July 30, 1968 SHOICHI MIYASHIRO ETAL 3,394,974

ELECTRON TUBE DEVICE AND METHOD OF MAKING THE SAME

Filed Nov. 14, 1966 3 Sheets-Sheet 1

FIG. 1

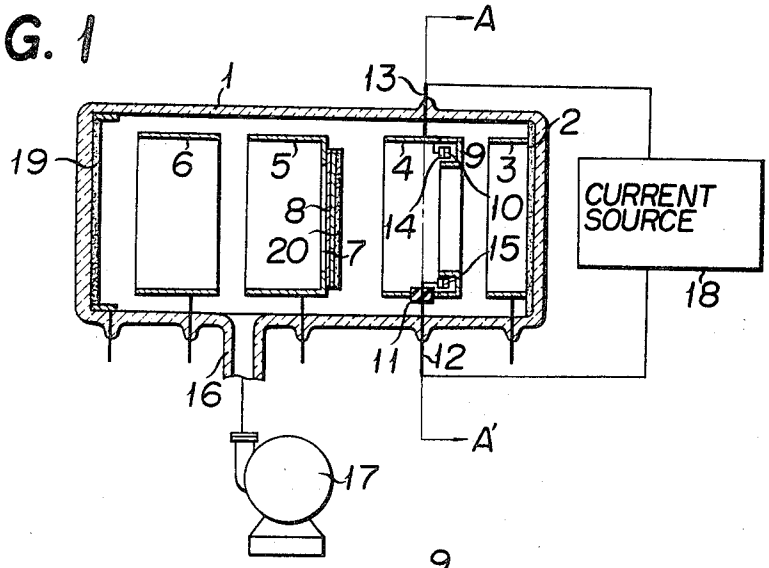
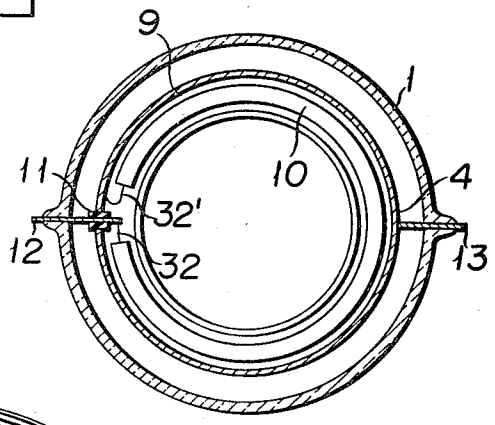


