cavity, wherein the cathode comprises a carbon-based cold emitter.
Vacuum electronic device

The invention relates to a vacuum electronic device comprising an electron source having at least one cathode for emitting of electrons, at least one electron beam guidance cavity for concentrating electrons emitted from the cathode, said cavity having an entrance aperture and an exit aperture, a portion of an inner side of said cavity around the exit aperture being provided with an insulating material, and a first electrode being connectable to a first power supply means for applying, in operation, an electric field with a first field strength $E_1$ between the cathode and the exit aperture to allow electron transport through the electron beam guidance cavity.

A vacuum electronic device of the kind mentioned in the opening paragraph is for example known from US 5,270,611. US 5,270,611 describes a cathode ray tube which is provided with a cathode, an electron beam guidance cavity and a first electrode connectable to a first power supply means for applying the electric field with a first field strength $E_1$ between the cathode and an exit aperture. The electron beam guidance cavity comprises walls in which, for example, a part of the wall near the exit aperture comprises an insulating material having a secondary emission coefficient $\delta$. Furthermore, the secondary emission coefficient $\delta$ and the first field strength $E_1$ have values which allow electron transport through the electron beam guidance cavity. The electron transport within the cavity is possible when a sufficiently strong electric field is applied in a longitudinal direction of the electron beam guidance cavity. The value of this field depends on the type of material and on the geometry and sizes of the walls of the cavity. In a steady state, the electron transport takes place via a secondary emission process so that, for each electron impinging on the cavity wall, one electron is emitted on average. The circumstances can be chosen to be such that as many electrons enter the entrance aperture of the electron beam guidance cavity as will leave the exit aperture. When the exit aperture is much smaller than the entrance aperture, an electron compressor is formed which concentrates a luminosity of the electron source by a factor of, for example, 100 to 1000. An electron source with a high current density can thus be made. An accelerating grid accelerates electrons leaving the cavity towards the main electron lens. A main electron lens images the exit aperture of the cavity on the display screen and, via a deflection unit, a raster image is formed on the display screen of the tube.
The spot size of the electron beam determines the resolution of the tube. Especially for computer monitor tubes and also television picture tubes, resolution may be an important feature. In the known cathode ray tube, the spot size of the electron beam on the display screen depends, amongst others, on the diameter of the exit aperture and the energy distribution of the electrons leaving the cavity.

Usually thermionic emitters are used as cathodes which operate at temperatures between 500 and 1200 °C. A drawback of the known thermionic emitters is that at these temperatures parts of the cathode evaporate and deposit again on the walls of the electron beam guidance cavity. These parts may severely disturb the electron transport within the cavity.

The US 5,270,611 also proposes the use of field emitters or p-n emitters. Such cold emitters operate at temperatures between room temperature and 200 °C. Due to the reduced operating temperatures no coverage of the walls in the electron beam guidance cavity occurs and the thermal strain of the electron beam guidance cavity is reduced. Thereby the lifetime of the cathode ray tube is increased and the performance of the cathode ray tube is improved.

One disadvantage of field emitters, such as so-called spindt emitters, and p-n emitters is the costly and difficult manufacturing process. In particular, the special structuring of spindt emitters is difficult and costly.

It is, inter alia, an object of the invention to provide a vacuum electronic device with a cheaper and easy to manufacture cathode.

This object is achieved by a vacuum electronic device comprising
- an electron source having at least one cathode for emitting of electrons,
- at least one electron beam guidance cavity for concentrating electrons emitted from the cathode, said cavity having an entrance aperture and an exit aperture, a portion of an inner side of said cavity around the exit aperture being provided with an insulating material, and
- a first electrode being connectable to a first power supply means for applying, in operation, an electric field with a first field strength E1 between the cathode and the exit aperture to allow electron transport through the electron beam guidance cavity, characterized in that the cathode comprises a carbon-based cold emitter.

Carbon-based cold emitters, especially the carbon-based cold emitters mentioned in claim 2, can be manufactured in large areas by vapor deposition. In addition, a
special structuring is not necessary since the carbon-based cold emitters emit electrons a low electric fields, e. g. < 20 V/μm.

A further embodiment of a vacuum electronic device according to the invention is defined in claim 3. In this embodiment, the cathode comprising an array of carbon-based cold emitter allows the use of a high electron beam current.

A further embodiment of a vacuum electronic device according to the invention is defined in claim 4. An array of cathodes also allows the use of a high electron beam current.

A further embodiment of a vacuum electronic device according to the invention is defined in claim 5. In this embodiment, the ring-like shaped cathode, which is placed concentrically around the entrance aperture, improves the symmetry of the electron beam. In addition, the surface of the electron beam guidance cavity is used more uniformly. This arrangement allows the use of an increased electron beam current. Moreover, the lifetime of the cathode ray tube is enhanced.

These and other aspects of the invention are apparent from and will be elucidated with reference to an embodiment described hereinafter.

In the drawing:
Fig. 1 shows an embodiment of an electrode structure according to the invention for use in a vacuum electronic device.

A vacuum electronic device may be a cathode ray tube, a matrix-addressed display, a travelling wave tube amplifier, a SEM electron gun or an electron beam lithography electron source. In addition, a vacuum electronic device may be a light-producing device which can be used in outdoor advertisement panels or can be used for indoor illumination. A matrix-addressed display may be for example a field emission display,

In the following, the invention will be described with reference to a cathode ray tube as one but not limiting embodiment of the invention.

