Dec. 2, 1941. G. B. BANKS 2,264,269

ELECTRON MULTIPLIER DISCHARGE DEVICE

Filed July 13, 1938

Fig. 1

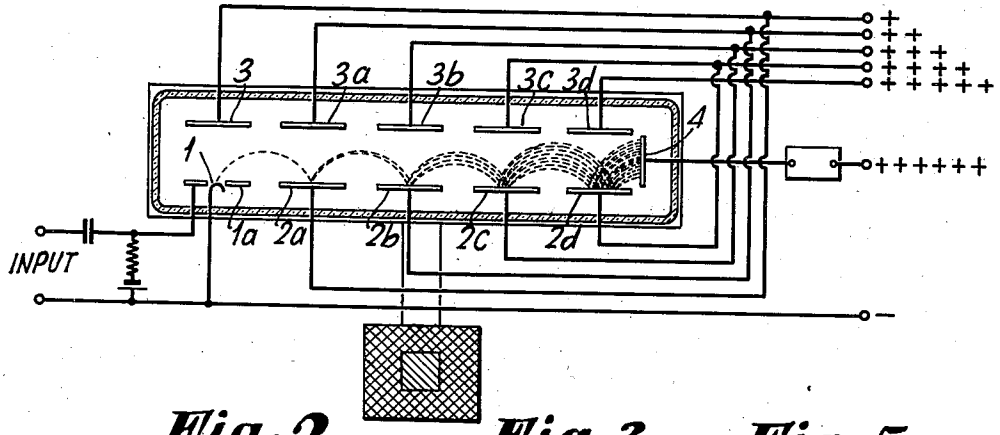


Fig. 2

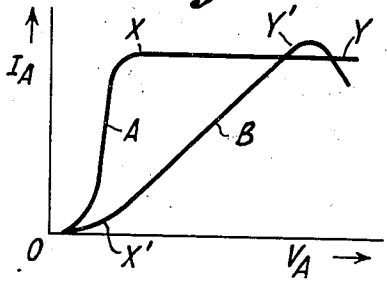


Fig. 3

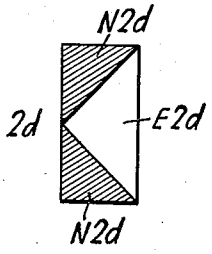


Fig. 5

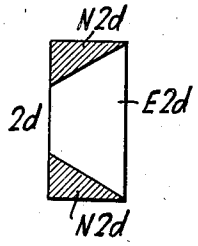
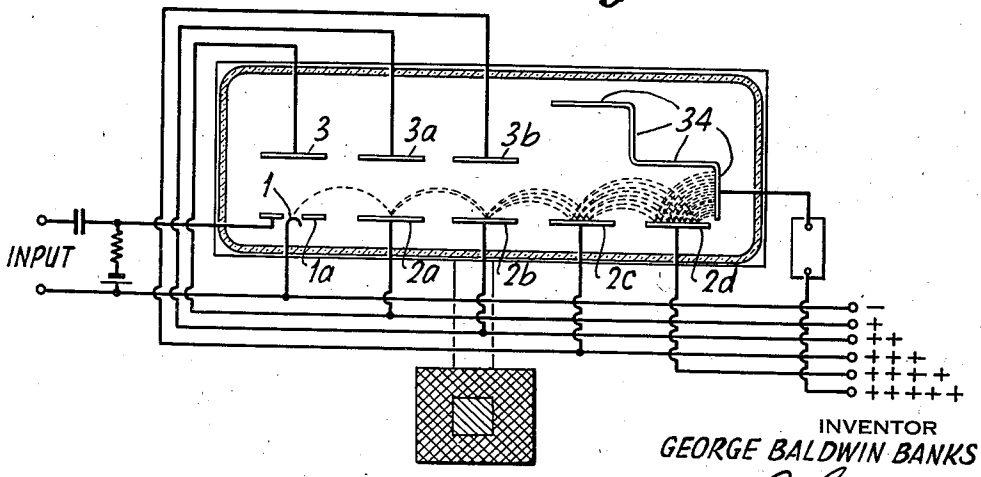


