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THERMIONIC VALVE UTILIZING SECONDARY
ELECTRON EMISSION AMPLIFICATION
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FIG. 1.

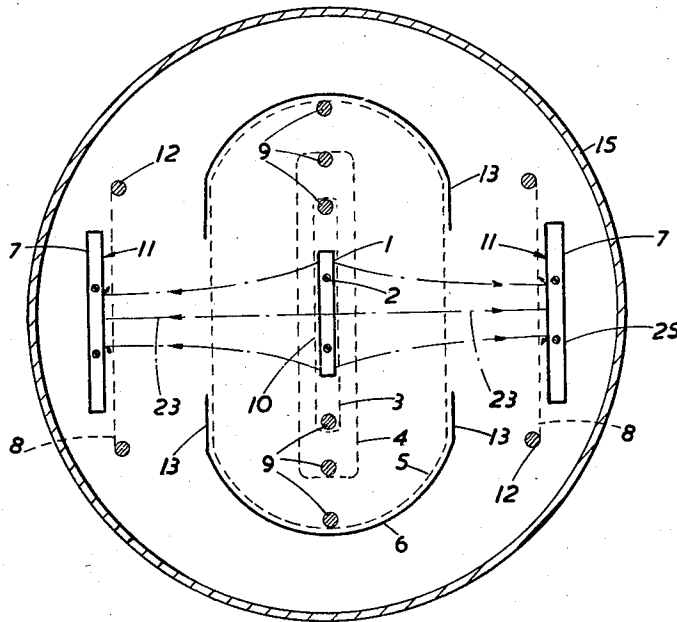
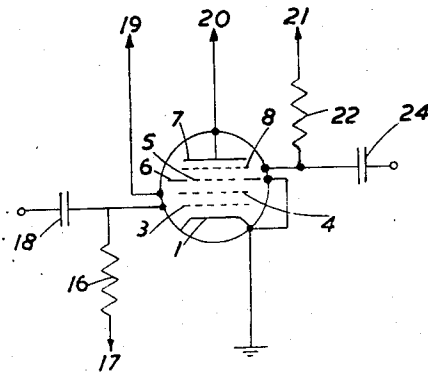


FIG. 2.



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THERMIONIC VALVE UTILIZING SECONDARY ELECTRON EMISSION AMPLIFICATION

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This invention relates to thermionic valves adapted to utilize secondary electron emission for obtaining amplification.

Various proposals have been made heretofore for constructing amplifying valves comprising a thermionic cathode, a control electrode to which signals to be amplified can be applied so as to control the emission of primary electrons from said thermionic cathode, a secondary electron-emitting electrode (referred to hereinafter and in the claims as a secondary cathode) on which the primary electrons are caused to impinge so that a greater number of secondary electrons are emitted than there are impinging primary electrons, and a collecting electrode for collecting the secondary electrons so that the amplified signals can be obtained from a load impedance connected to the collecting electrode.

The object of the present invention is to provide an improved and simplified thermionic valve which operates with secondary electron emission and such as is suitable for use as an amplifying valve.

According to the present invention there is provided a thermionic valve adapted to utilize secondary electron emission for obtaining amplification comprising a thermionic cathode and a secondary cathode between which there is provided a rectilinear space current path along which electrons emitted from said thermionic cathode can pass to bombard said secondary cathode to cause the emission therefrom of secondary electrons, a control electrode capable of controlling the emission of electrons from said thermionic cathode, and a collecting electrode capable of collecting secondary electrons from said secondary cathode, said control electrode and said secondary electrode being disposed in succession between said thermionic cathode and said secondary cathode and being pervious to electrons flowing in said path, and electron beam-forming means, the arrangement being such that in operation of the valve the electrons emitted from said thermionic cathode are formed by said beam-forming means into a beam of electrons which is caused to flow along said path to said secondary cathode without the beam being deflected.

According to a preferred form of this aspect of the present invention there is provided a thermionic valve adapted to utilize secondary electron emission for obtaining amplification, comprising a thermionic cathode and a secondary cathode between which there is provided a rectilinear space current path along which electrons emitted from said thermionic cathode can pass

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to bombard said secondary cathode to cause the emission therefrom of secondary electrons, a control electrode capable of controlling the emission of electrons from said thermionic cathode, an accelerating electrode capable of accelerating the electrons emitted from said thermionic cathode, and a collecting electrode capable of collecting secondary electrons from said secondary cathode, said control electrode, accelerating electrode and collecting electrode being disposed in succession between said thermionic cathode and said secondary cathode and being pervious to electrons flowing in said path, and electron beam-forming means disposed between said accelerating electrode and said collecting electrode, the arrangement being such that in operation of the valve the electrons emitted from said thermionic cathode are formed by said beam-forming means into a beam of electrons which is caused to flow along said path to said secondary cathode without the beam being deflected.