A hopping electron cathode ray tube is known per se from the cited US 5,270,611. A hopping electron cathode ray tube comprises an electrode structure having at least one cathode for emission of electrons, and at least one electron beam guidance cavity.

The cathode of the cathode ray tube comprises a carbon-based electron emitter. Furthermore, the cathode ray tube comprises an accelerating grid, a conventional main lens, a conventional magnetic deflection unit and a conventional color screen. All these parts are known from conventional color cathode ray tubes. The cathode ray tube according to this embodiment of the invention may be applied in television, projection television and computer monitors.
Fig. 1 shows a preferred embodiment of the electrode structure 1 in accordance with the invention, which electrode structure 1 may be applied in the above-described hopping electron cathode ray tube. The electrode structure 1 comprises a channel plate 9 and cathodes 2 comprising carbon-based cold emitters. Furthermore, the electrode structure 1 comprises electron beam guidance cavities 3 each having an entrance aperture 4, an exit aperture 5. The cathodes 2 and the electron beam cavities 3 are provided in triplicate so that the cathode ray tube may be used for the display of color images represented by red, green and blue signals. For display of black and white images with a monochrome cathode ray tube, a cathode source and one electron beam cavity 3 suffices. In addition, the electrode structure 1 comprises a first electrode 6. At least a part of the interior around the exit apertures 5 of the electron beam guidance cavities 3 is covered with an insulating material 7 having a secondary emission coefficient $\delta > 1$ for cooperation with the cathodes 2. This material comprises, for example, MgO. But in addition, other materials can be used. The first electrodes 6 are positioned around the exit apertures 5 on the outer side of the electron beam guidance cavities 3. The first electrodes 6 consist of a metal sheet. The metal sheet can be applied by metal evaporation of, for example a combination of aluminum and chromium.

In operation, the first electrode 6 is coupled to a first power supply V1 (not shown) for applying an electric field with a field strength $E_1$ between the cathode 2 and the exit aperture 5. The secondary emission coefficient $\delta$ of MgO and the given field strength $E_1$ have values which allow electron transport through the electron beam guidance cavity 3. This kind of electron transport is known per se from the cited US patent 5,270,611.

Preferably, a second electrode 8 is placed between the entrance aperture 4 and the cathodes 2. The second electrode 8 is coupled to a second power supply means V2 (not shown) for applying, in operation, an electric field with a second field strength $E_2$ between the cathode 2 and the second electrode 8 for controlling the emission of electrons. Preferably, the second electrode 8 comprises a gauze with a 60 % transmission of electrons. The gauze can be made of a metal, for example, molybdenum. In operation, a pulling field due to the voltage difference applied between the gauzes and the cathode 2 pulls the electrons away from the cathodes 2. The voltage differences between the cathodes 2 and corresponding gauzes corresponds to R,G,B signals, respectively, which represent the image.

After the electrons have left the exit aperture 5 of the electron beam guidance cavity 3, the accelerating grid accelerates the emitted electrons into the main lens. Via the main lens and the deflection unit, the three electron beams corresponding to the red, green and blue signals are directed to the color screen in order to build the image represented by
the red, green and blue signals. In order to reduce the spread of the energy distribution of the electrons leaving the electron beam guidance cavity 6, the electron beam guidance cavity 6 has a tapered shape.

The cathodes 2 comprise carbon-based cold emitters such as carbon nanotubes or sp²-hybridized graphitic carbon. These cold emitters can be manufactured in large areas by vapor deposition and need no special structuring. It can be preferred that a cathode 2 comprises an array of these carbon-based cold emitters. It may also be preferred that the cathode ray tube comprises an array of cathodes.

Alternatively, the vacuum electronic device may comprise an array of cathodes in combination with an array of electron beam guidance cavities.

It may also be preferred that the cathode 2 has a ring-like shape and is placed in a concentric manner around the entrance aperture 4. This arrangement improves the symmetry of the electron beam and allows the use of an increased electron beam current. In addition, the surface of the electron beam guidance cavity is used more uniformly, which enhances the lifetime of the vacuum electronic device.
1. A vacuum electronic device comprising  
   - an electron source having at least one cathode for emitting of electrons,  
   - at least one electron beam guidance cavity for concentrating electrons emitted  
     from the cathode, said cavity having an entrance aperture and an exit aperture, a portion of an  
     inner side of said cavity around the exit aperture being provided with an insulating material, and  
   - a first electrode being connectable to a first power supply means for applying,  
     in operation, an electric field with a first field strength E1 between the cathode and the exit  
     aperture to allow electron transport through the electron beam guidance cavity,  
   characterized in that the cathode comprises a carbon-based cold emitter.

2. A vacuum electronic device as claimed in claim 1, characterized in that the  
   carbon-based cold emitter is selected from the group of carbon nanotubes or sp2-hybridized  
   graphitic carbon.

3. A vacuum electronic device as claimed in claim 1, characterized in that the  
   cathode comprises an array of carbon-based cold emitters.

4. A vacuum electronic device as claimed in claim 1, characterized in that the  
   cathode comprises an array of cathodes.

5. A vacuum electronic device as claimed in claim 1, characterized in that the  
   cathode has a ring-like shape and is placed around the entrance aperture.

6. A vacuum electronic device as claimed in claim 1, characterized in that the  
   vacuum electronic device is selected from the group of cathode ray tubes, matrix-addressed  
   displays, travelling wave tube amplifiers, SEM electron guns, electron beam lithography  
   electron sources and light producing devices.