FIG. 2



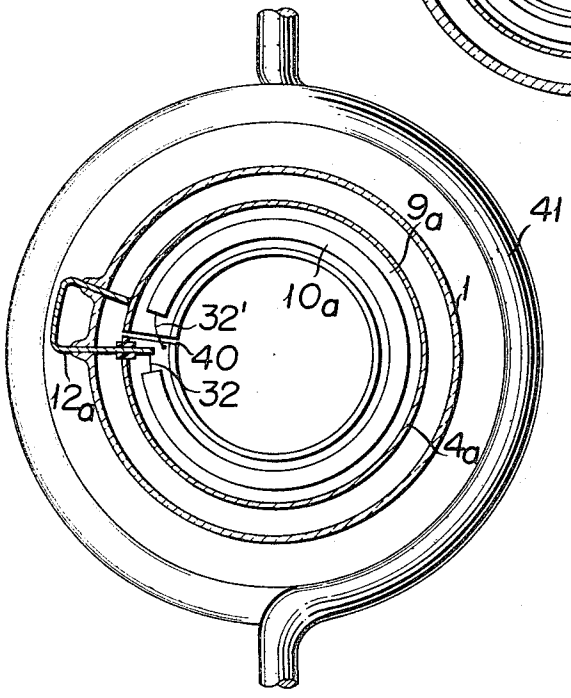


FIG. 3

FIG. 4

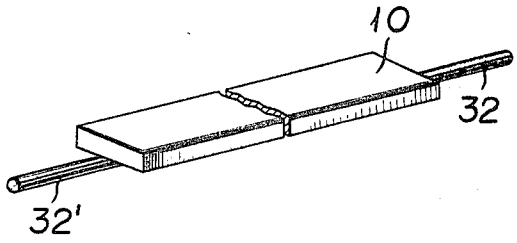


FIG. 5

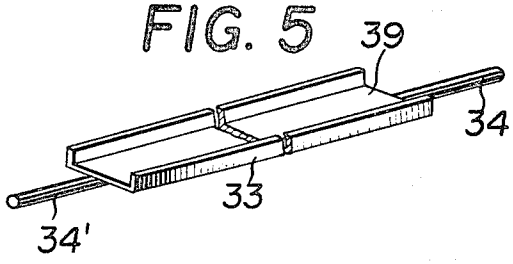


FIG. 6

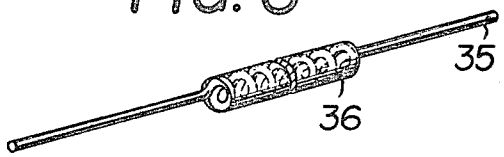


FIG. 7

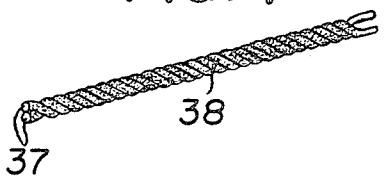
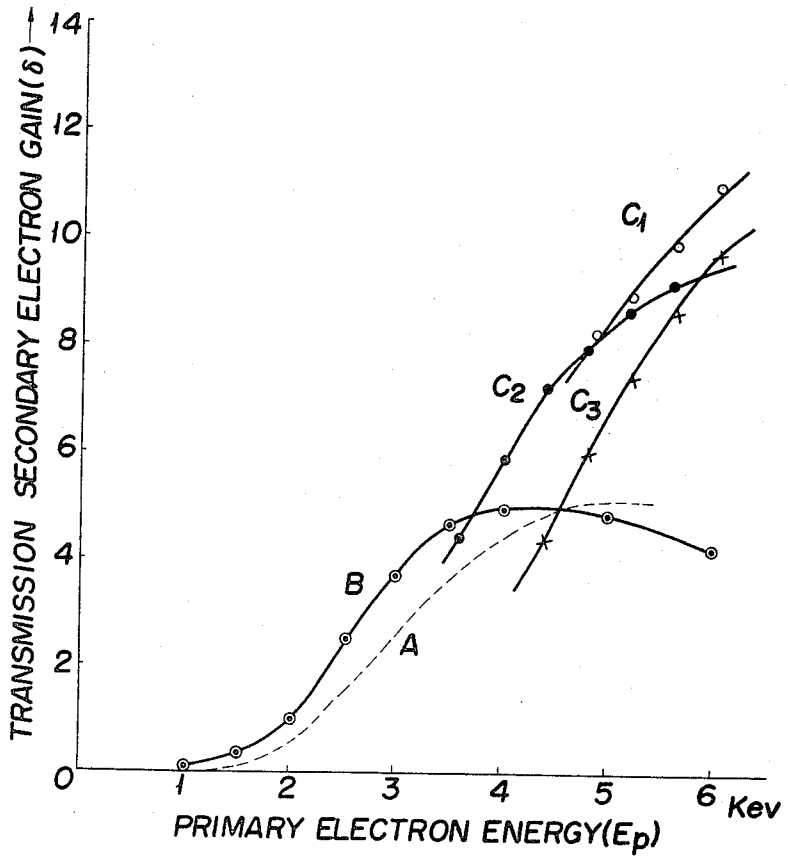


FIG. 8


TRANSMISSION SECONDARY ELECTRON GAIN(δ)
14
12
10
8
6
4
2
0
1
2
3
4
5
6 Kev
PRIMARY ELECTRON ENERGY(Ep)
C1
C2
C3
B
A

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ELECTRON TUBE DEVICE AND METHOD OF MAKING THE SAME

Shoichi Miyashiro, Yokohama-shi, and Katsuyuki Inoue, Kashimada, Kawasaki-shi, Japan, assignors to Tokyo Shibaura Electric Co., Ltd., Kawasaki-shi, Japan, a corporation of Japan

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Claims priority, application Japan, Nov. 17, 1965, 40/70,247
8 Claims. (Cl. 316—9)

This invention relates to electron tube devices and methods of manufacturing these tube devices, and more particularly to an electron tube device having at least one transmission type dynode for multiplication of electrons. By the transmissions type dynode is meant a dynode of such a type that it gives off secondary electrons by the excitation of incident primary electrons at its side opposite to the side upon which the primary electrons strike.