According to another aspect of the present invention there is provided a thermionic valve adapted to utilize secondary electron emission for obtaining amplification, comprising a thermionic cathode and a secondary cathode between which there is provided a rectilinear space current path along which electrons emitted from said thermionic cathode can pass to bombard said secondary cathode to cause the emission therefrom of secondary electrons, a control electrode capable of controlling the emission of electrons from said thermionic cathode, and a collecting electrode capable of collecting secondary electrons from said secondary cathode, said secondary cathode having a coating of secondary electron emitting material therefrom which comprises refractory oxides, 20 to 50 per cent of the total weight of said refractory oxides being alkaline earth oxide.

During the manufacture of valves which are adapted to utilize secondary electron emission it is desirable to activate both the primary and secondary electron-emitting electrodes by heating them in vacuo to a relatively high temperature, but if as in the example described in the preceding paragraph there is a rectilinear path between the thermionic cathode and a secondary cathode there is a risk of one of said cathodes being contaminated by the deposition of matter driven off from the other cathode during activation thereof.

Therefore the object of another feature of the invention is to provide an improved method of activating the electron emitting electrodes of

thermionic valves adapted to utilize secondary electron emission, with a view to reducing the risk referred to.

According to said feature of the present invention there is provided a method of activating the electrodes of a thermionic valve adapted to utilize secondary electron emission for obtaining amplification and which comprises a thermionic cathode and a secondary cathode, wherein said cathodes are heated simultaneously to such temperatures that the contamination of one of said cathodes by matter driven off by heating said other cathode is effectively avoided and the heating of said cathodes is simultaneously discontinued.

The heating of the secondary cathode may be effected wholly or in part by bombardment with electrons liberated from the thermionic cathode in which case of course the secondary cathode will attain its activating temperature later than the thermionic cathode, but this is immaterial provided the heating of the two electrodes is discontinued simultaneously. The secondary cathode may alternatively or additionally be heated by means of a separate heater.

In order that the said invention may be clearly understood and readily carried into effect, the same will now be more fully described with reference to the accompanying drawing, wherein—

Figure 1 illustrates diagrammatically in transverse section a thermionic valve in accordance with one example of the present invention, and

Figure 2 is a symbolic diagram illustrating a circuit arrangement embodying the valve illustrated in Figure 1.

Referring to the drawing, the valve comprises a tubular thermionic cathode 1 of rectangular section and enclosing a heater 2, a control electrode 3, an accelerating electrode 4, a suppressor electrode 5, two electron beam-forming plates 6, two secondary cathodes 7 and two collecting electrodes or anodes 8. The electrodes 3, 4 and 5 comprise wire wound grids surrounding the cathode 1 and supported in known manner on rods 9, while the cathode has two substantially plane surfaces 10 coated with thermionic electron-emitting material. The surfaces 10 face the secondary electron-emitting surfaces 11 of the secondary cathodes 7, the latter surfaces being also plane and coated with a suitable secondary electron-emitting material comprising, as described in the United States Patent application Ser. No. 711,860, refractory oxides 20 per cent to 50 per cent of the total weight of which is alkaline earth oxide, the expression "alkaline earth oxide" being intended to apply only to the oxides of calcium, strontium and barium. Preferably the coating material comprises magnesium oxide and barium oxide, the latter oxide constituting from 20 per cent to 50 per cent of the total weight of the latter two oxides, as described in the aforesaid co-pending United States application, and preferably also the coating is at least 10^{-4} inches thick. The collecting electrodes 8 comprise planar wire grids arranged in front of the surfaces 11 of the secondary cathodes 7 and parallel thereto, the collecting electrodes 8 being supported on rods 12. As can be seen in the drawing there is a rectilinear space current path between each surface 10 and the corresponding surface 11 and such electrodes as are disposed in said path are pervious to electrons, so that effectively said path is uninterrupted. The beam-forming plates 6 are of curved section as shown having inturned extensions 13, such that there

are extensions 13 on opposite sides of the path between each surface 10 of the thermionic cathode 1 and each surface 11 of the secondary cathodes 7, the plane of the extensions being normal to said path. The electrodes are of course supported in known manner within an evacuated glass envelope which is shown in section at 15.

