

July 11, 1961

D. REVERDIN
SUPPRESSOR DEVICE FOR THE SECONDARY EMISSION
CURRENT IN MAGNETIC FIELD ELECTRONIC TUBES

2,992,360

Filed May 12, 1954

3 Sheets-Sheet 1

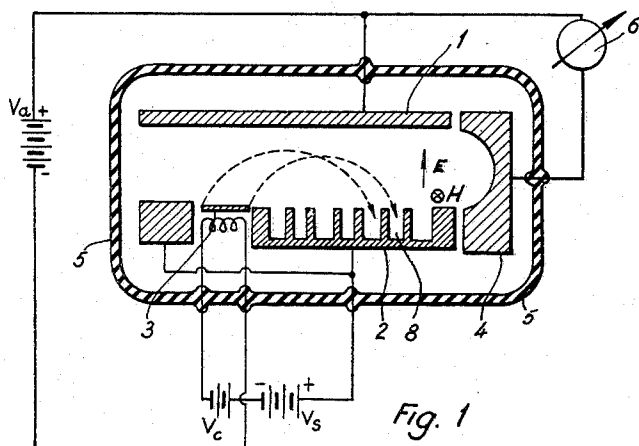


Fig. 1

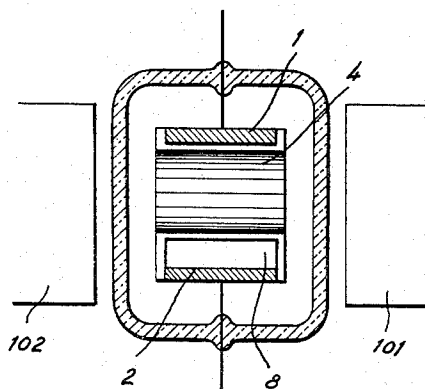


Fig. 1a

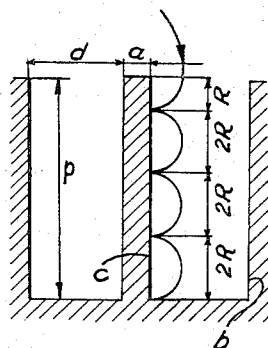


Fig. 2

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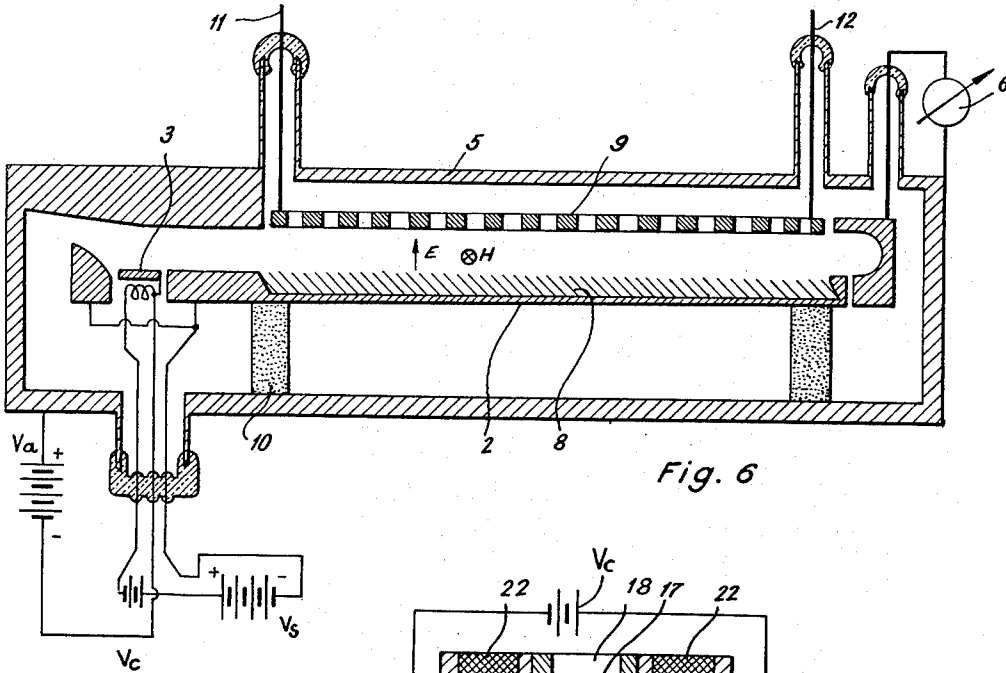


