

"CATHODE-RAY DEVICE AND SEMICONDUCTOR CATHODE"

The invention relates to cathode-ray devices and semiconductor cathodes for use in such cathode-ray devices. Such cathode-ray devices in accordance with the invention may serve for recording pictures and have a cathode-ray tube as part of a camera tube with a target which is a photosensitive layer, for example a photoconductive layer. Cathode-ray devices in accordance with the invention may serve for displaying pictures, and have a cathode-ray display tube with a target comprising a layer of fluorescent material or a pattern of lines or spots of fluorescent material. Such a device may also be designed for electron-lithographic or electron-microscopic uses.

In Netherlands Patent Application No. 7905470 (laid open to public inspection on January 15, 1981) a cathode-ray device is disclosed having a so-called "cold cathode". The operation of this cathode is based on the emanation of electrons from a semiconductor body in which a p-n junction is operated in the reverse direction in such manner that avalanche multiplication of charge carriers occurs. Some electrons obtain sufficient kinetic energy to overcome the electron work function; these electrons are then released at the major surface of the semiconductor body and thus provide in the vacuum space a current of electrons, frequently called "cathode rays".

Emission of the electrons is facilitated in this device by providing the semiconductor cathode with so-called accelerating electrodes which are located on an insulation layer present at the major surface and which do not cover a (slot-shaped, annular, circular, or rectangular) aperture in the insulating layer. In order to further facilitate the emission of the electrons the semiconductor surface is provided, as desired, with a material reducing the electron work function, for example caesium.

Because residual gases always remain in the vacuum space in the evacuated envelope of the device, negative and positive ions are liberated from these residual gases by the electron current. The negative ions are accelerated in the direction of the target. In the case of electrostatic deflection they may be incident on a small area of

the target and either damage it or disturb its operation. In order to prevent this detrimental effect, ion traps are used. An ion trap for negative ions is known, for example, from United States Patent Specification No. 2,913,612.

5 Under the influence of accelerating and focusing fields prevailing in the tube, some of the positive ions move in the direction of the cathode. When no special measures are taken, some of these will be incident on the semiconductor cathode and a kind of ion-etching takes place which can damage the cathode.

10 This damage may involve a gradual etching away of the electron work function reducing material. A redistribution or even total disappearance of this material causes the emission properties of the cathode to vary. When said layer is not present (or is removed entirely by the above-mentioned etching mechanism) even the major

15 surface of the semiconductor body may be attacked. In a semiconductor cathode based on avalanche multiplication of charge carriers as described in Netherlands Patent Application No. 7905470 in which the emitting p-n junction extends parallel to the major surface and is separated therefrom by a thin n-type surface zone, it is possible that as a result of said

20 gradual etching the said surface zone disappears entirely so that the cathode no longer functions. In a similar type of cold cathode, as described in Applicants' Netherlands Patent Application No. 7800987 (laid open to public inspection on 31st July, 1979) the p-n junction is exposed at the major surface of the semiconductor body. As a result of the

25 above-described damaging action of positive ions present in the electron tube, for example, the place where the p-n junction is exposed at the major surface may vary. This causes unstable emission behaviour.

Similar positive-ion problems can occur in cathode-ray devices in which the semiconductor cathode is of a different type, having a

30 p-n junction operated in the forward direction, the so-called negative electron affinity cathode (NEA-cathode). Netherlands Patent No. 150609 (published on August 16, 1976) discloses such a semiconductor cathode comprising a semiconductor body having at a major surface a p-type surface zone with at least two connections

35 at least one of which is an injecting connection located at a distance from the major surface which is at most equal to the diffusion recombination length of electrons in the p-type surface zone. The emission behaviour is affected by ion bombardment and etching. In

this case also, first the layer of electron work function reducing material is gradually etched away. The p-type surface zone of the cathode is then attacked until the cathode no longer functions.

It has been found that these problems can occur so rapidly that the life of cathode-ray devices manufactured with such semiconductor cathodes is considerably shortened hereby.

It is an object of the invention to provide such cathode-ray devices in which these disadvantages are avoided entirely or partly in that the positive ions describe such a path that they do not impinge or hardly impinge on the emissive part of the semiconductor cathode. The invention is inter alia based on the recognition of the fact that an electrostatic field required for this purpose can be obtained in a simple manner by means of a simple extension of the semiconductor cathode.

