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ANODE ELECTRODE FABRICATION

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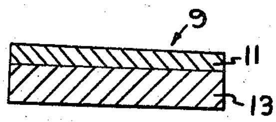

Fig. 1

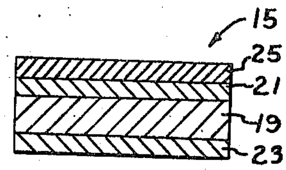

Fig. 2

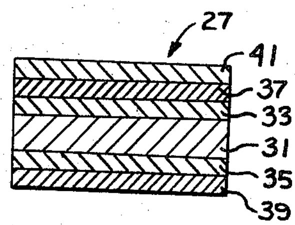

Fig. 3

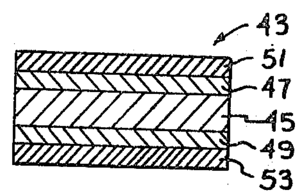

Fig. 4

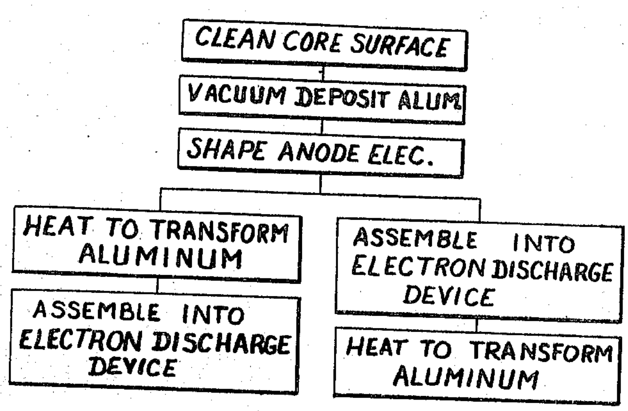

Fig. 5

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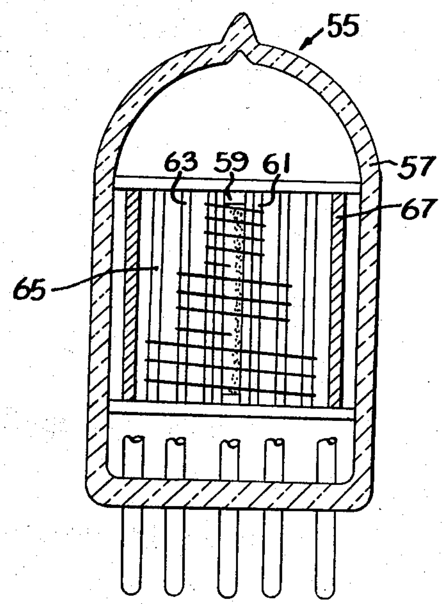

Fig. 6

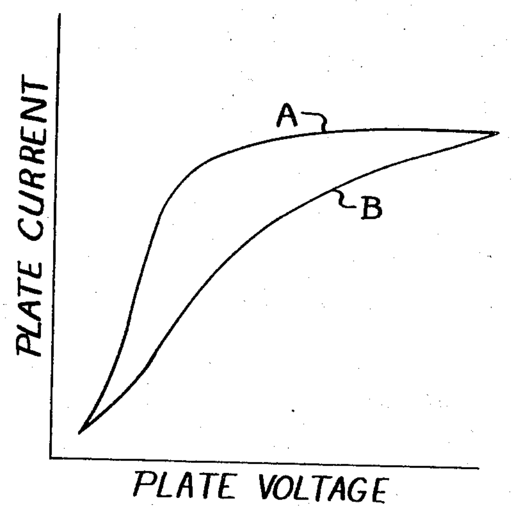

Fig. 7

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ANODE ELECTRODE FABRICATION

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Original application June 28, 1965, Ser. No. 467,639. Divided and this application Mar. 12, 1968, Ser. No. 712,434
Int. Cl. H01j *9/00*
U.S. Cl. 29—25.17 3 Claims

ABSTRACT OF THE DISCLOSURE

A process for fabricating a composite anode electrode adapted for use in an electron discharge device comprising the steps of: cleaning a core material of steel sandwiched between layers of nickel or copper, vacuum depositing a layer of aluminum, shaping the structure, and heating to transform the aluminum to an aluminum nickel or aluminum copper compound.

