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Aptt, Jr.

[11] **3,906,271**

[45] **Sept. 16, 1975**

[54] **CERAMIC CUP ELECTRODE FOR A GAS DISCHARGE DEVICE**

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[73] Assignee: **International Telephone and Telegraph Corporation**, Nutley, N.J.

[22] Filed: **Aug. 13, 1974**

[21] Appl. No.: **497,022**

[52] **U.S. Cl.**..... **313/213;** 313/217; 313/346 R; 313/491

[51] **Int. Cl.**[2]..... **H01J 1/14;** H01J 61/067; H01J 61/42

[58] **Field of Search**..... 313/346 R, 491, 213, 211, 313/209, 217

[56] **References Cited**

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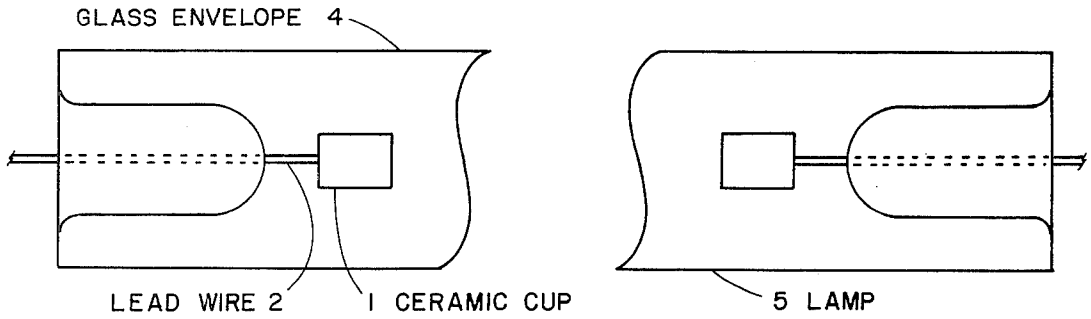
"Materials and Techniques for Electron Tubes," by W. H. Kohl, Table 2.23 on page 122 relied on, 1960, Reinhold Publishing Corp., N.Y., N.Y.

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Attorney, Agent, or Firm—John T. O'Halloran; Menotti J. Lombardi, Jr.; Richard A. Menelly

[57] **ABSTRACT**

Cup electrodes for cold cathode type discharge lamps comprising a ceramic cup containing an electron emissive material provide long operating lifetimes to lamps using these electrodes. Electrical contact is provided through a hole in the bottom of the ceramic cup and the electron emissive material is fused between the inner walls of the ceramic cup and a portion of the lead wire extending through the aforementioned hole. The ceramic cup provides a sputter-proof container for the emissive material contained within and thereby greatly diminishes end discoloration when used in cold cathode type fluorescent discharge lamps.

