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G. H. ROBERTSON

2,905,852

ELECTRON DISCHARGE DEVICE

Filed June 15, 1954

FIG. 1

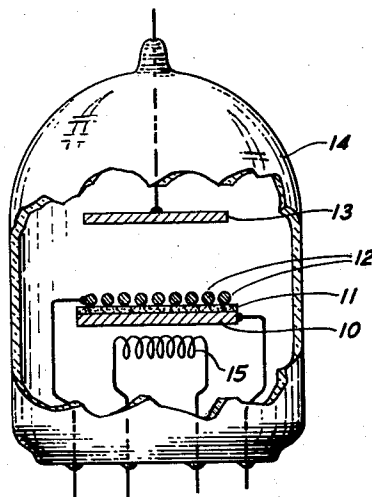


FIG. 2

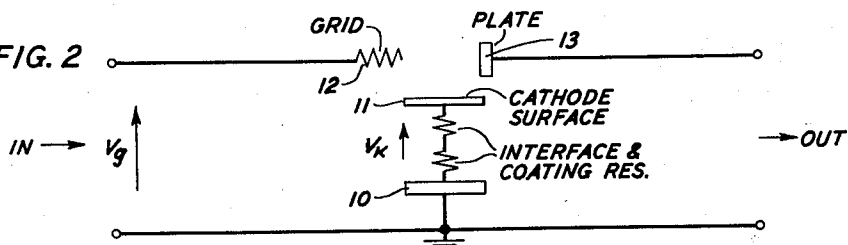


FIG. 3

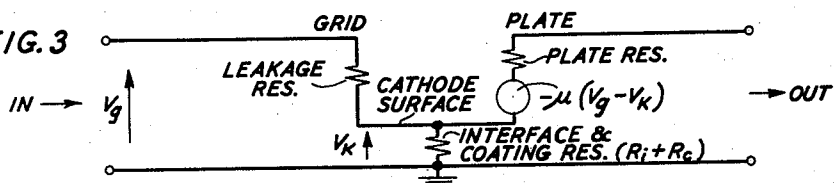


FIG. 4

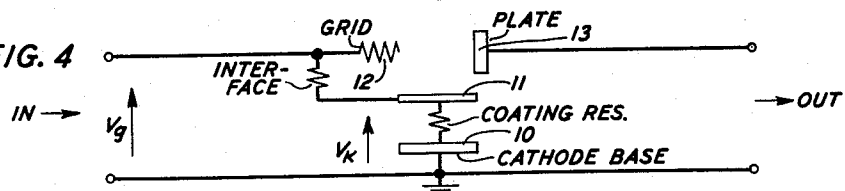
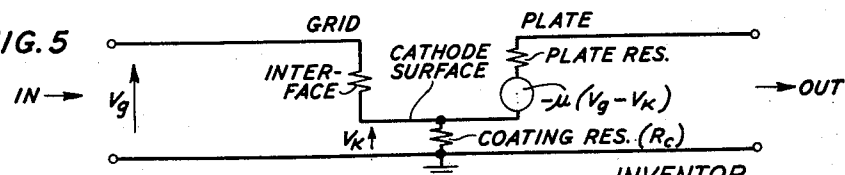


FIG. 5



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2,905,852

ELECTRON DISCHARGE DEVICE

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Application June 15, 1954, Serial No. 436,802

5 Claims. (Cl. 313—346)

This invention relates to electron discharge devices and more particularly to the activation of oxide coated cathodes in discharge devices wherein the control grid laterals are in direct contact with the cathode coating.

In accordance with conventional practices, cathodes for space discharge devices frequently are prepared by coating the metallic base or core element with an emissive layer of one or more of the alkaline earth metal compounds as, for example, the carbonates of barium, strontium and calcium, which are then heated to be broken down to the oxides. During the operation of the discharge devices, the oxide coatings are activated by reduction as reducing agents in the cathode core metal diffuse or migrate up to the emissive coating on the core and react with the oxides to produce the free metal, such as barium and the like, necessary for desirable cathode emission. The oxygen set free from the oxides as a result of this reaction combines with the reducing agents and forms a cathode interface layer at the boundary between the coating and the core.

The existence of this interface sometimes results in a number of disadvantages in the operation of space discharge devices. For example, the interface layers occurring between the oxide coating and the core metal may make further reduction of the emissive layer metal oxide to free metal more and more difficult by hindering the migration therethrough of the reducing agents in the cathode base. In addition to impairing the emissivity of the cathode, the interface layer can be further detrimental because the electrical resistance of the layer may be much higher than that of the oxide coating itself. Thus, the interface can impose severe limitations on low frequency signals in the signal path.

Further, the core metal-interface layer-oxide coating system may act like a rectifier due to the fact that it can be, in essence, a layer of metal and a semi-conductor having between them a layer of high resistance. Electrons in such a system preferably pass in the direction from semi-conductor to metal, for the resistance to electrons from the core to the coating is several times higher than that to electrons in the opposite direction. Thus, as the interface resistance renders passage of electrons from the core metal to the coating more difficult the drawing of high emission currents from the cathode may be greatly inhibited. In those cases where the cathode has to supply high peak currents, it becomes especially important to avoid as much as possible the formation of the interface layer.