It is furthermore based on the recognition of the fact that an oblique arrangement of the cathode with respect to the axis of a cathode-ray tube including such a cathode is of no influence or is hardly of influence on the capability of manufacturing the cathode-ray tube, and that such a cathode can be combined with conventional electrostatic deflection means in a very simple construction of cathode-ray tube.

According to a first aspect of the invention there is provided a cathode-ray device comprising a vacuum space which is evacuated at least during operation of the device, and a semiconductor cathode for emitting electrons in the vacuum space during operation of the device, said cathode comprising a semiconductor body at a major surface of which a first electrically insulating layer having at least one aperture is present, which semiconductor body comprises at least one p-n junction which can be reverse-biased to generate in the semiconductor body by avalanche multiplication electrons which emanate from the semiconductor body at the area of said aperture in the first insulating layer, an accelerating electrode being present on the first insulating layer at least at the area of the edge of said aperture, characterized in that the semiconductor body comprises a second electrically insulating layer which does not cover the aperture in the first insulating layer and on which at least two deflection electrodes are present for generating a static dipole field.

It will be obvious that the expression "dipole" is not to be considered a strictly mathematical dipole. A dipole field is to be

understood to mean in this connection the electric field which occurs between two electrodes which are at different voltages.

As a result of this measure it is possible to create an electric field in the proximity of the semiconductor cathode in which the said
5 positive ions do not reach or hardly reach the emissive surface of the semiconductor body. In general these ions are generated at some distance from the semiconductor cathode in the vacuum space, for example in that electrons, after having obtained sufficient energy in the high voltage part, experience interactions with residual gases. When
10 these ions reach the electric field generated by the deflection electrodes they thus have a higher kinetic energy than the electrons which are released at the surface of the semiconductor body. As a result of this difference in kinetic energy between the positive ions and the emanating electrons, the positive ions move along paths quite
15 different from those of the electrons generated in the cathode. As a result of this the active surface of the cathode experiences substantially no detrimental influence of the positive ions.

According to a second aspect of the invention there is provided a cathode-ray device comprising a vacuum space which is evacuated at
20 least during operation of the device, and a semiconductor cathode for emitting electrons in the vacuum space during operation of the device, said cathode comprising a semiconductor body having at a major surface a p-type surface zone with at least two connections at least one of which is an injecting connection located at a distance from the major surface
25 which is at most equal to the diffusion recombination length of electrons in the p-type surface zone, characterized in that the major surface is covered at least partly with an electrically insulating layer which leaves free at least a part of the p-type surface zone, and in that at least two deflection electrodes for generating a static dipole field are present on
30 the insulating layer.

For such a device again the same advantages apply as described above in connection with the device in accordance with the first aspect of the invention.

One preferred embodiment of a device in accordance with either the
35 first or the second aspect of the invention is characterized in that the normal to the major surface of the semiconductor body and the cathode-ray axis intersect each other at an acute angle. The oblique arrangement of the cathode with respect to the anode which results herefrom hardly

influences the generated electron beam. It has been found that the potential lines of the electric field generated by the deflection electrodes start extending parallel to the anode (display screen, target) after a short distance. As a result of this the emanating beam can be
5 directed in a simple manner with respect to the axis of the cathode-ray device. This beam may then be controlled in a generally known manner by means of electron optics.

Another preferred embodiment of a device in accordance with either the first or the second aspect of the invention is characterized in that
10 the cathode is provided so as to be eccentric with respect to the cathode-ray axis but with the major surface of the cathode body substantially perpendicular to the direction of said axis, and the vacuum space is provided with electron optical deflection means by which an electron beam generated by the cathode and deflected by the
15 deflection electrodes can be deflected in such manner as to travel subsequently along said cathode-ray axis. An advantage of this embodiment is that the cathode can be connected in an end wall of the cathode-ray device in a simple manner.

