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### (54) **METHOD OF MANUFACTURING AN ELECTRON GUN COMPRISING A SEMICONDUCTOR CATHODE**

VERFAHREN ZUR HERSTELLUNG EINER ELEKTRONENKANONE MIT HALBLEITERKATHODE

PROCEDE DE FABRICATION D'UN CANON ELECTRONIQUE MUNI D'UNE CATHODE A SEMI-CONDUCTEUR

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**EP 0 948 801 B1**

## Description

**[0001]** The invention relates to a method of manufacturing an electron gun comprising at least one cathode which, during operation, emits electrons by way of semiconductor action. The invention also relates to a method of manufacturing a cathode ray tube and a method of manufacturing a display device comprising such a method of manufacturing an electron gun.

**[0002]** A cathode ray tube is suitable as a pick-up or display tube, but may be alternatively used in apparatus for Auger spectroscopy, electron microscopy and electron lithography.

**[0003]** A cathode ray tube for a monochrome display device, for example a television or monitor, has a glass envelope which is composed of a screen and a cone. The widest end of the cone is secured to the screen. Its narrowest end terminates in a tubular end having a substantially circular cross-section, which end is referred to as the neck. A phosphor screen consisting of a phosphor layer is present on the screen. The tubular end accommodates an electron gun which emits an electron beam during operation. This beam can be sent to a given spot on the display screen by means of deflection coils which generate a given magnetic field.

**[0004]** The display screen is activated by scanning the electron beam along the screen, which beam is modulated by a video signal. This video signal is applied to the cathode via electric current conductors and ensures that the electrons emitted by the electron gun excite the phosphor in accordance with such a pattern that its luminescence produces an image. When many electrons land on the pixel during its excitation time, this pixel luminesces more brightly.

**[0005]** There are many pixels per unit of surface area. Moreover, the pixels are excited one after the other within a very short time. The viewer thus experiences a moving image from a normal viewing distance.

**[0006]** In a color display device, for example a color television or a color monitor, each pixel has three phosphor elements each luminescing in a different primary color. As it were, there are three uniform regular patterns on the display screen, each pattern having a different luminescence color. Instead of one electron beam, three electron beams emitted by three different cathodes in the color electron gun are scanned along the screen during operation. Each of these three beams excites the pixels with a given luminescence color. Since the phosphor elements of a pixel are located close together, the viewer experiences them as a single element, not as separate elements. The color which is experienced is a mixed color of the three elements. By exciting each element with a given intensity, the viewer experiences a given color. For example, if the red element and the blue element are excited to a large extent and the green element is excited to a small extent, the viewer will experience the mixed color purple. Furthermore, similarly as for a monochrome cathode ray tube, it holds that the

pixels are situated so close together that the viewer does not see them as separate pixels from a normal viewing distance. This produces a color image.

**[0007]** During production, the envelope of the cathode ray tube must be vacuum-exhausted before it is sealed. This is essential for its operation because an electron beam can only propagate substantially undisturbed through vacuum.

**[0008]** The electron beams are generated in, and emitted by an electron gun. This electron gun comprises a plurality of electrostatic grids which, in their sequence of increasing distance to the neck, are referred to as G1, G2, G3 and so forth. The different electrostatic grids have different electric potentials during operation and must therefore not be in contact with each other. To achieve this, they are fixed relative to each other by means of glass rods in which they are secured by means of brackets. The first grid is referred to as G1 (grid 1) and has a skirt accommodating one or more cathodes. These cathodes have a surface which emits electrons during operation. An electron emitted by such a cathode passes through an aperture in the G1 and subsequently through apertures in the G2, G3, and so forth. Finally, the electron leaves the electron gun so as to move towards the display screen.

**[0009]** A cathode ray tube may accommodate an electron gun with cathodes which function by way of semiconductor action (referred to as "semiconductor cathodes"). These may be, for example field emitters but particularly reverse-biased junction cathodes (such as the avalanche cold cathode). Such a type of semiconductor cathode is described in US patent 5,243,197.

**[0010]** The surface of a semiconductor cathode oxidizes in air. The oxide layer which is thus produced protects the cathode from damage during assembly of the electron gun. However, the surface of the cathode is inactive when an oxide layer is present on it. Before the cathode ray tube is sealed, the surface of the cathode must therefore be reactivated. To this end, two process steps are performed after the gun assembly:

- O<sub>3</sub> (ozone) etching: ozonization of the surface so as to remove a possible residue of contamination (such as hydrocarbons) so that the surface can be reached for further treatment.
- HF (hydrogen fluoride) etching for removing the oxide layer from the surface.