In utilizing the valve illustrated in Figure 1 as an amplifying valve it may for example be embodied in a circuit such as illustrated in Figure 2, and, for convenience, only one of the secondary cathodes 7 and one of the collecting electrodes 8 is indicated in the valve in Figure 2. As shown therein the suppressor electrode 5, the plates 6 and hence also the extensions 13 are maintained at the potential of the cathode 1, which is earthed in this example. The control electrode 3 is connected via a leak resistance 16 to a source of bias potential of about 1.5 to 2 volts negative indicated diagrammatically by the arrow 17, while the signals to be amplified can be applied to the control electrode via the coupling condenser 18. The accelerating electrode 4 is connected to a source 19 of positive potential of say 250 volts positive, the secondary cathodes 7 are connected to a source 20 of positive potential, also of 250 volts for example, while the collecting electrodes 8 are connected to a source 21 of positive potential of say 350 volts positive via a load resistance 22. The load resistance 22 may alternatively be connected in the external lead to the secondary cathode, but it will be appreciated that in either case the load impedance is connected in the anode-to-secondary cathode circuit of the valve. Where necessary the electrodes of the valve will be decoupled in known manner but in the interests of clearness such decoupling is not illustrated in the drawing. In operation of the valve the plates 6 and with them the extensions 13 serve, in conjunction with the other electrodes, to concentrate the electrons emitted from each surface 10 of the thermionic cathode and so form two beams, indicated at 23 in Figure 1, which without being deflected flow along the rectilinear paths between the surfaces 10 and the surfaces 11 and bombard the latter surfaces, whereby more than one secondary electron is emitted by each bombarding electron. The secondary electrons are collected by the collecting electrodes 8. The number of electrons in the beams 23 is controlled by the signals applied to the control electrode 3, and an amplified output of said signals is set up across the resistance 22 and can be fed by means of a condenser 24 to a subsequent stage. The collecting electrodes 8 are arranged close to the emitting surfaces 11 of the secondary cathodes 7, at say between 0.5 and 1 mm. from said surfaces, so as to provide a high field intensity at said surfaces 11 since it is found that with a greater separation between the collecting electrodes 8 and the emitting surfaces of the secondary cathodes 7 a higher positive potential is required at the collecting electrodes 8 in order to saturate the secondary electron current in the device.

During the manufacture of the valve, after the electrodes have been mounted in the envelope 15 and the envelope evacuated, activation of the thermionic cathode 1 and the secondary cathodes 7 is effected by heating in such manner that finally, at least, the electrodes 1 and 7 are maintained simultaneously at about 1100° C. for about 2 minutes. Bombardment with primary electrons emitted from the thermionic cathode 1 may be utilized for heating the cathode 7 but the electrodes 7 may if desired be provided with

separate heaters, in which case, as shown in the drawing, the electrodes 7 are preferably tubular and of rectangular section, with heaters 25 provided in the interior of the electrodes. It is also possible to utilize eddy current heating for activating the secondary cathodes 7.

The construction illustrated in the drawing enables the size of the valve to be considerably reduced and its manufacture simplified in comparison, for example, with the valve illustrated in United States patent application Ser. No. 695,531, while at the same time similar operating characteristics can be obtained. For example a slope of 14 milliamperes per volt has been obtained with valves of the kind illustrated in the drawing, the anode current being about 15 milliamperes and the valve being dimensioned to give a current in the electron beams impinging on the electrodes 7 of about 5 milliamperes per square centimeter of the total emitting surface.

Modifications may of course be made of the construction illustrated; for example the thermionic cathode 1 may have other than planar-emitting surfaces, for instance the cathode may be of circular section, and the beam forming plates 6 may be replaced by conductive rods, while in some cases the suppressor electrode 5 may be dispensed with. Moreover, the secondary electron-emitting surfaces 11 of the secondary cathodes 7 may be other than planar, for example they may be convex as seen from the thermionic cathode.

What I claim is:

1. In an amplifying circuit, a thermionic valve adapted to utilize secondary electron emission for obtaining amplification, comprising a thermionic cathode and a secondary cathode between which there is provided a rectilinear space current path along which electrons emitted from said thermionic cathode pass to bombard said secondary cathode to cause the emission therefrom of secondary electrons, a control electrode for controlling the emission of electrons from said thermionic cathode, a collecting electrode for collecting secondary electrons from said secondary cathode, and electron beam-forming means for forming the electrons emitted from said thermionic cathode into a beam of electrons caused to flow without substantial deflection along said path to impinge on said secondary cathode with a density of the order of 5 milliamperes per square cm. of emitting surface of said secondary cathode, said secondary cathode being provided with an electron-emissive coating which is at least 10^{-4} inches thick and consisting of refractory oxide material.