A still additional disadvantage of the interface can be that it is incapable of combining with the emissive coating material and a consequent inadhesion of the coating with respect to the core may occur. This could cause a partial, or possibly a complete, separation of the emissive coating and the cathode core with a resultant disruption in the operation of the discharge device.

The principal objects of the present invention are to overcome the aforementioned difficulties resulting from

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the cathode interface layer and to provide a reliable and efficient method of supplying the emissive cathode coating with the necessary reducing agents while substantially eliminating the cathode interface.

These and other objects of this invention are attained in accordance with one illustrative embodiment comprising an electron discharge device wherein the grid electrode contains a high proportion of reducing impurities and the cathode core consists of substantially pure metal, the grid laterals being in direct contact with the emissive coating as disclosed in application Serial No. 436,767, filed June 15, 1954, now abandoned, by N. C. Wittwer. Electron tubes of the type disclosed in the Wittwer application comprise a cathode having a metal core, a layer of electron emissive material upon a surface of the metal core and a control electrode in intimate contact with the emissive layer whereby a high value of transconductance is obtained due to the zero spaced relationship of the control grid and the cathode coating. Signals applied between the grid and cathode core are supported by the bulk resistivity or resistance of the coating. As most of the resistance between the grid wires and the metallic cathode is in the region of the coating adjacent the grid wires in these devices, a predominant portion of the input signal is developed between this region and the coating spaces between grid wires, thus enabling grid control of the space current.

In accordance with aspects of this invention, reducing agents are supplied by the grid wires rather than by the metallic core of the cathode. This permits the cathode core to be constructed of a high purity metal, which advantageously may be nickel, and substantially eliminates the cathode interface, thereby resulting in the core having a low resistance contact with the coating in place of the prior objectionable high resistance cathode interface layer. The resistance between the grid wires, which advantageously may also consist of nickel but having therein a high proportion of reducing impurities, and the cathode is greater than that of other tubes having the control grid in contact with the cathode coating due to the grid interface layer created by the migration of the reducing impurities to the cathode. This is especially so since the rectifying barrier so formed offers maximum resistance when the grid is slightly negative with respect to the cathode as in normal use it would be.

In accordance with one feature of this invention, the cathode emissive coating of a discharge device is activated by reducing agents contained in the control electrode of the device.

More specifically, in accordance with a feature of this invention the control electrode, in a discharge device having its cathode and control electrode in direct contact with each other, consists of metal conductors having a high proportion of reducing impurities therein, which impurities migrate to the cathode to activate the emissive coating thereon.

A further feature of this invention pertains to a discharge device in which the cathode coating is activated by impurities contained in the control electrode rather than the cathode core, permitting the core to consist of relatively pure metal thereby eliminating difficulties of the type introduced by the creation of a cathode interface layer.

A complete understanding of these and other various features of this invention may be gained from a consideration of the following detailed description and the accompanying drawing in which:

Fig. 1 is a side view of one specific illustrative embodiment of a zero spaced discharge device in accordance with the instant invention, a portion of the envelope having been broken away;

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Fig. 2 is a circuit representation of a space discharge device illustrating the effect of the cathode interface and coating resistance of prior art devices;

Fig. 3 is a diagram depicting the equivalent circuit for the structure of Fig. 2;

Fig. 4 is a circuit representation of a space discharge device in accordance with the embodiment of the present invention; and

Fig. 5 is a diagram depicting the equivalent circuit for the structure of Fig. 4.

Referring now to the drawing, the specific illustrative embodiment of this invention depicted in Fig. 1 comprises a discharge device including an envelope 14, a heater element 15, a cathode having a metal core or base 10 and a layer of electron emissive material 11 upon a surface of the metal core 10, a control electrode comprising a plurality of metallic conductors or grid laterals 12 in intimate contact with the layer of emissive material 11 and an anode 13. The metallic core 10 may advantageously consist of high purity nickel such as that having of the order of .01 percent total impurity or less; the Grade A nickel employed by many manufacturers has approximately one percent total impurities and is not sufficiently pure to eliminate satisfactorily undesirable cathode interface effects. Further, the cathode is advantageously held in position by supports substantially free of reduction impurities; such supports may be of very pure nickel, ceramics, molybdenum and the like, so that reducing agents cannot diffuse or migrate from the cathode supports into the cathode base metal and contaminate the same.

The electron emissive layer 11, which includes a reducible electron producing metal compound, may be applied to the surface of the metallic base 10 in any known manner as by spraying or dipping and may advantageously comprise one of the alkaline earth metal compounds such as the oxides of barium, strontium or calcium, or a mixture of two or more of the same.