There exists several possibilities for the type of semiconductor
20 cathode which can be used. For example, a cathode as described above, based on avalanche breakdown of a p-n junction may be used. Thus, according to a third aspect of the invention there is provided a semiconductor cathode comprising a semiconductor body at a major surface of which a first electrically insulating layer having at least one
25 aperture is provided, which semiconductor body comprises at least one p-n junction which can be reverse-biased to generate in the semiconductor body by avalanche multiplication electrons which emanate from the semiconductor body at the area of the aperture in the first insulating layer, an accelerating electrode being present on the first insulating
30 layer at least at the area of the edge of said aperture, characterized in that the semiconductor body comprises a second electrically insulating layer which does not cover the aperture in the first insulating layer and on which at least two deflection electrodes are present.

A first type of this semiconductor cathode is characterized in that the p-n junction, at least as viewed within the aperture in the first electrically insulating layer, extends substantially parallel to the major surface of the semiconductor body and has, within the aperture, a locally lower breakdown voltage than the remaining part of the p-n junction, the part of the p-n junction having the lower breakdown voltage being separated from the major surface by an n-type semiconductor zone having such a thickness and doping that at the breakdown voltage the depletion zone of the p-n junction does not extend to the surface but remains separated therefrom by a surface layer which is sufficiently thin to be traversed by the generated electrons which are to emanate from the surface.

A second type of semiconductor cathode based on avalanche breakdown and suitable for use in a cathode-ray device in accordance with the first aspect of the invention is characterized in that, at least in the operating condition, at least a part of the depletion layer associated with the p-n junction is exposed at the semiconductor surface within the aperture in the first electrically insulating layer.

In addition, the use of other semiconductor cathodes, for example the already mentioned negative electron affinity cathode, is also possible.

Thus, according to a fourth aspect of the present invention there is provided a semiconductor cathode for use in a cathode-ray device in accordance with the second aspect of the invention and comprising a semiconductor body having at a major surface a p-type surface zone with at least two connections at least one of which is an injecting connection located at a distance from the major surface which is at least equal to the diffusion-recombination length of electrons in the p-type surface zone, characterized in that the major surface is covered at least partly with an electrically insulating layer which leaves free at least a part of the p-type surface zone, and in that at least two deflection electrodes are present on the insulating layer.

Embodiments of the present invention will now be described, by way of example, with reference to the drawings, in which

Figure 1 shows diagrammatically a pick-up device having a cathode-ray tube in accordance with the invention,

Figure 2 shows diagrammatically a display tube having a cathode-ray tube in accordance with the invention,

5 Figure 3 is a diagrammatic plan view of a semiconductor cathode in accordance with the invention for use in such cathode-ray tubes,

Figure 4 is a diagrammatic cross-sectional view taken on the line IV-IV in Figure 3,

Figure 5 shows diagrammatically the variation of the potential
10 lines as they are generated in the operating condition by voltages at accelerating electrodes and deflection electrodes of such a semiconductor cathode in accordance with the invention,

Figure 6 is a diagrammatic cross-sectional view of another semiconductor cathode in accordance with the invention, and

15 Figure 7 is a diagrammatic cross-sectional view of yet another semiconductor cathode in accordance with the invention for use in a cathode-ray tube in accordance with the invention.

The Figures are not drawn to scale, and in the cross-sectional views in particular the dimensions in the direction of thickness are
20 considerably exaggerated for clarity. Semiconductor zones of the same conductivity type are generally shaded in the same direction; in the Figures corresponding parts are generally referred to by the same reference numerals.

Figure 1 shows diagrammatically a cathode-ray tube 1 for use in
25 a pick-up device. The pick-up tube 1 comprises in a hermetically sealed vacuum tube 2 a photoconductive target 3 and a screen grid 4. During operation the target 3 is scanned by means of an electron beam 10 generated by a semiconductor cathode 20. In order to be able to deflect the beam 10, the pick-up tube 1 furthermore comprises a system of
30 coils 5.

A scene to be picked up is projected on the target 3 by means of the lens 6, the end wall 7 of the vacuum tube 2 being transparent to radiation used. The end wall 8 of the vacuum tube 2 comprises leadthroughs 9 for electrical connections. In this example the
35 semiconductor cathode 20 is assembled obliquely with respect to the end wall 8. This may be done, for example, by an assembly on a wedge-shaped base plate.

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The angle ϕ between the normal 11 to the major surface 21 of the cathode 20 and the axis 12 of the cathode-ray tube 1 in this example is 45° . Dependent on the voltages used and the geometry of the electrodes of the semiconductor cathode, a different angle may be chosen.