2. A thermionic valve adapted to utilize secondary electron emissive for obtaining amplification, comprising a thermionic cathode, a secondary cathode facing the electron emissive surface of said thermionic cathode, a control electrode for controlling the emission of electrons from said thermionic cathode, a collecting electrode for collecting secondary electrons from said secondary cathode, said control electrode and collecting electrode being disposed in succession between said thermionic cathode and said secondary cathode and being pervious to electrons to provide a substantially rectilinear space current path between said cathodes, and said secondary cathode comprising a conductive support provided with secondary electron-emissive coating at least 10^{-4} inches thick and consisting of a mixture of magnesium oxide and barium

oxide, the barium oxide constituting from 20 to 50 percent of said mixture.

3. In an amplifying circuit, a thermionic valve adapted to utilize secondary emission for obtaining amplification, comprising a thermionic cathode and a secondary cathode, between which there is provided a rectilinear space current path along which electrons emitted from said thermionic cathode pass to bombard said secondary cathode to cause the emission therefrom of secondary electrons, a control electrode for controlling the emission of electrons from said thermionic cathode in response to signals applied to said circuit, an accelerating electrode for accelerating electrons emitted from said thermionic cathode, and a collecting electrode for collecting secondary electrons from said secondary cathode, said control electrode, accelerating electrode and collecting electrode being disposed in succession between said thermionic cathode and said secondary cathode and being pervious to electrons flowing in said path, and electron beam forming means disposed between said accelerating electrode and said collecting electrode to form primary electrons emitted from said thermionic cathode into a beam of electrons caused to flow without substantial deflection along said path and to impinge on said secondary cathode with a density of about 5 milliamperes per square cm. of emitting surface of said secondary cathode.

4. A thermionic electron discharge valve constructed to utilize secondary-electron emission for obtaining amplification, said valve including a thermionic cathode having an electron emissive surface, and a secondary cathode comprising a conductive support and a secondary-electron emissive coating on a surface of said support, said coating comprising refractory oxides of which from 20 to 50 per cent is alkaline earth oxide, and said support being disposed with said second surface in a direct electron path from said first surface.

5. A valve according to claim 4, comprising beam forming means disposed between said thermionic cathode and said secondary cathode for forming electrons emitted from said first surface into a beam of electrons directed to said second surface.

6. A thermionic electron discharge valve constructed to utilize secondary-electron emission for obtaining amplification, and said valve including a thermionic cathode having an electron emissive surface, and a secondary cathode comprising a conductive support and a secondary-electron emissive coating at least 10^{-4} inches thick on a surface of said support, said coating comprising refractory oxides of which from 20 to 50 per cent is alkaline earth oxide, and said support being disposed with said second surface in a direct electron path from said first surface.

7. A thermionic electron discharge valve constructed to utilize secondary-electron emission for obtaining amplification, said valve including a thermionic cathode having an electron emissive surface, and a secondary cathode comprising a conductive support and a secondary-electron emissive coating on a surface of said support, said coating consisting of magnesium oxide and barium oxide, said barium oxide constituting from 20 to 50 per cent by weight of the coating, and said support being disposed with said second surface in a direct electron path from said first surface.

8. An amplifying circuit embodying a ther-

mionic electron discharge valve constructed to utilize secondary-electron emission for obtaining amplification, said valve comprising at least a thermionic cathode having an electron emissive surface, a secondary cathode having a secondary-electron emissive surface facing said first surface, a control electrode for controlling the emission of electrons from said first surface in response to signals applied to said circuit, an accelerating electrode, a collecting electrode, said control electrode, accelerating electrode and collecting electrode being arranged in succession between said thermionic cathode and said secondary cathode and being pervious to electrons to provide a rectilinear electron path between said cathodes, beam forming members for forming electrons emitted from said first surface into a beam of electrons directed along said path to said second surface, said members being disposed on opposite sides of said paths between said accelerating electrode and collecting electrode and next adjacent said collecting electrode, and means maintaining positive potentials with reference to said thermionic cathode at said accelerating electrode, secondary cathode and collecting electrode, with the last electrode most positive, whereby secondary electrons from said secondary cathode are collected mainly by said collecting electrode.