4 Claims, 7 Drawing Figures



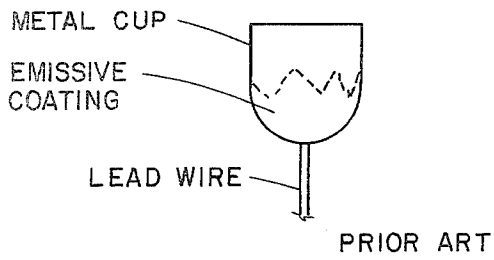


Fig. 1

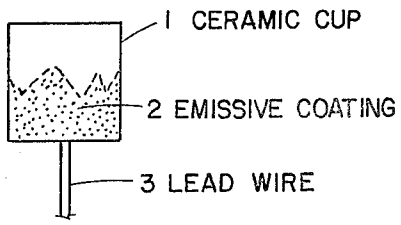


Fig. 2

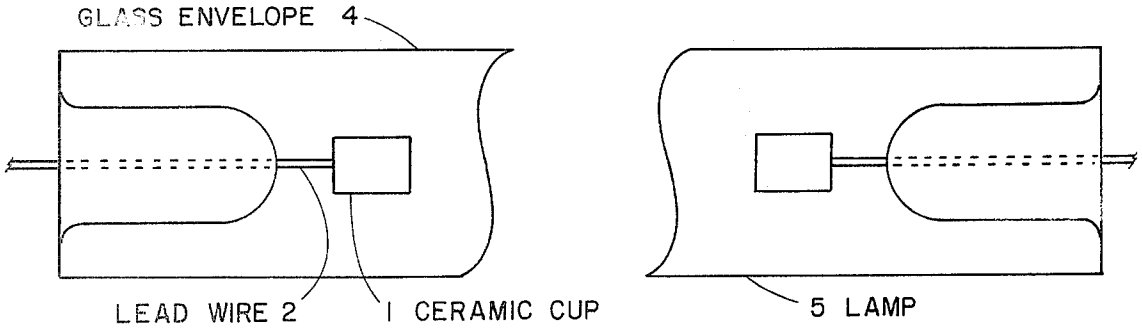


Fig. 3

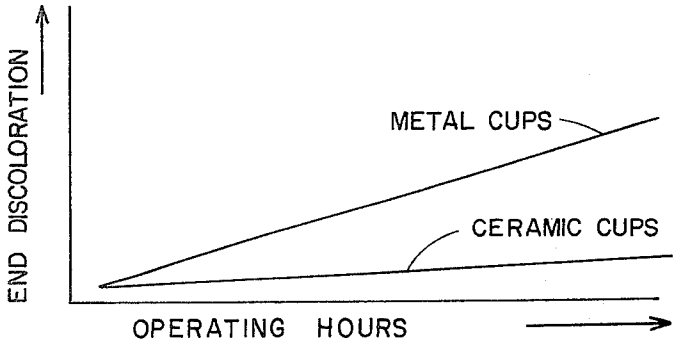


Fig. 6

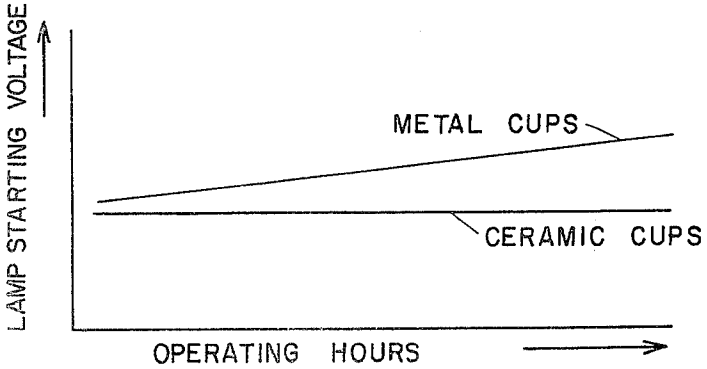


Fig. 7

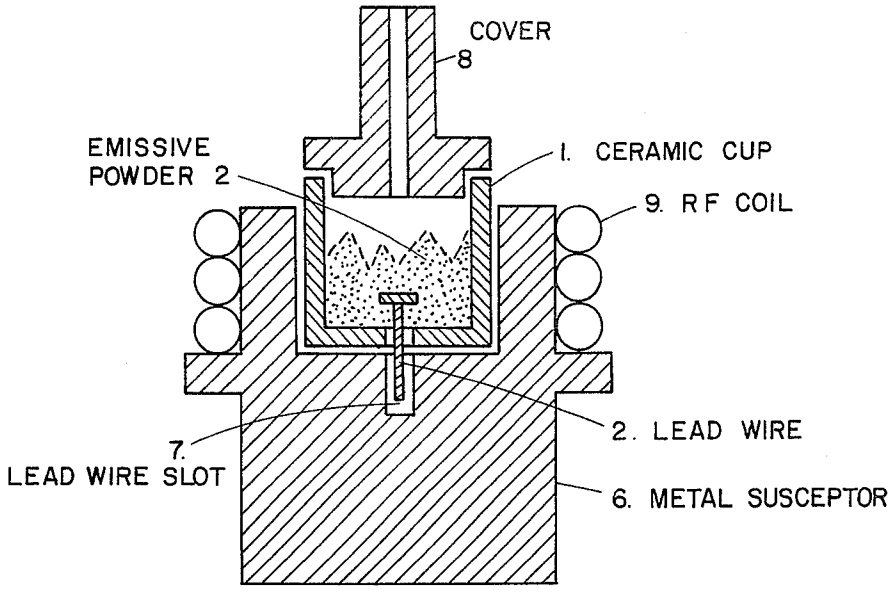

COVER
8
EMISSIVE
POWDER 2
1. CERAMIC CUP
9. RF COIL
2. LEAD WIRE
7.
LEAD WIRE SLOT
6. METAL SUSCEPTOR

Fig. 4

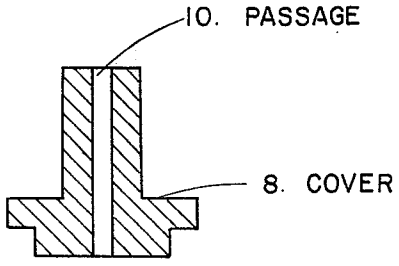

10. PASSAGE
8. COVER

Fig. 5

CERAMIC CUP ELECTRODE FOR A GAS DISCHARGE DEVICE

BACKGROUND OF THE INVENTION

Cold cathode lamps generally comprise a tubular envelope containing a mixture of inert gases and a small quantity of mercury. A pair of complementary electrodes are sealed at opposite ends of the tubular envelope in order to supply electrical current through the envelope, and a small quantity of an electron emissive material is coated on the surface of the electrodes in order to promote the emission of electrons. When a sufficiently high voltage is applied across the lamps, by means of the electrodes, the electric field established causes some of the electrons within the inert gas and mercury vapor to become accelerated in the direction of the electrodes. Some of the electrons and ions thereby created reach the electrodes with sufficient kinetic energy to cause the electrodes to become heated to emit more electrons partially by the mechanism of field emission and partially by thermionic emission. As the process continues and more and more electrons become created within the lamp volume the electrodes become heated to a point where the electron emission process from the cathode is mainly thermionic and the amount of energy required to sustain the electric discharge created through the lamp becomes substantially reduced.