In prior art manufacture of a transmission type dynode for use in an electron tube a substrate or supporting layer usually made of aluminum oxide or magnesium oxide and having a thickness of about 500 to 1000 angstroms is stretched on a ring-shaped member usually made of molybdenum, then the ring-shaped member having the supporting layer is inserted in an exhausted device to deposit an aluminum layer on said supporting layer by means of vacuum evaporation. Thereafter a secondary electron emissive film or layer having an excellent secondary electron emissive property and a high electric resistivity is deposited on the aluminum film also by vacuum evaporation process. The secondary electron emissive layer is usually obtained by heating alkali-halide powder such as potassium chloride powder contained in a molybdenum crucible to evaporate potassium chloride (KCl) and deposit the same on the aluminum layer. The transmission type dynode thus produced is then combined with the prefabricated electrode structures and tube envelope to prepare a final construction of the electron tube, which is brought to the final product after exhausting the tube envelope.

The electron tube obtained by the above prior art method however, has suffered from marked deterioration of the secondary electron emissive property of the transmission type dynode, because of the fact that the dynode prefabricated in the vacuum evaporating device had to be exposed in atmosphere at the time it was taken out of the evaporating device and inserted in the tube envelope. The deterioration of the secondary electron emissive property is attributable to such factors as deliquescence of potassium chloride constituting the secondary electron emissive while it is exposed in the atmosphere, sticking of dust wafting in the atmosphere to the surface of the potassium chloride layer and so forth.

To eliminate the above disadvantage the assemblage of the electron tube has usually been carried out in a box filled with dried air. Such an expedient, however, lacks work efficiency hardly enabling mass production and further results in remarkable irregularity of the characteristics of the obtained tubes.

Furthermore, when employing the above-described method of manufacturing electron tubes the heat treatment of the tube during the exhausting process to eliminate such elements which would evaporate with a reduced pressure and at an elevated temperature is restricted because of the extreme heat-sensitivity of transmission type dynode whose secondary electron emissive characteristic readily becomes irregular when excessively heated, so that ion spots will be appeared on the fluorescent screen of the produced tube in the course of using

the tube due to liberation of evaporative elements which have not been eliminated by the heat treatment.

Furthermore, instead of using potassium chloride which is rich in hygroscopic property it has been attempted to use materials which are comparatively poor in hygroscopic property such as lithium fluoride (LiF) to form the secondary electron emissive layer, but the obtained tube characteristic has still proved to be very irregular. In either case, the percentage of acceptable products has been very low and it has been practically impossible to obtain tubes having excellent characteristics. Usually the tubes rejected by tests of secondary electron emissive characteristic of their transmission type dynode has had a large percentage to increase the production cost.

Accordingly it is a primary object of this invention to provide an improved electron tube having one or more transmission type dynodes.

Another object of this invention is to provide an improved method of manufacturing improved electron tubes having one or more transmission type dynodes.

A further object of this invention is to provide an improved method of manufacturing electron tubes having excellent characteristics by keeping the transmission type dynode sealed within the tube envelope to prevent exposure of the dynode to the atmosphere.

A still further object of this invention is to provide an improved method of manufacturing electron tubes having uniform dynode characteristics and substantially free from appearance of ion spots on the fluorescent screen, by carrying out previous heat treatment of the prefabricated tube envelope and electrode structures at a predetermined temperature sufficient to drive off completely the evaporative elements prior to the formation of the transmission type dynode while sufficiently evacuating the tube envelope.

Another object of this invention is to provide a method of manufacturing electron tubes which can yield a good work efficiency and enables mass production.