Fig. 4



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Patented Dec. 2, 1941

2,264,269

UNITED STATES PATENT OFFICE

2,264,269

ELECTRON MULTIPLIER DISCHARGE DEVICE

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Application July 13, 1938, Serial No. 218,982
In Great Britain July 15, 1937

11 Claims. (Cl. 250—175)

This invention relates to electron discharge devices and more specifically to electron discharge devices of the electron multiplier type, that is to say electron discharge devices of the kind wherein a primary electron stream is multiplied one or more times by secondary emission effects to produce an amplified final electron current.

There are numerous known forms of electron multipliers but a common difficulty presented by all known electron multipliers as at present in use, is that the anode or output impedance is very high—approaching infinity. This, of course, constitutes a serious practical limitation because the obtaining of substantial power output from an electron discharge device involves that the load or utilization circuit be matched to the impedance of the said device, and if, as is the case with known electron multipliers, the anode or output impedance approaches infinity, it becomes practically impossible to match a loudspeaker, tank circuit, or other ordinary load to the device.

The principal object of the present invention is to avoid this limitation and to enable electron multipliers to be produced having output or anode impedance of desired convenient values. As will be seen later, the present invention enables electron multipliers to be made with either positive or negative resistance characteristics. In general, however, the most important use of the invention will be to provide electron multipliers of relatively low output impedance.

As is well known the ordinary known electron multiplier includes a primary cathode source, a control electrode, a final output electrode, and in succession between said source and said output electrode one or more similar secondary emissive electrodes which are substantially uniformly secondarily emissive over their whole operating surfaces. Electrons impinge on these emitters to release secondary electrons in multiplied quantity, electrons from the primary cathode travelling to the first secondary emitter electrode, secondary electrons from which pass to the next secondary emitter electrode, and so on, until the final output electrode is reached.

According to this invention at least the last secondary emitter electrode (i. e. that electrode from which secondary electrons pass to the final output electrode) is not made as has hitherto been usual of substantially uniform secondary emitting qualities over its whole operating surface, but is made more highly secondarily emissive over a predetermined selected part or parts of its surface than elsewhere, the choice of the selected more highly emissive part or parts being made in accordance with the operating characteristic required.

In order that the invention may be the better understood reference to the drawing will be made, in which

Figure 1 shows a known electron multiplier for explaining the invention,

Fig. 2 shows graphically a representation between voltage and current for explaining the theory of operation of the invention;

Figs. 3 and 5 show electrode structures for use in the electron multiplier, while

Fig. 4 shows an embodiment of the invention utilizing the new and improved form of electrodes.

In the known electron multiplier referred to and represented schematically in Figure 1 there is employed a primary cathode **1**, a control electrode **1***a*, a plurality of secondary emitter electrodes **2***a*, **2***b*, **2***c*, **2***d*, a plurality of field electrodes **3**, **3***a*, **3***b*, **3***c*, **3***d* and an output electrode **4**. Input potentials to be amplified may be applied as indicated at Input between the electrodes **1** and **1***a*. The surface which may be regarded as the effective plane of emission of primary electrons, and the secondary emitter electrodes **2***a* to **2***d* lie substantially in line and in one plane and the field electrodes **3** to **3***d* lie substantially in line and in a parallel plane, one field electrode **3** being opposite the primary cathode **1** and each remaining field electrode **2***a*, **3***b*, **3***c*, **3***d*, being each opposite the corresponding secondary emitter electrode **2***a*, **2***b*, **2***c* or **2***d*. The output electrode **4** is in a plane at right angles to the two parallel planes already mentioned, lying adjacent the last field electrode **3***d* and the last secondary emitter electrode **2***d* and a little outwardly of the space between the two. In use the field electrode **3** opposite the primary cathode **1** is connected to the first secondary emitter electrode **2***a*, the next field electrode **3***a* is connected to the second secondary emitter electrode **2***b*, and so on, increasing positive potentials being supplied to successive secondary emitter electrodes and the maximum positive potential being applied to the output electrode. A magnetic field is applied to thread the space between the "sheet" of field electrodes and the "sheet" of secondary emitter electrodes, the whole arrangement being such that the electrons travel (as indicated in broken lines) in more or less cycloidal paths from the primary cathode **1** to the first secondary emitter electrode **2***a*, thence to the second secondary

