in accordance with claim 1 comprising means integral with said primary cathode and means integral with each of said auxiliary cathodes for confining the electrons emitted from each of said cathodes to restricted paths toward the electrode in cooperative relation therewith.

3. An electron multiplier in accordance with claim 1 comprising field plates at opposite sides of said emissive portions of said auxiliary cathodes, and a plurality of baffle members, one for each of said portions, each extending from the corresponding one of said portions toward the preceding cathode.

4. An electron multiplier comprising a primary cathode having a substantially plane electron emitting portion, an auxiliary electrode having a substantially plane secondary electron emitting surface facing toward, diagonally offset with respect to, and at right angles to said portion, a second auxiliary electrode having a substantially plane secondary electron emitting surface facing toward, diagonally offset with respect to, and at substantially right angles to said first surface, and a collector electrode in cooperative relation with said second surface.

5. An electron multiplier in accordance with claim 4 comprising means electrically integral with said auxiliary electrodes and at opposite ends of said surfaces for confining the electron streams emanating from said surfaces.

6. An electron multiplier in accordance with claim 4 comprising a baffle member extending from the emitting surface of each of said auxiliary cathodes, at an angle thereto and toward the preceding cathode.

7. An electron multiplier in accordance with claim 4 comprising field plates at opposite ends of said surfaces, and a baffle member electrically integral with each of said auxiliary cathodes extending from the emitting surface thereof and toward the preceding cathode.

8. An electron multiplier comprising a primary cathode, a collector electrode, a plurality of superposed, electrically separate substantially parallel plate members having corresponding surfaces thereof coated with a secondary electron emissive material, and a plurality of other superposed substantially parallel plate members in staggered relation with said first plate members and at substantially right angles thereto, each of said other plate members having the surface thereof toward said first plate members coated with a secondary electron emissive material.

9. An electron multiplier in accordance with claim 8 comprising baffle members electrically integral with said first plate members and substantially parallel to said other plate members.

10. An electron multiplier in accordance with claim 8 comprising a plurality of baffle members each electrically integral with a corresponding one of said first and said other plate members, the baffle members integral with said first plate members being substantially parallel to said other plate members, and the baffle members integral with said other plate members being substantially parallel to said first plate members.

11. An electron multiplier comprising a primary cathode, a collector electrode, a plurality of electrically separate auxiliary electrodes each having a substantially plane secondary electron emissive portion, and an equal number of other auxiliary electrodes in staggered relation with said first auxiliary electrodes and each having a substantially plane secondary electron emissive portion in cooperative relation with and at substantially right angles to the emissive portion of

a corresponding one of said first auxiliary electrodes.

12. An electron multiplier comprising a primary cathode, a collector electrode, and a pair of rows of successively mounted auxiliary electrodes between said primary cathode and said collector electrode, the electrodes in each of said rows being in staggered relation with the electrodes in the other of said rows, and each of said auxiliary electrodes including a secondary electron emissive portion and a substantially plane baffle portion extending from one edge of the electron emissive portion and toward the opposite row, both said portions of said auxiliary electrodes being oblique with respect to the corresponding portion of the next preceding electrode.

13. An electron multiplier comprising a primary cathode, a collector electrode, a plurality of successively disposed auxiliary electrodes between said primary cathode and said collector electrode, each having a secondary electron emissive surface, the secondary electron emissive surface of each of said auxiliary electrodes except the auxiliary electrode nearest said primary cathode being oblique to the emissive surface of the next preceding auxiliary electrode, and reticulated screen members between the emissive surfaces of successive auxiliary electrodes and each overlying one of said surfaces, each screen member being electrically integral with a corresponding one of said auxiliary electrodes.

14. An electron multiplier comprising a primary cathode, a collector electrode, and a plurality of auxiliary electrodes mounted successively in staggered relation between said primary cathode and said collector electrode, each of said auxiliary electrodes having a secondary electron emissive portion, a baffle member extending toward the preceding electrode and a grid portion opposite said first portion, the electron emissive portions of successive auxiliary electrodes being oblique to one another.

15. An electron multiplier comprising a primary cathode, a collector electrode, and a plurality of auxiliary electrodes mounted successively in staggered relation between said cathode and said collector electrode, each of said auxiliary electrodes including a portion adapted to emit secondary electrons, field members at opposite ends of said portion, a baffle member extending from said portion and at an angle thereto toward the preceding electrode, and a grid extending from said baffle member and opposite said portion.

16. An electron multiplier in accordance with claim 15 wherein the emissive portions of alternate auxiliary electrodes are substantially parallel and the emissive portions of successive electrodes are at substantially right angles to one another.

17. An electron multiplier comprising a unitary cathode structure including a secondary electron emissive member and a reticulated member spaced from, overlying and substantially parallel to the emissive surface of said secondary electron emissive member and electrically integral therewith.

18. An electron multiplier comprising a unitary cathode structure including a plate member having a secondary electron emissive surface, electron confining field plates extending from two opposite edges of said emissive surface, a baffle extending from another edge of said surface and at an angle thereto, and a screen overlying said emissive surface.

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