5 The semiconductor cathode 20 the construction of which will be described hereinafter in detail comprises two deflection electrodes 32,33. These deflection electrodes are separated from the remaining part of the semiconductor cathode by an electrically insulating layer of, for example, silicon oxide. When applying potentials which differ from
10 each other to said deflection electrodes 32,33, the electric field generated hereby will deflect the path of the electrons which leave the semiconductor body from the major surface 21. If, as in the present example, the electrode 32 is positive with respect to the electrode 31, the emanating electron beam 10 will be deflected in the direction of
15 the deflection electrode 32.

It has been found that with a suitable choice of the angle ϕ and of the potentials at the deflection electrodes 32,33, the associated equipotential lines extend parallel to the end wall 7 of the vacuum tube 1 at a small distance from the cathode. By a correct positioning of the
20 semiconductor cathode 20 relative to the axis 12 of the cathode-ray tube it is thus possible to centre the beam 10 along said axis 12 before it experiences the influence of the system of coils 5. The pick-up tube furthermore comprises a grid 18 which serves as a diaphragm.

Figure 2 shows a cathode-ray tube 1 which serves as a display tube.
25 The hermetically sealed vacuum tube 2 opens into a funnel shape, the end wall 7 being coated on its inside with a fluorescent screen 17. The tube furthermore comprises focusing electrodes 13,14 and deflection plates 15,16. The electron beam 10 is generated in a semiconductor cathode 20 which is mounted on the end wall 8 of the tube either directly
30 or by means of a holder. Electric connections of the cathode are again led out via leadthroughs 9.

In this example the semiconductor cathode 20 is mounted eccentrically on the end wall 8 of the tube 2. An emanating electron beam 10 is deflected in the direction of the axis 12 of the cathode-ray
35 tube by the electric field generated by the voltages applied to the deflection electrodes 32 and 33. The electron beam is then deflected back by means of a magnetic field in such manner as to move

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substantially along the axis of the cathode-ray tube. The beam 10, after having been focused by means of the focusing electrodes 13, 14, is then further controlled by means of the deflection plates 15, 16. The cathode-ray tube furthermore again comprises a grid 18 (diaphragm).

5 The magnetic field which deflects the electron beam back can be generated inter alia by means of coils, shown diagrammatically in Figure 2 by means of the broken-line circle 19. The coils may be mounted inside or outside the tube 2 at will. In case of the assembly on the inside of the tube 2 the connections for said coils are also
10 provided with electric connections via leadthroughs 9 in the end wall 8.

Figures 3 and 4 show one example of the semiconductor cathode which can be used in these cathode-ray devices of Figures 1 and 2. It comprises a semiconductor body 35, in this example of silicon. The semiconductor body comprises an n-type surface region 22 which is provided at the
15 major surface 21 of the semiconductor body and which forms a p-n junction 24 with a p-type region 23. By applying a sufficiently high voltage in the reverse direction across the p-n junction 24, electrons are generated by avalanche multiplication and can emanate from the semiconductor body. This is indicated in the Figures by means of
20 arrow 10.

The semiconductor device furthermore comprises a connection electrode not shown with which the n-type surface region 22 is contacted. The p-type region 23 in this example is contacted on its lower side by a metallization layer 26. This contacting preferably takes place
25 via a highly doped p-type contact zone 25.

In the Figure 3 embodiment the donor concentration in the n-type region 22 at the surface is, for example, 5×10^{18} atoms/cm³, while the acceptor concentration in the p-type region 23 is much lower, for example 10^{15} atoms/cm³. In order to reduce the breakdown voltage
30 of the p-n junction 24 locally, the semiconductor device comprises a more highly doped p-type region 30 which forms a p-n junction with the n-type region 22. This p-type region 30 is situated within an aperture 28 in a first insulating layer 27, on which an accelerating electrode 29 of polycrystalline silicon is provided around the aperture 28.
35 If desired, the emission of electrons can be increased by covering the semiconductor surface 21 within the aperture 28 with a material reducing the work function, for example with a layer 34 of a material comprising

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barium or caesium. For further details of such a semiconductor cathode and its manufacture reference should be made to Netherlands Patent Application No. 7905470 laid open to public inspection on January 15, 1981 the contents of which are incorporated in this Application by reference.