Another object of this invention is to provide a method of manufacturing electron tubes capable of modifying the characteristics of their dynode or dynodes.

According to the invention, in the manufacture of an electron tube having a transmission type dynode emitting secondary electrons at the side opposite to the side of incident primary electron impingement, a dynode substrate consisting of an electroconductive layer such as an aluminum layer vapor-deposited on a supporting layer but not deposited with the secondary electron emissive layer and a secondary electron emissive material source disposed in the neighborhood of and facing to the substrate are hermetically sealed in advance within the tube envelope, and then after heat treatment of the tube envelope together with electrode structures while evacuating the tube envelope for eliminating evaporative elements the secondary electron emissive material is heated by a suitable means so as to evaporate it and deposit it on the aluminum layer of the substrate under the continued process of tube envelope evacuation, whereby exposure of the secondary electron emissive layer to the atmosphere, and hence its absorption of moisture and dust is avoided and an electron tube having excellent characteristics can be obtained.

The invention is now described in connection with some embodiments thereof, reference being had to the accompanying drawings, in which:

FIG. 1 is a longitudinal section, with some schematic illustration, illustrating the method of manufacturing a two-stage image brightness intensifier tube embodying this invention;

FIG. 2 is a section take along line A–A′ and viewed in

the direction of arrows illustrating the secondary electron emissive material source in detail;

FIG. 3 is a section similar to FIG. 2 illustrating a modified means to heat the secondary electron emissive material source;

FIGS. 4 and 5 are enlarged partial perspective views illustrating varieties of heating means to heat the secondary electron emissive material source;

FIGS. 6 and 7 are enlarged partial perspective views illustrating varieties of combinations of the secondary electron emissive material source and means to heat the same; and

FIG. 8 is a diagram illustrating characteristic of the electron tube manufactured in accordance with this invention and those of conventional electron tubes of the same type.

Referring now to FIG. 1, a substantially cylindrical airtight envelope **1** has one end face plate deposited at the inner side with a fluorescent layer or screen **2** by suitable means such as spraying the fluorescent material. A first cylindrical electrode **3** is disposed concentrically with the envelope **1**, one end of the electrode being in contact with the fluorescent layer **2**. There are also disposed within and concentrically with the envelope **1** a second, a third, and a fourth cylindrical electrode **4**, **5** and **6** respectively. These electrodes **3** to **6** all serve to accelerate and focus image electrons given off at a photocathode **19** or transmission type dynodes respectively. The end of the third electrode **5** facing the second electrode **4** has an inwardly bent annular integral flange portion on the outer side of which is stretchedly fixed a supporting layer **7** about 500 angstroms in thickness made of aluminum oxide whose side nearer to the second electrode **4** is in turn covered with an aluminum layer **8** serving as the conductive layer. These layers **7** and **8** constitute the substrate of the transmission type secondary electron emissive layer. Said aluminum oxide layer **7** may be obtained, for example, by oxidizing one side of an aluminum layer having an appropriate thickness, and by taking away the not-oxidized part of said aluminum layer in a suitable manner so as to form an aluminum oxide layer about 500 angstorms thick. The end of the second cylindrical electrode **4** facing the fluorescent layer **1** is provided with an annular container **9**, for instance, made of Nichrome and open toward the third electrode **5** to accommodate a unit **15** of the secondary electron emissive material **14** and means **10** to heat the same as described hereinbelow in detail. The heating means **10** may be a substantially circular Nichrome member as shown in FIG. 4, to which a secondary electron emissive material **14** having a high resistivity and a comparatively high secondary electron emissive ratio such as potassium chloride is fixed at the side facing its substrate.

As shown in FIG. 2, one end of the heater **10** is connected to a lead **32** which is in turn connected to a terminal member **12** extending through both of the second electrode **4** and the tube envelope **1** and insulated from the second electrode by an insulator **11**, while the other end of the heater is connected through a lead **32'** to the second electrode itself which is provided with a terminal member **13** extending through the tube envelope. The terminal member **13** serves both for insertion of a direct-current or alternating-current source **18**, FIG. 1, between it and the other terminal member **12** to energize the heater **10** and for applying a voltage to the second electrode in the operation of the tube. The heater **10** may, instead of the Nichrome member, comprise platinum-clad molybdenum wire or a tantalum member or other suitable members as well.