The electrodes generally used within cold cathode devices, for example, neon sign lamps, gas lasers and fluorescent lamps generally comprise a metallic cup-shaped container and the emissive coating usually consists of a thin coating on the inner surface of the cup.

The emissive coating most often used comprises a mixture of alkaline earth oxides coated onto the cup from a liquid suspension of their carbonates. Since the alkaline earth oxides are not air stable the dissociation of the carbonate to oxide transistion must occur in the absence of air. A convenient method for the thermal dissociation of the alkaline earth carbonate to the oxides for cold cathode cup electrodes is to apply the alkaline earth carbonates to the metallic cup electrode prior to processing of electrodes into lamps, and during the lamp manufacturing process, to heat the metallic cup by an external high frequency induction field, or by the aforementioned mechanism of ion bombardment and electron heating.

During the lamp starting process the so-called "glow to arc" transistion occurs, where the discharge initially goes from a condition of high localized fields in the vicinity of the electrodes until the electrodes become heated to thermionic emission and to a condition of relatively low energy localized fields in the vicinity of the electrodes when the lamp is in its operational arc discharge mode. During the condition of high localized fields in the vicinity of the cathode the entire electrode structure including the coating is continuously bombarded by relatively energetic electrons and ions until the thermionic emission process occurs. During this period of bombardment a quantity of the emissive coating becomes sputtered away and by this mechanism upon successive starting and "glow to arc" transistions the emissive coating becomes consumed until after a successive number of starts there is no longer sufficient emissive coating to supply electrons to the discharge so that the electrode becomes "deactivated" and the lamp is no longer operational.