emitter electrode 2*b* and so on from electrode to electrode until the output electrode 4 is reached.

If a curve connecting output electrode current (I_A—ordinates) and output electrode voltage (V_A—abscissae) for a known multiplier as illustrated in Figure 1 be plotted, a curve of the type illustrated by the curve A of the accompanying Figure 2 will be obtained. The current I_A rises steeply to a maximum value X and then proceeds substantially horizontally as represented at XY for increasing values of output electrode voltage. The useful portion of this characteristic curve is the substantially horizontal portion XY which, being substantially horizontal, represents an output impedance of substantially infinity.

In accordance with this invention the above described known electron multiplier is modified by making the final secondary emitter electrode—that is to say the electrode 2*d* which is nearest the output electrode—not of substantially uniform secondary emitting properties over its whole surface, but much more highly secondary emitting over parts of its surface than over other parts.

Electrode 2*d* may be a composite electrode made partly of silver and partly of some other metal so that when sensitized the emission from the silver portion is considerably greater than from the other portion. The electrode 2*d*, which is assumed to be rectangular in shape, as in the usual way, may be as shown in face view in the accompanying Figure 3 and have its highly emissive portion E2*d* (shown plain) of triangular form occupying about half the surface of the whole electrode, this triangular half having its base along one edge of the electrode and its apex at the middle of the parallel edge so that there are left two areas N2*d* (shown shaded) of lower secondary electron emission said areas being right angle triangles with their hypotenuses and apices meeting in that edge of the whole plate in which is the apex of the highly emissive triangle E2*d*. Further the output electrode 4 and the last two field electrodes 3*c* 3*d* instead of being separate and insulated from one another as shown in Figure 1 are connected together and preferably are integral with one another as shown in the accompanying Figure 4 where the composite electrode is marked 34. The separation between the portion of electrode 34 opposite the last secondary emitter electrode and the said last secondary emitter electrode 2*d* is the same as that between electrodes 3 and 1; 3*a* and 2*a*; and 3*b* and 2*b*; but the portion of the composite electrode 34 opposite the penultimate emitter electrode 2*c* is made double that employed elsewhere, i. e. between 3 and 1, 3*a* and 2*a* and 3*b* and 2*b*. Thus in the integral construction of output electrode and last two field electrodes illustrated these three electrodes are constituted by a single plate 34 having three right angled bends in it, one end portion lying in a plane at right angles to two parallel planes in which the intermediate portion and the other end portion (these two portions constitute the two field electrodes) lie. In use the usual magnetic field is applied and the voltage applied to the composite output electrode and last two field electrodes (34) exceeds that applied to the last secondary emitter electrode 2*d* by the same amount as that by which the last mentioned voltage exceeds that applied to the penultimate secondary emitter electrode 2*c* and to the field electrode 3*b* opposite the last secondary emitter but two (2*b*). As will be appreciated, the reason for making the separation of the penultimate field electrode from its opposite secondary emitter electrode twice the separation employed elsewhere is to enable the correct electrostatic field conditions to be obtained despite the fact that the last two field electrodes and the output electrodes are at the same voltage.