Fig. 6

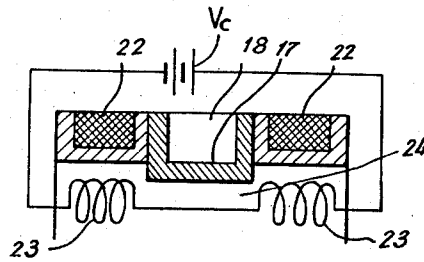


Fig. 9

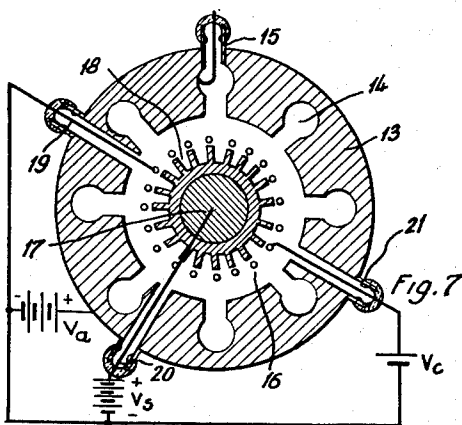


Fig. 7

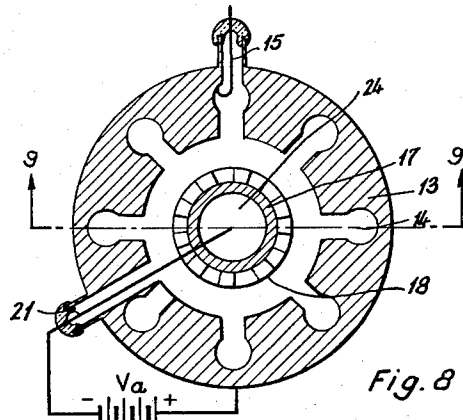


Fig. 8

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3 Sheets-Sheet 3

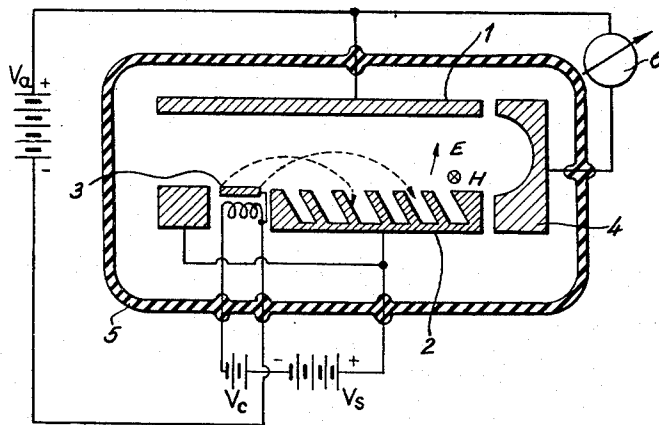


Fig. 3

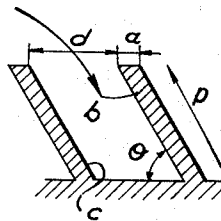


Fig. 4

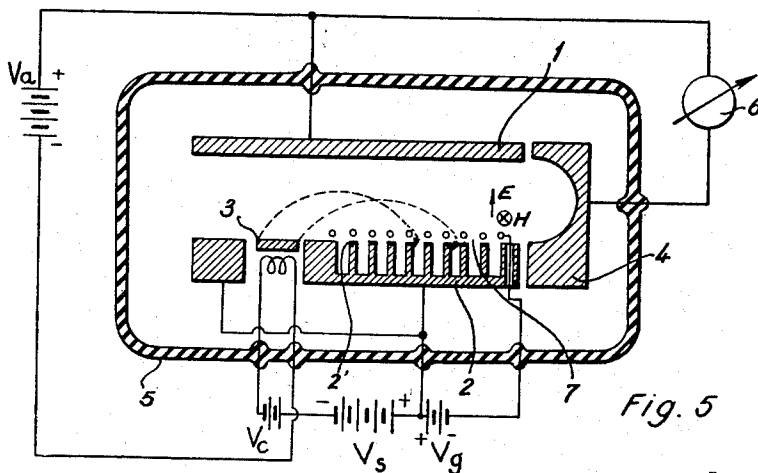


Fig. 5

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SUPPRESSOR DEVICE FOR THE SECONDARY EMISSION CURRENT IN MAGNETIC FIELD ELECTRONIC TUBES

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12 Claims. (Cl. 315-39.3)

The present invention relates to electronic tubes of the type comprising an electron emitting cathode feeding an electron beam into the space comprised between two parallel electrodes having different potentials, whereby one of them becomes positive and the other negative, and means for providing in this space a magnetic field whose lines of force are perpendicular both to the D.C. electric field existing therein and to the path of the electron beam.