The advent of methods and materials for providing large quantities of electron emissive materials to cold cathode lamps has substantially increased the lamp operating life by prolonging the time it takes for the larger quantity of electron emissive material to be consumed by the lamp starting and operating process. Density gradient electrodes formed from the fusion of alkaline earth peroxides and refractory metals as described for example with U.S. Pat. No. 3,798,492 and assigned to the assignee of the instant invention; and later by the development of the alkaline earth tantalate emissive coatings described within copending applications E. R. Kern-4 entitled "Emissive Coating for Electrodes" and E. R. Kern-5 entitled "Electron Emissive Coatings" provide large quantities of emissive coatings to produce long life gas discharge lamps. Lamps that have burned several thousands of hours using the aforementioned emissive coatings contained within metallic cup electrode containers have revealed that the metallic containers have become physically corroded by the action of the impending ions and electrons during the starting process. The end discoloration, that is the dark material on the inner lamp envelope surface in the vicinity of the cathode which generally occurs after several thousands of hours of normal lamp operation, occurs with the aforementioned novel electron emissive coatings within a few hundred hours because of the sputtering effects which occur during the lamp starting process in the "glow to arc" transition.

The purpose of this invention is to provide an electrode structure for housing the larger quantity density gradient and alkaline earth tantalate compounds and for providing low incidence of end discoloration when these coatings are used in cold cathode type electrical gas discharge devices.

SUMMARY OF THE INVENTION

Ceramic cup electrodes consisting of a cup-shaped container with a metal lead wire extending through the bottom for providing electrical contact between the lamp operational circuitry and an electron emissive coating on the internal surface of the cup provide long life and low end discoloration to cold cathode electrical gas discharge devices by substantially reducing electrode sputtering by means of the sputter resistant properties of the ceramic.

Cup-shaped aluminum oxide containers having large quantities of electron emissive coatings formed by the fusion of tantalum powder and barium peroxide adhere to the inner surface of the aluminum oxide container and to the nickel lead wire extending therethrough. The aluminum oxide cup-shaped structure besides providing housing and structural support to the emissive compound also protects the emissive compound from undue electron and ion bombardment that would otherwise dislodge the emissive compound from the container.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a cup electrode according to the prior art;

FIG. 2 shows the inventive cup electrode;

FIG. 3 is an enlarged front view of the electrode of FIG. 2 mounted in a fluorescent lamp;

FIG. 4 is a cross-sectional view of the electrode of FIG. 2 in an R.F. susceptor;

FIG. 5 is an enlarged view of the susceptor cover shown in FIG. 4;

FIG. 6 is a graph of end discoloration versus operating time for lamps containing the metallic cups of the prior art and the inventive cup electrodes; and

FIG. 7 is a graph of the lamp starting voltage as a function of lamp operating time for the metallic cups of the prior art and the ceramic cup electrodes of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A number of ceramic cups **1**, FIG. **2**, obtained from the American Lava Corp., Chattanooga, Tenn., having an outside diameter of 0.250 inch, an inside diameter of 0.030 inch and a thickness of 0.250 inch and having the composition of Al_2O_3 — 5.6%, SiO_2 — 61.5% and MaO — 27.0% the remainder being NaO, CaO and BaO with an 0.025 inch opening in the bottom of the cup were processed into electrodes for evaluation within cold cathode type eight foot long, one and one-half inch diameter fluorescent lamps. The location of the cups **1** within the lamp **5** is shown in FIG. **3.** A one inch length of 0.020 nickel wire **3** with a flat nail head at one end was inserted through the hole so that the nail head rested on the inside bottom surface of the cup **1** and the free end of the nickel wire extended from the bottom of the cup. From a barium peroxide powder and tantalum metal powder mix **2** consisting of 33% barium peroxide a sufficient quantity was placed in the cup in order to fill the cup **1** one-half its volume and to completely cover the nail head end of the nickel wire **3.** The powder mixture **2** was then lightly tapped with a forming tool in order to form a slight depression in the top surface of the powder mixture and to lightly compress the mixture against the sides of the cup and the flat nail head portion of the nickel wire. The location of the lead wire **2** within the cup **1** is shown in FIG. **4.** Reaction between the barium peroxide and tantalum powder mixture **2** was caused to occur exothermally by covering the open end of the cup with a specially designed cover **8** and by using a radio frequency coil **9** to inductively heat the mixture. A metal susceptor **6** shown in FIG. **4** is employed in order to localize the heat in the vicinity of the cup **1.** The susceptor **6** also provides for positioning the lead wire **2** in the center of the cup **1** by means of a lead wire alignment slot **7.** The use of the cover **8** ensured that the explosion would occur toward the open end of the cup **1** but created sufficient back pressure so that the resulting barium oxide tantalum powder **2** further exhibited the necessary density gradient structure as described within the aforementioned U.S. Pat. No. 3,798,492. The cover **8** shown in greater detail in FIG. **5** has a passage **10** extending through the cover for permitting the effluent gases to escape during the exothermal reaction. The fused compound exothermally formed within the cup was found to adhere to the cup **1** and to the nail-shaped portion of the lead **2** and resulted in good electrical continuity therebetween. A corresponding control batch of electrodes were processed using iron cups having the same dimensions and filled and exothermally fused with the peroxide tantalum mix in the same manner. Both the inventive ceramic cup electrodes **1** and the controlled group of iron cup electrodes, shown in FIG. **1,** were then activated for thermionic emission in the manner described in copending Application Ser. No. 389,833, R. A. Menelly, entitled "Method for Activating Electron Emissive Electrodes" and assigned to the assignee of the instant invention.