This application is a divisional application of U.S. Ser. No. 467,639 filed June 28, 1965, now abandoned.

This invention relates to anode electrode structures for electron discharge devices and more particularly to improved anode electrode structures and a process for fabricating such structures.

In electron discharge devices it is necessary to provide an anode electrode capable of dissipating heat resulting from the flow of electrons thereto. Accordingly, present-day anode electrode structures usually include a blackened outer surface of relatively high thermal radiation capability.

It has been a common practice to form anode electrode structures from a material such as steel, nickel, or nickel-plated steel and to blacken the outer surface thereof by gas carbonization and similar processes. However, it is well known that blackened outer surfaces provided by such processes have a number of disadvantages with respect to anode electrode structures for electron discharge devices. For example, the carbon tends to rub off and smudge during the assembly of a discharge device, the heat necessary for processing a discharge device causes the carbon to burn-off, flake, and blister, and rejection of both anode electrode structures and electron discharge devices due to such defects result in an excessive cost of materials.

These disadvantages have, for the most part, been overcome by fabricating anode electrode structures for discharge devices from an aluminum coated core material. The aluminum coating, which may be heated either before or during the normal processing of an electron discharge device, is transformed to an aluminum compound having the desired characteristics and capabilities.

At present, aluminum coated core material suitable for the fabrication of anode electrodes for electron discharge devices is provided by either a hot-dipping process or a cladding process. In both processes, an aluminum layer is applied to a relatively thick core material, the aluminum-coated core material is rolled to a thickness suitable for anode electrode shaping, and the aluminum-coated core material is annealed to provide a material having a temper which permits electrode shaping. As a specific example, a steel core having a thickness of about 0.040 inch is coated with an aluminum layer by a hot-dipping or cladding process, rolled to a finished thickness in the range of about 0.005 to 0.015 inch, annealed to a temper suitable for shaping, and shaped into an anode electrode configuration.

General disadvantages attend anode electrodes fabricated in accordance with such processes. For example, anode electrodes having a thickness in the range of about 0.005 to 0.0065 inch usually have a relatively thick aluminum layer in the range of about 0.0003 to 0.0006 inch when produced by a hot-dipping or cladding process. It has been found that an aluminum layer having a thickness in the above-mentioned range has a tendency to "sliver" during the electrode shaping process and these electrically conductive aluminum "slivers" present a continued possibility for short circuited elements and loose metal particles not only to the electrode fabricator and electron discharge device manufacturer but also to the consumer.

When the aluminum layer is relatively thick, as provided by hot-dipping and cladding processes, it has been found that the assembly process of electron discharge devices is deleteriously affected because of the difficulty encountered in attempting to consistently and reliably attach such structures to other metals by welding. Should the aluminum layer be in the form of an aluminum-core compound as a result of heat applied during an annealing process, attachment by welding becomes even more difficult.

Also, the application of an aluminum layer to a core by a hot-dipping or cladding process inherently introduces undesired impurities into the aluminum layer. Moreover, aluminum in a form suitable to such processes includes deleterious contaminants and impurities.

The hot-dipping and cladding processes require a rolling or sizing step which tends to introduce additional impurities into the aluminum layer and to harden the composite structure rendering it unsuitable for electrode shaping without additional processing. As a result, an annealing step is required in order to provide a material having the necessary ductility.

The annealing step has a tendency to heat transform the aluminum layer to an alumuinum compound accompanied by the undesired formation of unwanted aluminum oxides. Since oxides of aluminum are notoriously abrasive, it has been found necessary to construct the anode electrode shaping tools of relatively expensive and difficult to machine carbide materials in order to prevent rapid deterioration and wear thereof.

Other problem areas encountered with composite materials having an aluminum layer with a thickness in the above-mentioned range are a relatively high residual gas content, a tendency to provide an undesired excessive amount of vaporized aluminum during normal processing of an electron discharge device, and a lack of consistency and uniformity of the aluminum-core compound upon transformation of the aluminum layer by heat. Also, electron discharge devices utilizing anode electrode structures having an aluminum layer provided by the above processes have a residual gas content and a plate current-plate voltage characteristic curve which leaves much to be desired.

Therefore, it is an object of this invention to provide an improved process for fabricating an anode electrode for use in an electron discharge device.