9. A circuit according to claim 8, said secondary cathode comprising a conductive support having a surface facing said first surface, and a coating of secondary electron emissive material on said surface of the support, said coating comprising refractory oxides of which from 20 to 50 per cent is alkaline earth oxide.

10. An amplifying circuit embodying a thermionic electron discharge valve constructed to utilize secondary-electron emission for obtaining amplification, said valve comprising at least a thermionic cathode having an electron emissive surface, a secondary cathode having a planar secondary-electron emissive surface facing said first surface, a control electrode for controlling the emission of electrons from said first surface in response to signals applied to said circuit, an accelerating electrode, a planar apertured collecting electrode parallel to said second surface, said control electrode, accelerating electrode and collecting electrode being arranged in succession between said thermionic cathode and said secondary cathode and being pervious to electrons to provide a rectilinear electron path between said surfaces, beam forming means for forming electrons emitted from said first surface into a beam of electrons directed along said path to said second surface, said means being disposed between said accelerating electrode and collecting electrode and next adjacent to said collecting electrode, and means maintaining positive potentials with reference to said thermionic cathode at said accelerating electrode, secondary cathode and collecting electrode with the last electrode most positive, whereby secondary electrons from said secondary cathode are collected mainly by said collecting electrode.

11. A circuit according to claim 10, said secondary cathode comprising a conductive support having a planar surface facing and parallel with said first surface, and a secondary electron emissive coating on said support surface, said coating consisting of magnesium oxide and barium oxide of which from 20 to 50 per cent by weight is barium oxide.

12. A circuit according to claim 11, said coating being at least 10^{-4} inches thick.

13. An amplifying circuit embodying a thermionic electron discharge valve constructed to utilize secondary-electron emission for obtaining amplification, said valve comprising at least a thermionic cathode having an electron emissive surface, a secondary cathode having a planar secondary-electron emissive surface facing said first surface, a control electrode for controlling the emission of electrons from said first surface in response to signals applied to said circuit, an accelerating electrode, a planar apertured collecting electrode parallel to said second surface, said control electrode, accelerating electrode and collecting electrode being arranged in succession between said thermionic cathode and said secondary cathode and being pervious to electrons to provide a rectilinear electron path between said surfaces, and beam forming means disposed between said accelerating electrode and collecting electrode and next adjacent to said collecting electrode for forming electrons emitted from said first surface into a beam of electrons flowing without substantial deflection along said path to impinge on said second surface with a density of about 5 milliamperes per square centimeter of said second surface.

14. An amplifying circuit embodying a thermionic electron discharge valve constructed to utilize secondary-electron emission for obtaining amplification, said valve comprising at least a thermionic cathode having an electron emissive surface, a secondary cathode having a secondary-electron emissive surface facing said first surface, a control electrode for controlling the emission of electrons from said first surface in response to signals applied to said circuit, an accelerating electrode, a collecting electrode, said control electrode, accelerating electrode and collecting electrode being arranged in succession between said thermionic cathode and said secondary cathode and being pervious to electrons to provide a rectilinear electron path between said cathodes, beam forming members for forming electrons emitted from said first surface into a beam of electrons directed along said path to said second surface, said members being disposed on opposite sides of said paths between said accelerating electrode and collecting electrode and next adjacent said collecting electrode, means for maintaining said beam forming members at the same potential as that of said thermionic cathode, and means maintaining positive potentials with reference to said thermionic cathode at said accelerating electrode, secondary cathode and collecting electrode with the last electrode most positive.

15. A circuit according to claim 14 comprising a suppressor electrode in said valve disposed between said accelerating electrode and said beam forming members, and means for maintaining said suppressor electrode at the same potential as that of said beam forming members.

16. A thermionic electron discharge valve constructed to utilize secondary-electron emission for obtaining amplification, said valve including a thermionic cathode having an electron emissive surface, a secondary cathode comprising a conductive support and a secondary-electron emissive coating on a surface of said support, said coating comprising refractory oxides of which from 20 to 50 per cent is alkaline earth oxide and said support being disposed with said second surface in a direct electron path from said first surface, and said thermionic cathode and said secondary cathode being arranged for simultaneous heating to such temperatures that contamination of one of said cathodes by matter driven off

by heating the other of said cathodes is effectively avoided, the heating of said cathodes being simultaneously discontinued.

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