It is known that such a magnetic field has for effect to bend the electron beam towards the negative electrode. For this and other reasons, a certain amount of electrons of the beam bombard this electrode. This bombardment is capable of causing a secondary emission. If the electrons resulting from this secondary emission reach the collector of the electron beam, generally provided in tubes of this type, there is established between this collector and the negative electrode an undesirable current which occasions losses. It is therefore advantageous to suppress this current.

It has already been proposed, to this end, to dispose parallel to the negative electrode a suitably biased suppressor grid which stops the electrons that tend to reach the negative electrode. However, this merely replaces the current which would have passed through the collector and the negative electrode by a current passing across the suppressor grid and the collector, which does not solve the problem in question.

The present invention has for object to provide a tube of the above type which is free of this disadvantage.

According to the invention secondary electron traps are provided on the negative electrode of the tube.

Preferably these traps are in the form of grooves formed in the surface of the electrode in a direction parallel to the lines of force of the magnetic field.

The invention will be better understood from the ensuing description, with reference to the accompanying drawings, in which:

FIG. 1 shows a longitudinal sectional view of a magnetic field tube according to the invention;

FIG. 1a shows a cross-sectional view of the tube of FIG. 1;

FIG. 2 shows a detail of the tube shown in FIG. 1;

FIGS. 3 and 5 show a longitudinal sectional view of other embodiments of the tube according to the invention;

FIG. 4 shows a detail of the tube shown in FIG. 3;

FIG. 6 shows a longitudinal section view of an amplifying traveling wave tube according to the invention;

FIGS. 7 and 8 show sectional views perpendicular to their axes of two examples of magnetrons according to the invention;

FIG. 9 shows an axial sectional view of a cathode detail of the tube shown in FIG. 8 as seen along line 9-9 thereof with a heater circuit shown schematically.

FIG. 1 shows a tube comprising two parallel electrodes 1 and 2 between which is established an electric field E by means of source V_a, the electrode 1 being positive (anode) and the electrode 2 negative. A magnetic field H produced by the poles 101, 102 (FIG. 1a) traverses the space between the electrodes in a direction perpendicular to the plane of the figure. An electron-emitting

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cathode 3, heated by a heating element fed by a source V_h and negatively biased with respect to the electrode 2 by the source V_s (the voltage V_s being less than V_a), emits electrons whose paths are curved towards the electrode 2 under the combined influence of the fields E and H. At the end of the path of the beam is disposed a collector 4 connected to the anode potential V_a source for instance through an ammeter 6. The above assembly is housed in an evacuated envelope 5.

According to the invention there are disposed in the negative electrode 2 secondary electron traps 8. In FIG. 1 these traps are shown as grooves or recesses provided in this electrode in a direction parallel to the magnetic field. Two of these traps are shown in FIG. 2. The depth p of these grooves is several times larger than their width d. The electric field may therefore be considered as nil inside each groove and constant in the space between the electrodes 1 and 2. The widths d are several times greater than the thicknesses a of the teeth comprised between the grooves. Assuming as a first approximation that all the electrons leave the cathode 3 in a direction normal thereto and that, in consequence, the electrons that attain the electrode 2 have an impact velocity normal to the latter, the electrons enter the groove shown in FIG. 2 at a velocity corresponding to the potential V_s of the electrode 2 and in a direction parallel to the sides of the groove. It is known that when the electrons having a certain initial velocity are subjected solely to the action of a magnetic field H, to the exclusion of any electric field, they describe circles the radius of which is given in centimeters by the formula

$$R = 3.37 \sqrt{\frac{V_s}{H}}$$

where V_s is expressed in volts, H in gauss. The concave side of the electron paths is adjacent the electrode 2 in the space 1-2. Thus, the path of an electron in the groove connecting up with its path in the space 1-2 is a portion of a circle whose centre is situated between the face c and the initial position M of the electron in the groove. Thus, in order to ensure that a primary electron does not issue from the groove it is merely necessary that it strikes the face c of the groove situated towards the gun. In other words, if d is the width of the groove, it must be arranged that d < 2R, where 2R is the diameter of the circle described by the electron, for this impact to take place.

