July 10, 1934. T. E. FOULKE 1,965,585

ELECTRIC GASEOUS DISCHARGE DEVICE

Filed Oct. 7, 1929

Fig. 1

Fig. 3

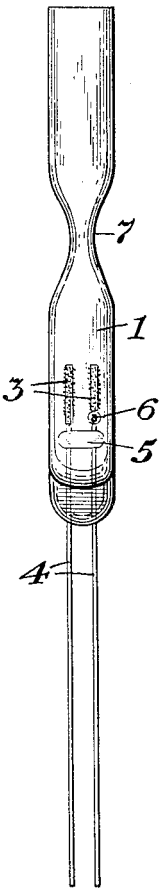


Fig. 2

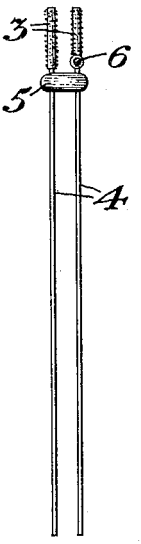
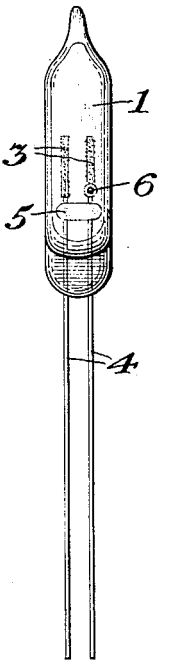


Fig. 4



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ELECTRIC GASEOUS DISCHARGE DEVICE

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6 Claims. (Cl. 176—126)

The present invention relates to electric discharge devices, and to electrodes therefor.

The particular object of the invention is to provide a gaseous discharge device which will start with a cold cathode upon the application of a relatively low potential, will operate at a correspondingly low potential, and will maintain these characteristics throughout a long useful life. Another object of the invention is to provide a gaseous discharge device which will be extremely simple and inexpensive in construction. A further object of the invention is to provide a method of producing such a discharge device. Other objects and advantages of the invention will appear from the following detailed description of a gaseous discharge device embodying my invention or from an inspection of the accompanying drawing.

The invention consists of certain new and novel features of construction and combinations of parts and also in the new and novel steps in the process of manufacture thereof, as hereinafter set forth and claimed.

Despite the many advantages of electric gaseous discharge devices of the cathode glow tube for such uses as signals, indicators, signs and other purposes where a low intensity light source will suffice these devices have not been extensively used, largely due to the fact that it has been impossible to produce such a device which would function on normal commercial potentials. The production of such a device which would operate on 110 volts D. C., and at the same time have a reasonably long useful life, has been an especially difficult problem. I have discovered a new process of activating the cathode which results in an electrode having not only an extremely low work function but also a low sputtering rate. This new process is especially effective in the manufacture of lamps having very small electrodes thus making possible for the first time the production of such devices of exceedingly small sizes, to wit: complete lamps having bulbs of about one eighth and about one quarter of an inch in diameter. Discharge devices constructed according to this invention will start upon the application of low potentials either alternating or direct current and as low as 50 volts D. C. and have a useful life of several hundred to several thousand hours, depending upon the current density employed. I have further found that the cost of a device of this type may be materially reduced by fabricating the envelope from glass tubing instead of the conventional blown bulb.

For the purpose of illustration I have shown a gaseous discharge device embodying my invention, as it appears at several stages in the manufacture thereof, in the accompanying drawing, in which

Fig. 1 is an elevation of the glass tubing used to form the envelope,

Fig. 2 is an elevation of the electrode assembly,

Fig. 3 is an elevation of the device before sealing off, and

Fig. 4 is an elevation of the completed device, which is especially designed for use, in combination with a suitable series resistance, in testing electrical circuits of varying voltages to determine whether they are energized, but which is also useful for many other purposes.

In the drawing a piece of tubing 1 of glass or other vitreous material of say ¼ inch diameter and of about one inch or other suitable length is utilized for the gas tight envelope of the device. The cylindrical electrodes 3 which are preferably of nickel or the like, are each welded at one end to the ends of an inlead 4 of dumet or other material having a suitable coefficient of expansion for sealing into the tube 1. A vitreous bead 5 which is fused to the inleads 4 near the electrodes 3 maintains said electrodes with their axes parallel, and with a space of about a millimeter between said electrodes. One of said electrodes has welded thereto adjacent to the inlead end a small piece 6 of magnesium, calcium or the like, magnesium being preferred because of greater ease in handling during manufacture of the device. In practice the electrode 3 is slightly flattened at this point to facilitate the welding operation. Each of the electrodes 3 is then coated with an alkaline or alkaline earth oxygen compound. This compound can be the oxide, but since it is difficult to maintain the purity of the oxide in the air it is preferably one which will readily decompose under the influence of ionic bombardment, such as the carbonate or nitrate of barium or of strontium. A mixture of the carbonates of barium and strontium, for example, gives very good results. This compound is most conveniently applied by mixing it with a vehicle, preferably one which will decompose when heated in a vacuum leaving a carbonaceous residue, collodion, or a solution of cellulose in ethyl acetate, for example, and sprayed or painted on the electrodes, or the electrodes are dipped therein.