The semiconductor body 35 furthermore comprises a second insulating layer 31 on which two deflection electrodes 32, 33 are present, for example, of aluminium. By means of these deflection electrodes and the accelerating electrode 29 an electric field is generated in the operating condition near the semiconductor surface. Figure 5 shows diagrammatically potential lines 36 associated with such an electric field in which a first insulating layer 27 having therein an aperture 28 is provided on a semiconductor body 35. An accelerating electrode 29 is present on the insulating layer 27 at the edge of the aperture 28. Moreover, two deflection electrodes 32, 33 are shown which are separated from the accelerating electrode by a second insulating layer 31. In the present embodiment the electric field lines 36 are shown in Figure 5 for the case in which a voltage of 5 volts is set up at the accelerating electrode 29, while voltages of 0 volt and 20 volts, respectively, are set up at the deflection electrodes 32 and 33, respectively.

Electrons emitted at the major surface 21 follow the path indicated by means of the arrow 10 under the influence of the prevailing electric field. As already described above, said electron path is deflected under the influence of electric voltages on the electrodes 32 and 33. A number of positive ions which may be generated in the vacuum tube 2 by collision of the generated and accelerated electrons with residual gases and electrodes are accelerated in the direction of the cathode by the prevailing electric fields.

These positive ions reach the electric field near the cathode, for example, along the paths 37, 38 indicated in broken lines in Figure 5. Since they have often traversed a part of the accelerating field of the cathode-ray tube, their kinetic energy generally is very large. As a result of this, these ions generally have a high kinetic energy when they reach the electric field of the cathode shown in Figure 5

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by means of the potential lines 36. Although they experience the influence of the associated electric force, only a small path curvature will occur due to their high kinetic energy as is shown diagrammatically in Figure 5 by the variation of the broken lines 37,38. As a result, substantially no or only very few positive ions can reach the emissive semiconductor surface. Therefore the cathode will experience hardly any degradation effects as a result of etching or other damaging action by positive ions.

In the example shown the semiconductor cathode body 35 comprises only one electron source having one aperture 28. In other devices this number may be extended; for example, for colour television applications three or more apertures 28 may be provided at the area of individually controllable p-n junctions, with common deflection electrodes 32 and 33, and an accelerating electrode 29.

Figure 6 is a cross-sectional view of another embodiment of a semiconductor cathode 20 based on avalanche breakdown of a p-n junction. In this embodiment the semiconductor body 35 comprises an n-type substrate 22 in which a p-type surface region 23 is present. As a result of this, a p-n junction 24 which adjoins the major surface 21 is formed the associated depletion zone of which is exposed at the semiconductor surface. This surface 21 furthermore comprises a first electrically insulating layer 27, for example, of silicon oxide. In this layer 27 at least one aperture 28 is provided within which at least a part of the p-n junction 24 adjoins the major surface 21 of the semiconductor body. Furthermore, an accelerating electrode 29 which in this example is of aluminium is provided on the electrically insulating layer 27 at the edge of the aperture 28 in the immediate proximity of the p-n junction 24. The semiconductor device furthermore comprises connection electrodes not shown which are connected to the n-type substrate 22, if desired via a highly doped contact zone, and to the p-type surface region 23. If desired, the semiconductor surface 21 within the aperture 28 may again be covered with a layer 34 of a work function-reducing material. For further details of such a semiconductor cathode and its manufacture reference should be made to Netherlands Patent Application No. 7800987 laid open to public inspection on July 31, 1979, the contents of which are incorporated in this Application by reference.

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The deflection electrodes 32, 33 in Figures 3, 4, 6 may be provided, for example, by means of a lift-off technique. After the semiconductor cathodes have been manufactured as described in the said Netherlands Patent Applications No. 7905470 and No. 7800987, the whole surface is covered with, for example, a photolacquer which is then removed at the area of the electrodes to be formed. The assembly is then covered with a layer of aluminium. The photolacquer layer with the aluminium deposited thereon is then removed so that aluminium remains only at the area of the deflection electrodes 32, 33 and connection tracks, if any.