In the static condition the potential applied to the output electrode is such that electrons take a mean path and strike the last secondary emitter electrode at its centre line, the secondary emission obtained in this condition being the mean output electrode current. Under dynamic conditions the potential of the output electrode varies about the mean value and the number of electrons released from the last secondary emitter electrode varies accordingly, for, under dynamic conditions the point of impact of electrons on the last secondary emitter electrode depends on the output electrode voltage. If the said voltage is high the substantially cycloidal paths followed by electrons will be long and they will fall on an area of high emissivity, if said voltage is low the paths become shorter and areas of lower emissivity are struck.

By suitably choosing the shape and disposition of the more highly emissive portion or portions of the last secondary emitter electrode 2*d* an output electrode current (I_A—ordinates)—output electrode voltage (V_A—abscissae) curve like that shown by the curve B of Fig. 2 can be obtained this curve comprising a substantially straight rising line X'Y' representing a relatively low finite output impedance.

By differently choosing the arrangement and disposition of the more highly emissive portion or portions of the last secondary emitter electrode, other desired shapes of characteristic may be obtained. For example as shown in the accompanying Figure 5 by making the more highly emissive portion E2*d* of trapezoidal shape with one of the two parallel edges constituted by one edge of the whole plate and the other lying in the other (thus leaving two triangles N2*d* of low emission properties, one at each end) a higher output impedance may be obtained. Again, by reversing the form of final secondary emitter electrode illustrated in Figure 3, that is to say, by making the triangular area E2*d* of Fig. 3 of low emission and the triangular areas N2*d* of Fig. 3 of high emission, a negatively sloping characteristic may be obtained.

In experimental practice with a tube having a final emitter electrode constructed as represented in Fig. 3 an output impedance or characteristic slope of 15,000 ohms was obtained, a figure which is very much lower than is obtained with normal known electron multipliers.

Having now described my invention, what I claim is:

1. An electron multiplier tube comprising a cathode, a control electrode, a first set and a second set of secondary electron emissive plates, both of said sets being co-planar, a plurality of planar electrodes each of said electrodes being parallel to and in register with one of the plates of said first set of plates, and an output electrode positioned beyond said second set of plates, said output electrode having two faces parallel to and another face perpendicular to said second set of plates, the surface of the plate of said second set of plates nearest the perpendicular face of said output electrode having two triangular portions of lower secondary electron emissivity than the

emissivity of the remaining portion of said plate.

2. A tube comprising a primary cathode, a control electrode, a series of secondary emitter electrodes co-planar with one another and with said primary cathode, a plurality of field electrodes, one opposite the primary cathode and one opposite each of the secondary emitter electrodes, and an output electrode substantially at right angles to the plane of said secondary emitter electrodes, said output electrode being at the end of said series remote from the primary cathode and between said plane and a second plane which is parallel thereto all the field electrodes except the last but one being in said second plane the separation between said last but one field electrode and the secondary emitter electrode opposite the same being substantially twice the separation between the two said planes.

3. A tube comprising a primary cathode, a control electrode, a series of secondary emitter electrodes, a series of field electrodes, one adjacent the primary cathode and one adjacent each of the secondary emitter electrodes, and an output electrode, the distance between the penultimate field electrode and the secondary emitter electrode adjacent thereto being substantially twice the distance between any other field electrode and its secondary emitter electrode therewith associated.

4. An electron multiplier tube comprising a cathode, a control electrode, a plurality of pairs of parallel plate electrodes, one plate of each pair being secondary electron emissive, said secondary electron emissive plates being coplanar, an electrode in register with said cathode and said control electrode for directing electrons from the cathode onto one of said secondary electron emissive plates, a planar secondary emissive cathode coplanar with and longitudinally displaced from said secondary electron emissive plates, a second planar secondary electron emissive electrode coplanar with said first named planar electrode, said second planar electrode having a predetermined secondary electron emissivity over a predetermined area of the electrode and a different predetermined secondary emissivity over the remainder of the area of the electrode, and an output electrode having both a face parallel to and in register with each of the two planar secondary emissive electrodes and a face perpendicular to the plane of said planar secondary emissive electrodes.