If V_s = 300 volts and H = 500 gauss, R = 0.116 cm.

Thus, it suffices that d < 0.232 cm.

The primary electrons incident to the faces c of the traps produce secondary electrons whose initial velocities may be considered as imparted by an acceleration voltage V_{sec}. Now, a study of the energy spectrum of the secondary electrons shows that most (90%) of the secondary electrons leave the emitting surface at velocities imparted by potentials V_{sec} which are less than 20 volts if the potential V_s is greater than 50 volts. These secondary electrons leave the face c at an initial velocity which is always directed towards the bottom of the groove or at most horizontally. In order to ensure that they return to this face, it therefore suffices that, if r is the radius of their path, d > 2r.

Under the present conditions

$$r = \frac{3.37 \sqrt{20}}{500} = 0.03 \text{ cm.}$$

d will be selected so that 0.06 cm. < d < 0.232 cm.

For example d = 0.2 cm.

Thus, low velocity secondary electrons, constituting by far the major part of the emission spectrum, have only a small chance of producing a tertiary emission.

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On the other hand, the relatively high velocity secondary electrons (10% of the total number of electrons) are capable of producing tertiary electrons in falling on the face *c* of the trap. These tertiary electrons return to the same face of the trap, as the primary and secondary electrons do.

The worst case will now be considered, i.e. the case where the primary electrons arrive in the groove at a distance *R* from the face *c* and where the secondary electrons and tertiary electrons are emitted in a direction perpendicular to this face at the highest possible velocity imparted by the potential V_s . If the depth of the trap is equal to $5R$, the tertiary electrons all fall back onto the face *c*. Thus, in order to be sure that the tertiary electrons fall back onto the face *c*, it therefore suffices to arrange that the quaternary electrons also return to the face *c*, it suffices to give the depth *p* a value equal to $7R$, namely about 8 mm. in the numerical example given above. In practice this depth may be less, since it is not objectionable that the electrons are possibly absorbed not only by the face *c* but also by the bottom of the trap and its face *b*, up to a certain height of the latter above the bottom. The above indicated figures show that the number of fast quaternary electrons is negligible, i.e. that the trap has effectively absorbed practically the whole chain of successive emissions.

It is, however, important that the primary electrons do not strike the upper parts of the face *b*, since if this occurred it would be possible for the secondary electrons to escape from the trap and attain the collector. This is possible when the angle of incidence of the primary electrons on the negative electrode is an angle definitely less than 90° .

Now, this angle θ is related to the electric field *E*, existing in the space 1—2, to the field *H* and to the potential *V* by the appropriate formula

$$\tan \theta = \sqrt{11.38 \frac{E^2}{H^2 V_s} - 1}$$

where *E* is expressed in *V/cm*. This angle is equal to

$$\frac{\pi}{2}$$

if $V_s = 0$. In order to ensure that the primary electrons do not strike the face *b* it suffices to give the groove an inclination equal to θ (FIG. 4). FIG. 3 shows a tube provided with grooves such as those shown in FIG. 4.

FIG. 5 shows a modification which differs from FIG. 1 in that a grid 7 is disposed in the vicinity of the negative electrode 2 in a plane parallel to its surface. This grid may be either brought to the potential of the latter or brought to a negative potential V_g less than V_s . The use of such a grid is known in tubes in which the negative electrode does not include traps. However, according to the invention, this grid is positioned in such a way that the free intervals of the grid meshes coincide respectively with the entries of the traps, so that the front faces of the teeth are shielded by the grid wires against the input of the incoming electrons.

Another means of preventing the secondary emission from these front faces consists in applying thereon a coating, as indicated at 2' in FIGURE 5, of a substance having a low secondary emission ratio for example graphite, the body of the negative electrode being for example formed of a metal having any secondary emission ratio, for example copper.

The invention is of particular interest in traveling wave tubes having crossed electric and magnetic fields, since in the interaction space of such tubes the secondary electrons are not in a phase favorable to amplification, so that their presence decreases the gain of the tube.