In accordance with an aspect of this invention the activating agents for these oxides are contained in the control electrode conductors 12 which may advantageously consist of fine nickel wires made from nickel having a high proportion of such reducing agents therein. This method may have up to the order of one percent or more impurities, of which about a half are reducing agents, depending on the operating conditions of the tube, particularly the temperature of the cathode. These reducing agents may be silicon, carbon, magnesium, aluminum and other metals of the type which will react with the oxides of the emissive coating to provide the free barium or other oxide metals contained in the coating. The reducing agents migrate through the electrode conductors 12 on heating of the cathode coating by the heater element 15 or in other ways known in the art, to attain thermionic emission from the coating. The anode 13 is conventional and may be constructed in any manner known in the art. Manifestly, the principles of the instant invention are not limited in their application to particular electron tube configurations and may advantageously be utilized in a wide variety of multielectrode tubes such as tetrodes, pentodes, and the like.

Figs. 2 and 3 are the schematic diagram and the equivalent circuit respectively of a discharge device of the type wherein the reducing agents are supplied by the cathode base, in accordance with the prior art, and illustrate the effect of the cathode interface layer.

In Fig. 2, V_g is the input signal voltage applied between the grid and ground and V_k is the voltage drop across the combined resistance of the cathode interface layer and the emissive coating, which may be referred to as the feedback voltage. As can be seen from the equivalent circuit depicted in Fig. 3, the voltage drop V_k across the combined resistance will be equal to the plate signal current i_p times the combined cathode resistance $R_c + R_i$, written as:

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$$V_k = i_p(R_i + R_c) \quad (1)$$

This means that if the interface resistance R_i is high, not only is a large proportion of the output signal voltage dissipated across the interface layer and thus not available to the output load circuit, but the value of the output generator electromotive force is greatly reduced by the component $i_p R_i$ of the feedback voltage V_k .

However, in a discharge device in accordance with the present invention, as shown schematically in Fig. 4 and in equivalent circuit form in Fig. 5, the interface layer is built up at the boundary of the cathode surface and the control grid and is not therefore in the output signal path. As shown in Figs. 4 and 5, the output signal voltage drop V_k across the cathode is the product of the plate current i_p and only the coating resistance R_c , which voltage may be written as:

$$V_k = i_p(R_c) \quad (2)$$

The grid interface resistance is now in the input circuit, and as long as it is substantially greater than, i.e., in the order of ten times or more, the loading resistance on the input circuit it will have no deleterious effect on the operation of the discharge device.

It is desirable that the ratio of the grid interface resistance R_i to the cathode coating resistance R_c be relatively high in order that most of the input voltage V_g appear between the grid and cathode surface. Advantageously, this can be done by including in the grid wires impurities, such as silicon and the like, which are known to form high resistance interfaces between the wires and the cathode coating. In addition, the fact that the area of contact between the grid wires and the cathode coating is small compared with the area of the cathode helps to provide the desired high ratio of interface to cathode coating resistance. A still further means of keeping this ratio high is to provide a low value of cathode coating resistance such as by operating with an excess of free barium in the coating. This will have the additional advantage of keeping the feedback voltage V_k to a small value.

The advantages of the instant invention are then manifest because in addition to the elimination of the difficulties recited heretofore, the equivalent circuits of Figs. 3 and 5 and the Equations 1 and 2 make it clear that in order to get the same output voltage across a given load a higher value of input signal voltage V_g is needed for the tube with cathode interface than for the tube in which this has been eliminated.

Thus, I have shown and described a specific illustrative embodiment of a high transconductance zero spaced discharge device in which the reducing agents for the emissive coating of the cathode are obtained from the grid electrode rather than from the cathode base metal. It is to be understood that the above-described arrangements are but illustrative of the application of the principles of this invention and that other arrangements may be made by those skilled in the art without departing from the spirit and scope of this invention.

What is claimed is:

1. An electron discharge device comprising a cathode, an anode, and a control electrode for controlling electron emission from said cathode in response to applied signals, said cathode comprising a core, an emissive layer on said core including as an element thereof a reducible electron producing metal compound, said control electrode being in direct contact with said emissive layer, said core having an insufficient amount of reducing agents therein to reduce said compound appreciably, and means for activating said emissive layer comprising a plurality of reducing agents in the material of said control electrode.

2. An electron discharge device comprising a cathode, an anode, and a control electrode for controlling electron emission from said cathode in response to applied signals, said cathode comprising a core of a sub-

stantially pure refractory metal and a layer of electron emissive material thereon, said control electrode being in direct contact with said emissive layer, and means for activating said emissive layer comprising a plurality of reducing agents in the material of said control electrode. 5

3. An electron discharge device in accordance with claim 2 in which said cathode core is comprised of nickel.

4. An electron discharge device in accordance with claim 2 in which said control electrode comprises relatively impure nickel having a plurality of reducing agents 10 therein.

5. An electron discharge device in accordance with claim 1 in which said layer comprises at least one of the alkaline earth metal oxides.

References Cited in the file of this patent

UNITED STATES PATENTS

1,708,571	Hartmann et al. -----	Apr. 9, 1929
1,839,899	Slepian -----	Jan. 5, 1932
2,306,290	Widell -----	Dec. 22, 1942
2,430,309	Spencer -----	Nov. 4, 1947
2,601,024	Jacobs -----	June 17, 1952

FOREIGN PATENTS

115,700	Great Britain -----	May 21, 1918
310,034	Germany -----	Oct. 7, 1919