In another method the semiconductor body is covered with an insulating layer which can be grown thermally or deposited from the vapour phase. This layer may consist of silicon oxide and/or silicon nitride on which metal is vapour-deposited which is patterned by means of photolithographic techniques, after which the insulating layer is removed by means of known etching methods while covering the metal at the area of the apertures 28 to be formed.

The cathode again comprises a second electrically insulating layer 31 on which deflection electrodes 32 and 33 are present. Again such voltages may be set up at said deflection electrodes 32, 33 and the accelerating electrode 29 that the associated electric field exerts a similar influence on positive ions present in the vacuum tube 2 as described above with reference to Figure 5 for the cathode of Figure 3.

Figure 7 finally shows the cross-sectional view of a cathode of the negative electron affinity type (NEA-cathode), in which a p-n junction is operative in the forward direction. In this example, the semiconductor cathode 20 comprises an n-type semiconductor body 41, for example of gallium arsenide, with a concentration of 10^{17} donors/cm³ and a thickness of 0.5 millimetre. Present at a major surface 21 is a part 42 of p-type conductivity having a thickness of approximately 10 micrometres and a surface concentration exceeding 10^{19} acceptor atoms/cm³. The p-type part 42 is covered with a coating 34 of electron work function-reducing material and has two electrical connections. One of these two electric connections is an injecting connection which

in this case is formed by the p-n junction 40 between the p-type surface part 42 and the n-type body 41. The other connection 43 contacts the p-type part 42 via a contact window 44 in an electrically insulating layer 31. The operation and manufacture of such a cathode
5 is described in greater detail in granted Netherlands Patent Specification No. 150609 the contents of which are deemed to be incorporated in this Application by reference.

Deflection electrodes 32 and 33 are present on the electrically insulating layer 31. Herewith an electric field can be generated
10 of such a shape that in a manner similar to that described above with reference to Figures 4 and 5, positive ions which are accelerated in the direction of the semiconductor cathode 20 do not impinge or hardly impinge on the emissive surface.

It will be obvious that the invention is not restricted to the
15 above-described examples but that many variations are possible to those skilled in the art without departing from the scope of this invention. For example, as already indicated in the Figure 4 embodiment, the number of apertures 28 in the insulating layer where separately controllable emission occurs may also be extended to three in the
20 Figure 7 device for colour television applications.

Instead of mounting the cathode obliquely as shown in Figure 1, an oblique rear wall 8 may also be used. The semiconductor cathode itself may moreover be manufactured in various other manners, as described in the above-mentioned Netherlands Patent and Patent
25 Applications.

Many variations are also possible for the shape of the deflection electrodes. This may present advantages in avoiding deflection errors. If desired, a split pattern may also be chosen for one of the deflection electrodes (or for both), while nonetheless electrically connecting the
30 split parts in such a way as to still obtain a dipole field.

CLAIMS:

1. A cathode-ray device comprising a vacuum space which is evacuated at least during operation of the device, and a semiconductor cathode for emitting electrons in the vacuum space during operation of the device, said cathode comprising
5 a semiconductor body at a major surface of which a first electrically insulating layer having at least one aperture is present, which semiconductor body comprises at least one p-n junction which can be reverse-biased to generate in the semiconductor body by avalanche multiplication electrons which emanate from the semiconductor body
10 at the area of said aperture in the first insulating layer, an accelerating electrode being present on the first insulating layer at least at the area of the edge of said aperture, characterized in that the semiconductor body comprises a second electrically
15 insulating layer which does not cover the aperture in the first insulating layer and on which at least two deflection electrodes are present for generating a static dipole field.
2. A cathode-ray device comprising a vacuum space which is evacuated at least during operation of the device, and a
20 semiconductor cathode for emitting electrons in the vacuum space during operation of the device, said cathode comprising a semiconductor body having at a major surface a p-type surface zone with at least two connections at least one of which is an injecting connection located at a distance from the major surface
25 which is at most equal to the diffusion recombination length of electrons in the p-type surface zone, characterized in that the major surface is covered at least partly with an electrically insulating layer which leaves free at least a part of the p-type surface zone, and in that at least two deflection electrodes for
30 generating a static dipole field are present on the insulating layer.