Another object of the invention is to improve the weldability of an anode electrode having an aluminum layer by fabricating the electrode in accordance with an improved process.

Still another object of the invention is to improve the plate current-plate voltage characteristic curve of an electron discharge device utilizing an anode electrode having an aluminum compound layer.

A further object of the invention is to provide an anode electrode having an oxide-free and contaminant-free aluminum layer.

A still further object of the invention is to enhance the thermal radiation properties and reduce the residual gas content and aluminum vaporization of an aluminized anode electrode utilized in an electron discharge device.

These and other objects are achieved in one aspect of the invention by a process wherein a core material having a finished thickness and temper is cleaned to provide an oxide-free and contaminant-free surface, a layer of pure aluminum is vacuum deposited onto this surface to provide a composite structure, and the composite structure is shaped into an anode electrode configuration. Thereafter, the anode electrode configuration is heated, either prior to or after inclusion thereof in an electron discharge device, to transform the aluminum layer to an aluminum-core compound.

For a better understanding of the present invention, together with other and further objects, advantages, and capabilities thereof, reference is made to the following diclosure in connection with the accompanying drawings in which:

FIGS. 1, 2, 3, and 4 illustrate a cross-sectional view of several embodiments of anode electrode materials suitable for use in an electron discharge device;

FIG. 5 is a flow chart illustrating a process for providing an anode electrode structure as illustrated in FIGS. 1, 2, 3, and 4;

FIG. 6 illustrates a perspective view of an electron discharge device utilizing an anode electrode structure fabricated in accordance with the process illustrated in FIG. 5; and

FIG. 7 is a graphical representation illustrating the plate current-plate voltage characteristic curve of a discharge device utilizing one of the anode electrode embodiments of FIGS. 1, 2, 3, and 4.

Referring to the drawings, FIG. 1 illustrates a cross-sectional view of an anode electrode material **9** suitable for fabrication into anode electrode structures for use in electron discharge devices. The anode electrode material **9** has at least one aluminum layer **11** bonded to a core **13** which includes at least one and may include all of the metals selected from the group consisting of steel, nickel, and copper.

The core **13** is of a thickness and temper suitable for direct shaping into an anode electrode configuration without need for further sizing or annealing. Preferably, the core **13** has a thickness in the range of about 0.004 to 0.020 inch depending upon the type and ultimate use of the anode electrode to be fabricated therefrom and the type and use of the electron discharge device wherein the anode electrode is to be utilized.

The aluminum layer **11** is substantially pure aluminum having an especially uniform and controllable thickness. Preferably, the thickness of the aluminum layer **11** is in the range of about 0.00003 to 0.0003 inch. When the layer **11** of aluminum is less than about 0.00003 inch, it has been found that the uniformity of transformation thereof to an aluminum compound, which may occur prior to or during the processing of an electron discharge device, and the thermal radiation properties or reflective properties of the transformed compound leave much to be desired.

Also, a core material having an aluminum layer **11** greater than about 0.0003 inch in thickness has been found most difficult to shape into an anode electrode configuration without the appearance of undesired and unwanted "slivers" of aluminum. Further, anode electrodes having an aluminum layer **11** greater than about 0.0003 inch have been found most difficult to attach to other metals by welding during an electron discharge device assembly process and tend to exhibit excessive aluminum vaporization and a relatively high residual gas content during normal processing of a discharge device.

Alternate embodiments of composite materials suitable for fabrication into anode electrode configurations for electron discharge devices are illustrated in FIGS. 2, 3, and 4. FIG. 2 illustrates a composite anode electrode **15** having a core **17** which includes a copper layer **19** sandwiched between steel layers **21** and **23**. A substantially pure aluminum layer **25** is bonded to the outer steel layer **21** and the composite structure is of a thickness and temper suitable for shaping into an anode electrode configuration having the aluminum layer **25** on the outer surface. Since aluminum is heat transformable to an aluminum compound during normal processing of an electron discharge device, the anode electrode **15** of the discharge device utilizing the above-mentioned material has an outer layer of an aluminium-iron compound which is dark grey in appearance, has high thermal radiation properties, good adherence to the core material, a low residual gas content, and a non-oxidizing surface.