**[0011]** It has been found that there are many rejects among electron guns with semiconductor cathodes. A large number does not function as desired.

**[0012]** It is an object of the invention to provide a method of manufacturing an electron gun in which the number of rejects is reduced.

**[0013]** To this end, the method according to the invention is characterized in that, prior to the gun assembly, the surface of the cathode is cleaned in a clean room, whereafter the surface is oxidized in a controlled man-

ner. It has surprisingly been found that the number of rejects is greatly reduced when using this method. The cause of rejection appears to be the fact that, during oxidizing in air, the oxide layer is contaminated underneath or takes up contaminations. Due to the necessary sequence of the process steps, the ozone cannot reach the surface to remove this contamination. The contamination present in the layer impedes the etching of this layer. The contamination present underneath the layer is left after the layer has been removed and then impedes the operation of the cathode. Since the air in the clean room is almost completely pure, an oxide layer grown in this air is substantially not contaminated.

**[0014]** The process of controlled oxidizing in the clean room can be performed in different ways. In accordance with a preferred embodiment, the surface of the cathode is oxidized by etching it with nitric acid. This has the advantage that there is a small risk of overetching. In fact, the process continues at an increasingly slower rate and saturates at approximately 2.5 to 3 nm thickness of the silicon oxide layer on the cathode. Moreover, nitric acid is a very strong oxidant so that the process has a shorter duration as compared with that performed when using another agent. By varying the nitric acid concentration and temperature, and the duration of the process, the thickness of the layer can be controlled. When one of these variables increases while the others remain equal, a thicker layer is obtained, with a maximum of the saturation thickness. It has been found that when using substantially pure  $\text{HNO}_3$  (fuming nitric acid) as an etchant, its immersion in a bath for 10 minutes at room temperature is sufficient to obtain a layer thickness of 2.5 to 3 nm of the silicon oxide.

**[0015]** These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter.

**[0016]** In the drawings:

Fig. 1 is a diagrammatic cross-section of a display device comprising a cathode ray tube,  
 Fig. 2 is a diagrammatic cross-section of an electron gun,  
 Fig. 3 is a diagrammatic cross-section of a part of an electron gun, provided with semiconductor cathodes.

**[0017]** Fig. 1 is a diagrammatic cross-section of a display device comprising a cathode ray tube. A cabinet 1 accommodates a cathode ray tube 2 which has a glass envelope composed of a screen 3 and a cone 4. The reference numeral 5 denotes the neck. The glass envelope accommodates an electron gun 6 and a phosphor screen 7. Deflection coils 8 are arranged around the cathode ray tube. When the device is operative, the electron gun 6 emits electrons which, if desired, are deflected by the deflection coils 8, whereafter they land on the desired spot on the phosphor screen 7. The electron gun accommodates one or more cathodes (not shown).

When operating a color display device, three electron beams are generated by means of an electron gun comprising three separate cathodes. The reference numeral 9 denotes these three electron beams.

**[0018]** Fig. 2 is a diagrammatic cross-section of an electron gun. An electron gun emits electron beams towards the screen of the display device. Such a gun comprises a plurality of consecutively arranged electrostatic grids 10, 11, 12, 13. The first grid G1 (grid 1) 10 has a skirt 14 accommodating one or more cathodes (not shown). The grids are provided with brackets 15, 15', 15'', 15'''. The brackets of the electrostatic grids are pressed into glass rods 17 so that the electrostatic grids 10, 11, 12, 13 are positioned and fixed with respect to each other. The electric connections of the different parts of the electron gun are secured to metal pins. These pins are mounted in a glass ring, the base. After the electron gun has been introduced into the neck of the display tube, the base is secured to the entrance of the neck. In this way, the electron gun is secured in the display tube.

**[0019]** Fig. 3 is a diagrammatic cross-section of a part of an electron gun in a display device, provided with semiconductor cathodes. A support 31 is provided with a layer of electron-emissive material 30. The support 31 is secured by means of straps 32 to the first grid (G1) 33. The first grid (G1) 33 has an aperture 34 through which electrons emitted by the cathode during operation find their way to the further grid system of the electron gun. The first grid 33 has a skirt 35 and brackets 36, 36'. The second grid (G2) 42 is present close to the first grid 33. The second grid also has an aperture 37 and brackets 38, 38'.