FIG. 6 shows an example of an amplifier tube of this type provided with a negative electrode according to the invention. This tube is identical to that shown in FIG. 75

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3 in which the anode plate 1 has been replaced by a delay line having an input 11 and an output 12 for the amplified ultrahigh frequency energy. The traps 8 are inclined as in FIG. 3. The invention is also applicable to magnetrons. Two non-limitative examples of magnetrons, constructed in accordance with the invention, are shown in FIGS. 7 and 8. FIG. 7 shows a magnetron comprising an anode 13 having resonators 14 and an output 15. The cathode comprises a series of filaments 16 disposed around the negative cylinder 17 in which are formed the traps 18 whose width corresponds to the space between two adjacent filaments. The cylinder 17 is brought to the same potential as the filaments and the supply from the sources V_a , V_s , V_c is effected through the leads 19, 20, 21. If desired, the potential of the negative cylinder may be different from that of the filaments so as to improve the focusing of the primary electrons towards the traps.

The modification of FIG. 8 differs from that of FIG. 7 in that the primary emission occurs from two indirectly heated cathodes visible in the longitudinal sectional view of FIG. 9 and disposed in the axial direction on either side of the cylinder 17. Each cathode comprises (FIG. 9) an emitting ring, 22 heated by a coil filament 23, the two filaments being connected in series by a conductor extending through an axial passageway 24 in the cylinder 17. Further, the magnetron does not differ from that shown in FIG. 7 and comprises, in particular, traps 18 disposed in the same manner.

What I claim is:

1. In an electron tube having a source of primary electrons and comprising a first electrode, means for guiding said electrons in a first direction past said electrode, said means including means for generating an electric field and a magnetic field crossed with said electric field thereby guiding said electrons perpendicularly to both said fields, and second means for preventing the escape of secondary electrons from said first electrode due to impact thereagainst of said primary electrons, said second means including means for suppressing at least partially said electric field adjacent predetermined areas of said electrode and guiding said secondary electrons to move in a second direction in said areas primarily under the influence of said magnetic field.

2. In an electron tube the combination as claimed in claim 1, wherein said electric field suppressing means include grooves parallel to each other, provided in the surface of said electrode adjacent the space of movement of said primary electrons.

3. In an electron tube the combination as claimed in claim 2, wherein said grooves are parallel to the lines of force of said magnetic field.

4. An electron discharge tube for operation with crossed electric and magnetic fields and an electron stream propagating in non-parallel relationship to said crossed fields comprising a first electrode and a second electrode defining therebetween an electron path and adapted to establish therebetween the electric field, and means including a cathode for emitting an electron stream into said path, one of said electrodes being the electrode maintained negative relative the other electrode by the electric field and including trap means for effectively suppressing secondary emission of electrons from said one electrode produced by the impact of electrons of said stream directed against said one electrode by the magnetic field of said crossed fields.

5. An electron discharge tube according to claim 4, wherein said cathode is at a different potential than said one electrode, and wherein said trap means is formed by at least one slot in said one electrode having a width smaller than twice the radius *R* in centimeters of the circular path described by electrons, whereby

$$R = 3.37 \sqrt{\frac{V}{H}}$$

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V being the potential difference in volts between said cathode and said one electrode and H being the field strength in gauss of said magnetic field.

6. An electron discharge tube according to claim 5, wherein said slot has a width greater than twice the radius r in centimeters of the circular path described by the secondary electrons, whereby

$$r = \frac{3.37\sqrt{V_{\text{sec}}}}{H}$$

V_{sec} being the effective accelerating voltage for the secondary electrons and H being the field strength in gauss of said magnetic field.

7. An electron discharge tube according to claim 6, wherein the depth of said slot is several times the value of R.

8. A tube according to claim 3, wherein said grooves have cross-sections in the shape of a parallelogram.

9. A tube according to claim 2 wherein the cross section of said grooves is a rectangle.

10. A tube according to claim 8 wherein the walls of said grooves are slanting toward said source of electrons.

11. A tube according to claim 2 wherein the front surface of the walls of said grooves is coated with a material having a weak secondary emission ratio.

12. A tube according claim 2 further comprising elements forming a grid parallel to said electrode, said

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elements being respectively located in front of the surfaces separating said grooves, and energized connections for bringing said grid to a potential lower than the potential of said electrode.

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