A number of ceramic cup electrodes **1** were then mounted within a statistical sample of 96 inch T12 instant start lamps **5** of the cold cathode type, as shown in FIG. **3** for example, for evaluation therein. For comparison purposes an equivalent number of lamps using iron cup electrodes prepared as described in the aforementioned Menelly patent incorporated herein by reference were also prepared in a similar manner. The lamps were then processed in the usual manner of fluorescent manufacture and tested upon life test burning cycles consisting of a cycle test lamp operation for three hours followed by a 20 minute off period for each three hours burning operation. Periodic visual inspection of the bulb ends in the vicinity of the electrodes were made in order to determine the rate and intensity of end discoloration formation as the lamps continued to operate. The effect of end discoloration on both groups of lamps is shown graphically in FIG. **6.**

In order to determine the stability of the lamp operating characteristics over a period of time the lamp starting voltage was also periodically measured over the life of the lamp. The lamp starting voltage, which is one measure of the electrode emission properties for cup electrodes, was shown to continuously increase for the iron cup electrode lamps over the operating life of the lamp. The starting voltage for the ceramic cup electrode lamps, however, remained substantially constant over the same period of time. These results are shown graphically in FIG. **7** where starting voltage is plotted as a function of burning time for both the ceramic cup electrode lamps and for the iron cup electrode lamps.

Observation of the ends of the lamps having the ceramic cup electrodes showed that these lamps were relatively clear of end discoloration whereas the ends of the iron cup electrodes indicated the formation of end discoloration within a few hundred hours of operation.

After **5,000** hours of operation a number of lamps from both the ceramic electrode group and the iron electrode group were removed from operation and the ceramic cups and the iron cups were in turn removed from the lamps for microscopic investigation. The outer rim of the open end of the iron cups in all cases were found to be eroded indicating the effect of sputtering upon the iron during the aforementioned "glow to arc" transition in the lamp starting process. The outer surface of the iron cup showed a polished sheen indicating quite possibly that the outer surface in subjection to localized glow discharges may have become polished by the removal of surface impurities under the influence of the electronic energy imparted to the surface of the cup during the glow transistion of the cycle. The inner bulb surface in close proximity to the clean outer surface of the iron cup was correspondingly coated with a darkish material identified by wet chemical analysis to consist mainly of iron. The overall condition of the iron cup therefore indicated that material is continuously sputtered from the open end of the cup by the mechanism of ion and electron bombardment during the lamp starting cycle. The iron material constituting the rim of the cup is correspondingly sputtered and removed therefrom some of which quite possibly mixing with and contaminating the electron emissive coating resulting in the gradual increasing lamp starting

voltage which is the usual case of electrode contamination in operating lamps.