**[0020]** An important type of semiconductor cathode is known as the ACC (Avalanche Cold Cathode). An important aspect in a semiconductor cathode such as the ACC is that the electron-emissive layer has an undamaged clean surface. If this is not the case, the electron emission is strongly inhibited. During assembly of the electron gun, the surface must be protected. This can be realized with a layer of oxide which is formed on the surface of the cathode by exposing it to air. However, under these circumstances the problem arises that all kinds of contaminations are enclosed underneath and within this layer. These contaminations impede the removal of the layer after assembly of the electron gun. Contaminations (such as hydrocarbons) underneath the oxide layer also impede the operation of the cathode after this layer has been removed.

**[0021]** To obviate this problem, contaminations (such as hydrocarbons) are removed from the surface by means of ozone etching in a clean room, after removal of possible oxide, whereafter the surface is actively oxidized. It is then certain that the layer is substantially free from contaminations. In addition to the fact that this method solves the problem found, it has another considerable advantage. When the oxide layer is actively provided, it can be ensured that the layer thickness on

all cathodes manufactured is substantially equal. Consequently, the duration of the HF etching step during treatment of the cathodes can be maintained equal after the gun assembly step. This simplifies the production process. It is not necessary to constantly measure the thickness of the layer and adapt the etching step thereto. Moreover, there is a smaller risk of over and underetching.

## Claims

1. A method of manufacturing an electron gun comprising at least one cathode which, during operation, emits electrons by way of semiconductor action, **characterized in that**, prior to the gun assembly, the surface of the cathode is cleaned in a clean room, whereafter the surface is oxidized in a controlled manner.
2. A method as claimed in claim 1, **characterized in that** the surface is oxidized in a controlled manner by means of etching with nitric acid.
3. A method as claimed in claim 2, **characterized in that** the surface is etched in a bath containing substantially pure nitric acid (HNO<sub>3</sub>) for 10 minutes at room temperature.
4. A method of manufacturing a cathode ray tube comprising the method of manufacturing an electron gun according to claim 1, 2 or 3.
5. A method of manufacturing a display device comprising the method of manufacturing a cathode ray tube according to claim 4.

## Patentansprüche

1. Verfahren zum Herstellen eines Elektronenstrahlerzeugungssystems mit wenigstens einer Kathode, die im Betrieb durch Halbleiterwirkung Elektronen emittiert, **dadurch gekennzeichnet, dass** vor dem Zusammenbauen des Elektronenstrahlerzeugungssystems die Oberfläche der Kathode in einem Reinraum gereinigt wird, wonach die Oberfläche auf eine kontrollierte Art und Weise oxidiert wird.
2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** die Oberfläche durch Ätzen mit Salpetersäure auf eine kontrollierte Art und Weise oxidiert wird.
3. Verfahren nach Anspruch 2, **dadurch gekennzeichnet, dass** die Oberfläche in einem Bad mit im Wesentlichen reiner Salpetersäure (HNO<sub>3</sub>) 10 Minuten lang auf Raumtemperatur geätzt wird.

4. Verfahren zum Herstellen einer Elektronenstrahlröhre, wobei dieses Verfahren das Verfahren zum Herstellen eines Elektronenstrahlerzeugungssystems nach Anspruch 1, 2 oder 3 umfasst.
5. Verfahren zum Herstellen einer Wiedergabeanordnung, wobei dieses Verfahren das Verfahren zum Herstellen einer Elektronenstrahlröhre nach Anspruch 4 umfasst.

## Revendications

1. Procédé pour la fabrication d'un canon électronique comprenant au moins une cathode qui, lors du fonctionnement, émet des électrons par effet de semiconducteur, **caractérisé en ce qu'avant l'assemblage du canon, la surface de la cathode est nettoyée dans une chambre de nettoyage, après quoi la surface est soumise à une oxydation d'une façon contrôlée.**
2. Procédé selon la revendication 1, **caractérisé en ce que** la surface est soumise à oxydation d'une façon contrôlée par décapage à l'aide d'acide nitrique.
3. Procédé selon la revendication 2, **caractérisé en ce que** la surface est soumise à décapage dans un bain contenant de l'acide nitrique (HNO<sub>3</sub>) à l'état pratiquement pur pendant 10 minutes à la température ambiante normale.
4. Procédé pour la fabrication d'un tube à rayons cathodiques comprenant le procédé pour la fabrication d'un canon électronique conforme à la revendication 1, 2 ou 3.
5. Procédé pour la fabrication d'un dispositif de reproduction d'images comprenant le procédé pour la fabrication d'un tube à rayons cathodiques conforme à la revendication 4.