5. An electron multiplier tube comprising a cathode, a control electrode, a plurality of pairs of parallel plate electrodes, one plate of each pair being secondary electron emissive, said secondary electron emissive plates being coplanar, an electrode in register with said cathode and said control electrode for directing electrons from the cathode onto one of said secondary electron emissive plates, a planar secondary emissive cathode coplanar with and longitudinally displaced from said secondary electron emissive plates, a rectangular secondary electron emissive planar electrode coplanar with said first planar secondary emissive electrode, said rectangular electrode having a triangular area of predetermined secondary electron emissivity and a different predetermined secondary electron emissivity over the remainder of the area of said electrode, and an output electrode having both a face parallel to and in register with each of the two planar secondary emissive electrodes and a face perpendicular to the plane of said planar secondary emissive electrodes.

6. An electron multiplier tube comprising a cathode, a control electrode, a plurality of pairs of parallel plate electrodes, one plate of each pair being secondary electron emissive, said secondary electron emissive plates being coplanar, an electrode in register with said cathode and said control electrode for directing electrons from the cathode onto one of said secondary electron emissive plates, a planar secondary emissive cathode coplanar with and longitudinally displaced from said secondary electron emissive plates, a rectangular secondary electron emissive planar electrode coplanar with said first planar secondary emissive electrode, said rectangular electrode having a trapezoidal area of predetermined secondary electron emissivity and a different predetermined secondary electron emissivity over the remainder of the area of said electrode, and an output electrode having both a face parallel to and in register with each of the two planar secondary emissive electrodes and a face perpendicular to the plane of said planar secondary emissive electrodes.

7. An electron multiplier tube comprising a cathode, a control electrode, a first set and a second set of secondary electron emissive plates, both of said sets being co-planar, a plurality of planar electrodes each of said electrodes being parallel to and in register with one of the plates of said first set of plates, and an output electrode positioned beyond said second set of plates, said output electrode having two faces parallel to and another face perpendicular to said second set of plates.

8. An electron multiplier tube comprising a cathode, a control electrode, a first set and a second set of secondary electron emissive plates, both of said sets being co-planar, a plurality of planar electrodes, each of said electrodes being parallel to and in register with one of the plates of said first set of plates, a further electrode in register with said cathode and control electrode for directing electrons from said cathode onto one of the plates of said first set of plates, and an output electrode positioned beyond said second set of plates, said output electrode having two faces parallel to and another face perpendicular to said second set of plates.

9. An electron multiplier tube comprising a cathode, a control electrode, a first set and a second set of secondary electron emissive plates, both of said sets being co-planar, a plurality of planar electrodes, each of said electrodes being parallel to and in register with one of the plates of said first set of plates, a further electrode in register with said cathode and control electrode for directing electrons from said cathode onto one of the plates of said first set of plates, an output electrode positioned beyond said second set of plates, said output electrode having two faces parallel to and another face perpendicular to said second set of plates, and potential supply leads connected to said cathode, said first set and second set of plates, and all of said electrodes.

10. An electron multiplier tube comprising a cathode, a control electrode, a first set and a second set of secondary electron emissive plates, both of said sets being co-planar with the plates of said second set being progressively longitudinally displaced from said first set, the furthest displaced plate of said second set having a higher secondary electron emissivity over a predetermined selected part of its surface than the emissivity of the remaining part of its surface, the area of the predetermined selected part varying pro-

gressively in the direction of the longitudinal displacement of the plates of said second sets, a plurality of planar electrodes, each of said electrodes being parallel to and in register with each plate of said first set of plates, a further electrode in register with said cathode and control electrode for directing electrons from said cathode onto one of the plates of said first set of plates, and an output electrode positioned beyond said second set of plates, said output electrode having two faces parallel to and another face perpendicular to said furthest displaced plate.

11. A tube as claimed in claim 10 wherein the predetermined selected part is of sensitized silver and the remaining part of said electrode is of a different metal.

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