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3. A cathode-ray device as claimed in Claim 1, characterized in that the normal to the major surface of the semiconductor body and the cathode-ray axis of the vacuum space intersect each other at an acute angle.

5 4. A cathode-ray device as claimed in Claim 1, characterized in that the semiconductor cathode is provided so as to be eccentric with respect to the cathode-ray axis of the vacuum space, but with the major surface of the cathode body substantially perpendicular to said axis, and the vacuum space is provided with
10 electron optical deflection means by which an electron beam generated by the cathode and deflected by the deflection electrodes can be deflected in such manner as to travel subsequently along said axis.

15 5. A semiconductor cathode for use in a cathode-ray device as claimed in any of Claims 1, 3 or 4 having a semiconductor body at a major surface of which a first electrically insulating layer having at least one aperture is provided, which semiconductor body comprises at least one p-n junction which can be reverse-biased to generate in the semiconductor body by avalanche multiplication
20 electrons which emanate from the semiconductor body at the area of the aperture in the first insulating layer, an accelerating electrode being present on the first insulating layer at least at the area of the edge of said aperture, characterized in that the semiconductor body comprises a second electrically insulating layer
25 which does not cover the aperture in the first insulating layer and on which at least two deflection electrodes are present.

6. A cathode-ray device as claimed in any of Claims 1, 3 or 4, or a semiconductor cathode as claimed in Claim 5, characterized in that the p-n junction, at least as viewed within the aperture
30 in the first electrically insulating layer, extends substantially parallel to the major surface of the semiconductor body and has within the aperture a locally lower breakdown voltage than the remaining part of the p-n junction, the part of the p-n junction having the lower breakdown voltage being separated from the major
35 surface by an n-type semiconductor zone having such a thickness



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and doping that at the breakdown voltage the depletion zone of the p-n junction does not extend to the surface but remains separated therefrom by a surface layer which is sufficiently thin to be traversed by the generated electrons which are to emanate from the surface.

7. A cathode-ray device as claimed in any of Claims 1, 3 or 4, or a semiconductor cathode as claimed in Claim 5, characterized in that, at least in the operating condition, at least a part of the depletion layer associated with the p-n junction is exposed at the semiconductor surface within the aperture in the first electrically insulating layer.

8. A cathode-ray device as claimed in Claim 1 or any of Claims 3 to 7, or a semiconductor cathode as claimed in any of Claims 5 to 7, characterized in that the body comprises several independently controllable p-n junctions at which electrons can be generated and is provided with an accelerating electrode and deflection electrodes, which are common to the apertures associated with said p-n junctions.

9. A cathode-ray device as claimed in Claim 2, characterized in that the normal to the major surface of the semiconductor body and the cathode-ray axis of the vacuum space intersect each other at an acute angle.

10. A cathode-ray device as claimed in Claim 2, characterized in that the semiconductor cathode is provided so as to be eccentric with respect to the cathode-ray axis of the vacuum space, but with the major surface of the cathode body substantially perpendicular to said axis, and the vacuum space is provided with electron optical deflection means by which an electron beam generated by the cathode and deflected by the deflection electrodes can be deflected in such manner as to travel subsequently along said axis.

11. A semiconductor cathode for use in a cathode-ray device as claimed in any of Claims 2, 9 or 10, comprising a semiconductor body having at a major surface a p-type surface zone with at least two connections at least one of which is an injecting connection



located at a distance from the major surface which is at least equal to the diffusion-recombination length of electrons in the p-type surface zone, characterized in that the major surface is covered at least partly with an electrically insulating layer which leaves free at least a part of the p-type surface zone, and in that at least two deflection electrodes are present on the insulating layer.

12. A cathode-ray device or a semiconductor cathode as claimed in any of the preceding Claims, characterized in that the area of the major surface of the semiconductor body at which the electrons emanate is covered with a material reducing the electron work function.

13. A cathode-ray device or a semiconductor cathode as claimed in Claim 12, characterized in that the electron work function reducing material comprises one of the materials from the group of caesium and barium.

14. A cathode-ray device substantially as described with reference to any of Figures 1 to 7 of the accompanying drawings.

15. A semiconductor cathode substantially as described with reference to Figures 3, 4 and 5, or to Figure 6 or to Figure 7 of the accompanying drawings.