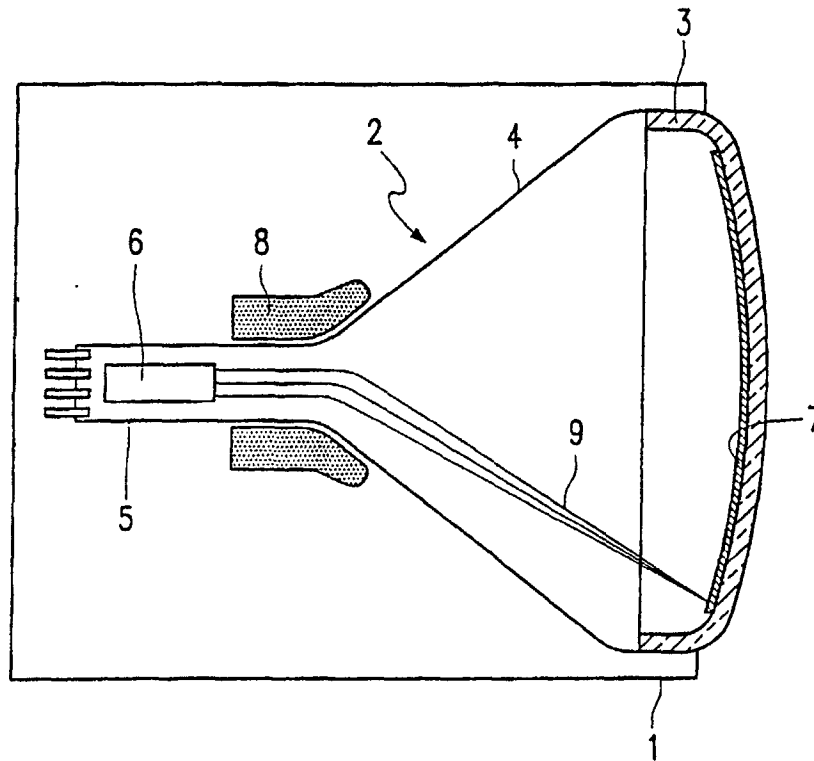


FIG. 1

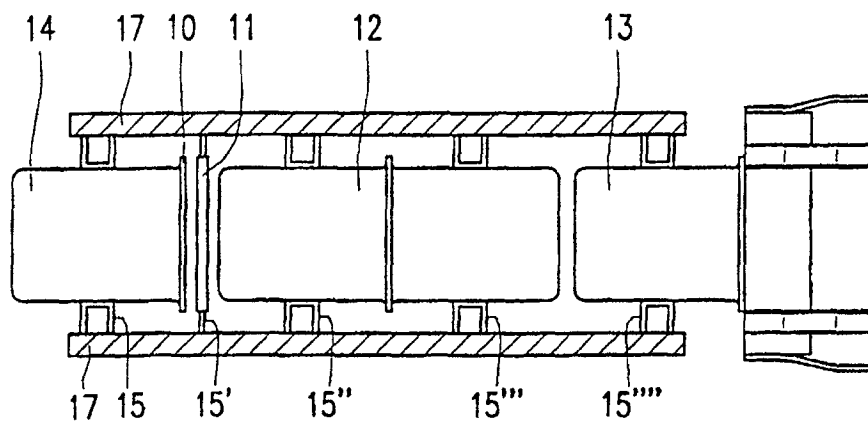


FIG. 2

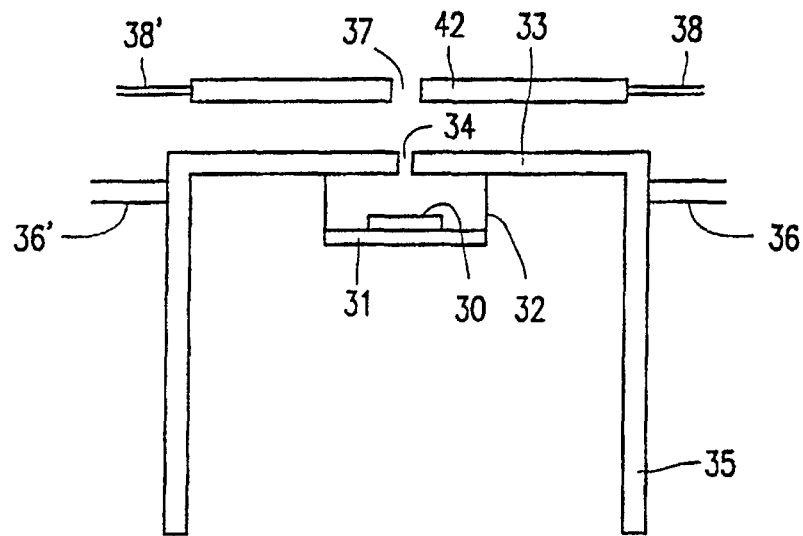


FIG. 3