To fix potassium chloride to the heating means **10**, potassium chloride is first dissolved in water and the resultant solution is then applied on the heater **10** and dried. If desired, the applied potassium chloride may be dried by heating in vacuum or inert gas atmosphere, whereby potassium chloride sticks to the heating means **10** excellently. In this way a desired amount of potassium chloride may be fixed to the heater by adjusting either the amount of application of the solution or the concentration of the solution.

The airtight cylindrical envelope **1** is provided with an integral exhaust tubulation **16** leading to an evacuating device **17** as schematically shown in FIG. 1.

The tube envelope **1** containing various component structures as described hereinabove is first evacuated by the evacuating device **17** until substantially all of the air within the envelope is driven out. Then the entire unit is heated at about 350° C. while continuing the evacuating process so as to drive out most part of such elements that are sticking to the envelope **1** as well as to the various electrode structures and tend to evaporate at an elevated temperature and under a reduced pressure.

When the heat treatment to eliminate the above evaporative elements has been finished, a photocathode **19** is formed on the inner side of the end face plate of the airtight cylindrical envelope **1** remote from the fluorescent layer **2**. There are various well known methods to form the photocathode **1** and any suitable method may be employed: for example, in case the photocathode is formed by activation of silver-bismuth mixture with cesium, the silver-bismuth mixture suitably disposed somewhere within the envelope **1** may be heated so that it will vaporize and deposit on the above-mentioned inner side of the envelope to form a thin layer consisting of silver and bismuth, which is then activated by cesium vapor introduced within the envelope, for instance, through the exhaust tubulation **16**.

After the formation of the photocathode **19**, the heater **10** is energized from the current source **18** while maintaining the process of evacuating the envelope **1** to heat the highly resistive, secondary electron emissive material **14**. As the result the heated secondary electron emissive material evaporates and is directed toward the third electrode **5** to be deposited on the aluminum layer **8** of the substrate provided on the third electrode, so as to form the secondary electron emissive layer **20** on the substrate without exposure to the atmosphere.

Thereafter the tubulation **16** is closed up and cut off in a well-known manner to obtain a two-stage brightness intensifier tube generally indicated at **21**.

While the above-mentioned secondary electron emissive material is deposited on the aluminum layer **8**, it is also possible to deposit on an aluminum oxide layer in the same manner.

Moreover, in the foregoing description the potassium chloride (KCl) and lithium fluoride (LiF) are used as the secondary electron emissive material, it is also possible to use the alkali-halide such as sodium chloride (NaCl), potassium bromide (KBr), cesium iodide (CsI) and barium fluoride (BaF_2).

The tube thus obtained is given tests of the secondary electron emissive characteristic of the transmission type dynode. In case the tests result in an inferior characteristic of the transmission dynode due to insufficient deposition of the secondary electron emissive material the correction of the characteristic may be readily made by an additional deposition of the secondary electron emissive material on the already deposited emissive layer **20** by further heating the emissive material source **14** remaining in the container **9**.

While the heater **10** is directly connected across the external source **18** to supply current therethrough in the previous embodiment, it is also possible to carry out the heating by high frequency induction with a structure as shown in FIG. 3. Since the radioheating can not be attained with the structure shown in FIG. 1 where the heater **10** is shielded by the second electrode **4**, an axial gap **40** is formed as in FIG. 3 in the structure comprising the second electrode **4*a*** and the integral emissive material-heater unit container **9*a*** and one end of the heater **10** is connected to the container **9*a*** through a lead **32'** crossing the gap **40**, while the other end of the heater **10** is

connected through a lead **32** to a bridging lead member **12***a* which is partly identical with the terminal member **12** of the previous embodiment except that it has an integral extension folded back outside the envelope **1** and re-entiring into the envelope to be connected to the container such that it bridges the gap **20**, thereby completing a two-turn loop circuit. With this structure it is possible to pass current through the heater **10** by feeding a radio-heating coil **41** with power at a predetermined frequency from an appropriate high frequency power source not shown.