FIG. 3 illustrates a cross-sectionl view of another composite anode electrode **27** having a core **29** which includes a copper layer **31** sandwiched between steel layers **33** and **35**. The steel layers **33** and **35** have outer nickel layers **37** and **39** and a relatively pure aluminum layer **41** bonded to one of the nickel layers **37**. Obviously, an aluminum layer **41** may be bonded to both of the outer nickel layers **37** and **39**. The composite structure is of a temper and thickness suitable for direct shaping into an anode electrode configuration with the aluminum layer **41** as the outer surface. During normal processing of an electron discharge device, the aluminum layer **41** is transformed by heat to an aluminum-nickel compound having a blackened velvet-like appearance, relatively high thermal radiation properties, good adherence to the core **29**, and low residual gas content. The nickel coating **39** on the other steel layer **35**, located on the inner surface of the anode electrode configuration, remains substantially unchanged during normal tube processing and serves to provide a heat reflective surface of relatively high capability which assists in the activation of the discharge device.

In still another embodiment, FIG. 4 illustrates a cross-sectional view of a composite anode electrode **43** which includes a steel layer **45** sandwiched between copper layers **47** and **49**. Substantially pure aluminum layers **51** and **53** are bonded to the outer surface of each of the copper layers **47** and **49**. The outer aluminum layers **51** and **53** are transformable by heat to an aluminum-copper compound having a bright golden appearance, a relatively high reflective capability, and a relatively high resistance to oxidation.

Referring to FIG. 5, the flow chart illustrates a preferred process for fabricating a composite anode electrode. In the process a material which includes at least one and may include all of the metals selected from the group consisting of steel, nickel, and copper and having, or processed to have, a temper and approximate thickness suitable for mechanical shaping into an anode electrode configuration is selected for the core material.

The core material is thoroughly cleaned to remove all traces of oxides and contaminants and provide an oxide-free and contaminant-free outer surface. Obviously, the cleaning process for providing the oxide-free and contaminant-free outer surface may utilize caustics, detergents, or any one of a number of well-known cleaning agents for metal surfaces.

Then, a layer of relatively pure aluminum is affixed to the oxide-free and contaminant-free surface by a vacuum deposition process. Numerous techniques for vapor depositing aluminum onto a metal surface are known and a preferred process includes the locating of the core material and a source of aluminum in a reduced atmosphere of about 5×10^{-4} mm. of mercury and the heating of the aluminum contained therein to a temperature in the range of about 1200 to 1400° C. for a period sufficient to provide the desired aluminum deposition on the oxide-free and contaminant-free surface of the core. Thus, a relatively pure aluminum layer is deposited upon the oxide-free and contaminant-free surface of the core without the formation of undesired interfacial contaminants and abrasive aluminum oxides.

Having provided a composite material which includes a core and an aluminum layer affixed thereto and which has a desired finished thickness and is of a temper suitable for mechanical working, the composite material is shaped in an anode electrode configuration suitable for use in an electron discharge device. Obviously, the aluminum layer may be utilized as either an inner surface or an outer surface depending upon the core material selected and the physical characteristics desired.

Thus, there has been provided an anode electrode having at least one layer of relatively pure aluminum deposited onto an oxide-free and contaminant-free surface by a vacuum deposition process which insures an oxide and contaminant-free interface between the aluminum layer and the surface. The outer surface of the aluminum layer has a bright shiny appearance and a relatively low porosity in contrast to the relatively porous and dull satin-like aluminum layers obtained by a hot-dipping or cladding process.

Thereafter, the aluminum layer is transformed by heat to an aluminum-core compound having characteristics dependent upon the nature of the core material immediately adjacent thereto. Preferably, the anode electrode is assembled into an electron discharge device prior to the transformation of the aluminum layer by heat because of the relatively good weldability characteristics of the electrode. However, the aluminum layer may be transformed by heat to an aluminum-core compound and the electrode assembled into an electron discharge device prior to the processing thereof.

When an anode electrode having a core of steel, nickel, or copper and a layer of vacuum deposited oxide and contaminant-free aluminum bonded thereto is utilized in an electron discharge device, it has been found that the discharge device has a plate current-plate voltage characteristic curve of greatly enhanced slope as compared with the previously known aluminized anode electrodes provided by hot-dipping and cladding techniques.