The rim of the ceramic cup on the open end showed no evidence of erosion and sputtering by ion bombardment, and remained virtually intact under further microscopic investigation. The outer surface of the ceramic cup showed a slightly grayish discoloration, the exact nature and cause of which has not as yet been determined. There is no evidence of end discoloration in the ends of the lamps near the electrodes indicating therefore that the end discoloration formation rate has been substantially reduced.

Other types of ceramic cup materials were evaluated with the aforementioned tantalum metal and barium peroxide fused emissive coating in order to determine whether the lamp starting voltage may be further reduced in view of the unique sputter ion resistant properties of the ceramic material. A series of ceramic materials designated Alsimag 645, 447 and 614 were therefore processed into electrodes by the method as described earlier. The analysis of the various Alsimag ceramic cups showed the Alsimag 614 to have the higher alumina content (96%), the Alsimag 447 having 31.4% alumina and the Alsimag 645 having as low as 5.6% alumina. The silica and magnesia being proportionately varied for the different Alsimag types. Along with varying alumina content of the cup material, varying concentrations of barium peroxide were chosen from 10% barium peroxide to 60% in mixtures of corresponding quantities of tantalum metal powder plus the barium peroxide where the total barium peroxide-tantalum powder mix was fixed. The results showed that the higher alumina ceramic electrodes forestalled the formation of end discoloration for longer periods of time, and for all concentrations of alumina in the ceramic cups the higher barium peroxide content in the tantalum metal barium peroxide mix resulted in the lowest lamp starting voltages and the lowest incidence of end discoloration.

Observation made on the lamp electrical operating parameters indicated that the initial lamp starting voltages and initial lamp operating voltages were identical for both the ceramic cup electrodes and for the iron cup electrodes. The electrical equivalence of starting and operating voltages is indicative to the practitioner in electrical gas discharge phenomena that the electrically insulative properties of the ceramic cup electrode structure must therefore provide sufficient anode area to the electrode. This is surprising since the iron container, at least during lamp "glow to arc" transitions, serves as an anode and iron, a known electrical conducting material, is chosen as a container for the electron emissive material because of its electron conducting properties.

Although the inventive ceramic structure electrode has been disclosed for application within cold cathode type fluorescent lamps the electrode lends itself to the analgous discharge devices that employ electrodes and electron emissive coatings such as high pressure lamps, electron tubes and gas lasers.

What is claimed is:

1. A cup electrode for cold cathode gas discharge devices comprising:

a cup-shaped ceramic container having a forward open end for facilitating the emission of electrons therefrom and opposing closed end, said ceramic consisting of aluminum oxide, magnesium oxide and silicon oxide;

a quantity of thermionic emissive material formed from the exothermal reaction between a refractory metal powder and at least one alkaline earth peroxide within said container;

a passage through the closed end for providing electrical contact between the emissive coating contained within the electrode; and

a metal lead wire extending through said passage for providing electrical connection with said electron emissive coating.

2. The cup electrode of claim **1** wherein said aluminum oxide content is greater than either the silicon oxide or the magnesium oxide.

3. A lamp comprising:

a light transmissive envelope;

a quantity of ionizable gas within said envelope;

at least one ceramic cup electrode sealed within said envelope, said ceramic cup consisting of aluminum oxide, magnesium oxide and silicon oxide and containing a quantity of electron emissive material formed from the exothermal reaction between a refractory metal powder and at least one alkaline earth peroxide.

4. A fluorescent lamp of the type having a light transmissive tubular elongated envelope, a coating of fluorescent material on the inner surface of said envelope, and a quantity of mercury and inert gas within said envelope comprising: a pair of ceramic cup electrodes consisting of aluminum oxide, magnesium oxide and silicon oxide, one at either end of said envelope, said electrodes containing a quantity of electron emissive material formed from the exothermal reaction between a refractory metal powder and at least one alkaline earth peroxide therein and an electrical lead wire extending therethrough each of said ceramic cup electrodes and said envelope for providing electrical contact between said electron emissive material and associated lamp electrical circuitry.

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