In the foregoing description the heater **10** is made to have a circular narrow strip form and provided at its end with leads **32** and **32'** as shown in FIG. 4. Alternatively, it may have other suitable configuration such as that shown in FIG. 5 having an annular groove **39** in which the secondary electron emissive material is to be filled. It may also comprise a wire, for example, as shown in FIG. 6 which illustrates a single wire **35** having a coiled portion constituting the heater to which the secondary electron emissive material **36** is fixed. Further, it may comprise two or more wires **37** as shown in FIG. 7 suitably twisted together and the secondary electron emissive material is fixed to the twisted portion. Of course, the invention is not restricted to the above heater structures, but heaters of any other suitable configuration permitting efficient transfer to heat from the heater to the secondary electron emissive material may be used.

Also, in the foregoing description the method according to the invention is employed to manufacture a two-stage image brightness intensifier tube, but the invention is not restricted to the manufacture of the above tube. The invention may as well be applied to the manufacture of multi-stage intensifier tubes having two or more transmission type secondary emission or any other electron tubes having at least one transmission type dynode as described above.

FIG. 8 illustrates plots of transmission secondary electron gain (δ) versus primary electron energy (E_p) of five-stage image brightness intensifier tubes manufactured in accordance with this invention and two prior tubes which are manufactured conventionally for the sake of comparison. In the figure the characteristic curve A is derived from a conventional tube described in an article by D. L. Emberson et al. entitled "Advances in Electronics and Electron Physics" presented in Academic Press, vol. 16 (1962), pages 127 to 139. The characteristic curve B is obtained from another conventional tube manufactured by first prefabricating a transmission type secondary emission dynode within a separate vacuum container and then inserting it in an intensifier image orthicon. Characteristic curves C_1, C_2 and C_3 are resulted respectively from three five-stage intensifier tubes of same specifications manufactured in accordance with this invention. The transmission secondary electron gain (δ) represents a fourth root of the total gain due to four dynodes.

As is apparent from the figure, the dynodes according to the invention yields far greater transmission secondary electron gain with the same primary electron energy than do the conventional dynodes.

While the invention has been described in connection with several preferred examples, it will be obvious to those skilled in the art that the invention is not limited to the preceding examples but various changes and modifications can be made in the details of the method and structure without departing from the true spirit and scope of the invention.

What is claimed is:

1. A method of manufacturing an electron tube having at least one electron multiplying dynode of transmission secondary emissive type, said method comprising steps of preparing a gas-tight tube envelope provided with an evacuating tubulation and containing at least one electroconductive base substrate, highly resistive secondary electron emissive material source disposed in the neighborhood of and facing to said substrate, evacuating said tube, envelope through said evacuating tubulation, electrically heating source to evaporate said secondary electron emissive material and deposit the same on said base substrate so as to form afore-said transmission type dynode, and sealing off said evacuating tubulation.

2. The method of manufacturing an electron tube according to claim **1**, wherein the heating of said source is made by supplying current directly to a heater.

3. The method of manufacturing an electron tube according to claim **1**, wherein the heating of said source is made by high frequency induction heating.

4. A method of manufacturing an electron tube according to claim **1**, said steps of preparing a gas-tight tube envelope include the steps of preparing said source to deposit in the neighborhood of and facing toward said substrate.

5. A method of manufacturing an electron tube according to claim **1**, wherein said steps of preparing a gas-tight tube envelope include the steps of preparing a substantially circular narrow strip piece as a heater.

6. A method of manufacturing an electron tube according to claim **1**, wherein said steps of preparing a gas-tight tube envelope includes the steps of preparing a substantially annular groove to be filled with said secondary electron emissive material as a heater.

7. A method of manufacturing an electron tube according to claim **1**, wherein said steps of preparing a gas-tight tube envelope include the steps of preparing a coiled wire as a heater.

8. A method of manufacturing an electron tube according to claim **1**, wherein said steps of preparing a gas-tight tube envelope include the steps of preparing a plurality of twisted wires.

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