Although no exacting theoretical explanation for the unique and highly desirable results obtained is presently available, it is believed that the purity of the aluminum layer in a vacuum deposition technique, the absence of normally present oxides and contaminants from the aluminum layer and intermediate thereto and the core material, and the provision of an aluminum-covered core having a temper and size which requires neither rolling nor annealing prior to shaping into an electrode configuration are contributing factors to the improved and highly desirable surface condition of the aluminum layer. Further, the purity of the aluminum compound formed during the processing of the discharge device as well as the relative thinness thereof are factors which are believed to contribute to the unexpected and highly desirable improvements in the electrical parameters of the discharge device.

As a specific example, FIG. 6 illustrates a typical electron discharge device **55** having an envelope **57**; a cathode electrode **59**; first, second, and third grid electrodes **61**, **63**, and **65**, respectively; and an anode electrode **67**. As previously mentioned, the anode electrode **67** has a core **13** which includes at least one metal selected from the group consisting of steel, nickel, and copper. Bonded to at least one surface of the core **13** is a relatively thin layer **11** of vacuum deposited oxide-free and contaminant-free aluminum.

As a specific example, two groups of power pentode-electron discharge devices, similar to the above configuration and known as type 6GK6, were assembled and processed under substantially identical conditions. The groups were similar in all respects except for the anode electrodes. One group, Group A, included an anode electrode having an outer layer of vacuum deposited oxide and contaminant-free aluminum bonded to a core which included a copper layer sandwiched between steel layers. The other group, Group B, had substantially the same core material and the outer aluminum layer was applied thereto by a cladding process.

After the usual processing and activation of the two groups, discharge device Groups A and B, a comparison of electrical parameters were made. As graphically illustrated in FIG. 7, it was found that Group A, the group having an oxide and contaminant-free vacuum deposited aluminum layer, had a plate current-plate voltage characteristic curve, curve A, of enhanced slope as compared with the characteristic curve, curve B, of discharge devices of Group B wherein the anode electrode was of an aluminum-clad material. Obviously, the enhanced slope of the discharge device having a vacuum deposited aluminum layer providing an increased value of plate current at a reduced value of plate voltage offers numerous advantages especially when the commercial trend is toward a reduction in power supply requirements.

Thus, there has been provided a composite anode electrode suitable for use in an electron discharge device and a process for fabricating such electrodes as well as an electron discharge device having numerous advantages over any of the known and available anode electrodes and discharge devices. The elimination or at least the reduction in "slivering" of aluminum during the fabrication of an aluminized electrode greatly enhances the use of such material. The provision of a composite aluminized electrode having a weldability, low residual gas level, absence of vaporized aluminum problems, uniformity of transformation, non-porous surface resistant to contamination, and reduced cost of manufacture is believed to be unobtainable in any other known structure. Moreover, the enhanced electrical characteristics of an electron discharge device utilizing the unique anode electrode are believed to be unobtainable in any other discharge device.

While there have been shown and described what are at present considered the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modification may be made therein without departing from the invention as defined by the appended claims.

What is claimed is:

1. A process for fabricating a composite anode electrode adapted for use in an electron discharge device comprising the steps of:

cleaning a core material to provide at least one oxide-free and contaminant-free surface, said core material being of finished thickness and temper for shaping into an anode electrode and including a layer of steel sandwiched between layers of one metal selected from the group consisting of nickel and copper;

vacuum depositing a layer of pure aluminum having a thickness in the range of about 0.00003 to 0.0003 inch onto said oxide-free and contaminant-free surface to provide a composite structure;

shaping said composite structure into an anode electrode configuration having a layer of pure aluminum bonded to said core material whereby aluminum sliver formation normally occuring during electrode shaping is prevented and the anode electrode has a relatively good weldability and a bright surface; and

heating said anode electrode configuration to transform said layer of pure aluminum to an aluminum compound.

2. The process of claim **1** wherein said core material includes a layer of steel sandwiched between layers of nickel and said heating transforms said aluminum to an aluminum-nickel compound having a fine-grained velvet-like blackened outer surface.

3. The process of claim **1** wherein said core material includes a layer of steel sandwiched between layers of copper and said heating transforms said aluminum to an aluminum-copper compound having a bright golden surface resistant to oxidation.

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29—25.11; 313—107