After the electrodes are dry the complete electrode assembly, as shown in Fig. 2, is inserted within the tube 1 and the end of said tube 1 fused to form a pinch seal on the inleads 4, as

shown in Fig. 3. In some cases this pinch seal is relied upon to maintain the electrode spacing, the bead 5 being omitted. A constriction 7 is then formed in the tube 1 at a suitable distance from the electrodes 3, in effect tubulating the tube 1. The tube 1 is then connected to a suitable exhaust system and evacuated. While the vacuum is maintained the tube 1 is heated to a temperature of from 400° C. to 450° C. for several minutes in order to drive out substantially all water vapor, occluded gases and vaporizable material. While still connected to the exhaust system the tube 1 is allowed to cool to atmospheric temperature, after which it is filled with a suitable gaseous atmosphere. A filling of neon with about .7% of argon at a pressure of 40–50 mm. of mercury has been found to give the lowest breakdown potential which is consistent with long life of the device. Satisfactory results may also be obtained with mixtures of neon with from .1% to about 3% of argon, but with the higher percentages of argon the luminosity of the device is somewhat impaired. The pressure may likewise be varied, but either an increase or a decrease from the range given above results in increased breakdown potential. It has been found that small traces of impurities such as oxygen, nitrogen, carbon dioxide, hydrogen, air, and the like—water vapor and hydrocarbons being excepted—improve the lamp in certain respects which will be set forth hereinafter, although their use is not recommended if extremely low breakdown potential is desired. After receiving its gaseous filling the tube 1 is then sealed off at the constriction 7, as shown in Fig. 4, the device being complete except for the activation of the electrodes.

To activate the electrodes 3 the device is connected by the inleads 4 to a source of electrical energy of high potential, high frequency and steep wave front, a discharge thereupon occurring between said electrodes 3. Due to the shape of the electrodes 3 and to the wave shape impressed thereon an electrostatic field of high intensity is set up adjacent to said electrodes which causes a severe bombardment of said electrodes by the positive ions generated by said discharge. This bombardment results in the decomposition of both the alkaline compound and the carbonaceous binder, and in the sputtering of the magnesium 6. The magnesium being thus in a finely divided state readily combines with the free oxygen atoms given up by the alkaline compound and reduces the carbon dioxide which is also evolved. This bombardment is continued until substantially all the alkaline compound has been reduced to the oxide, with a small portion thereof still further reduced, probably all of it to the metallic form. This intermixture of oxide and metal has an extremely low work function, which results in the device having a correspondingly low breakdown potential. The function of the carbon residue from the carbonaceous vehicle in this activation process is not entirely understood, but it has been definitely observed that the reduction of the alkaline compound is more easily produced when a small amount of carbon is used so that its presence, while not entirely essential, is preferred.

After the bombardment has produced the desired reduction the device is then preferably aged to set its characteristics by operating it for several minutes on 110 volts A. C. at a low current density, say .5 milliamperes for electrodes ¼ inch in length and having a diameter of 30 mils. The device is then ready for any suitable commercial application.

The operating characteristics of such a device will remain substantially uniform throughout its useful life, despite the slight sputtering of the alkaline metal from the electrodes during operation, due to the fact that more metal is reduced by the same ionic bombardment which causes the sputtering.

During the activation process a certain amount of blackening appears on the wall of the envelope 1, due to the sputtering of the magnesium 6 and of the electrode material. By placing the magnesium 6 at the lower end of the electrode 3 this blackening is substantially confined to the inlead end of the envelope 1 and does not seriously impair the light emission from the device. It has been found, however, that traces of the order of 0.1–1.0% of oxygen, nitrogen, or other impurities, as set forth above, tend to reduce this blackening and hence are desirable in certain cases. One theory of the effect of these gases is that they aid in cementing the activating material into a monomolecular layer on the electrodes, although this is uncertain. The blackening is, however, markedly decreased in certain cases.

While I have illustrated and described my invention in connection with a particular gaseous discharge device it is to be understood that various changes, substitutions and omissions, within the scope of the appended claims, may be made in the structure and in the steps of the process without departing from the spirit of my invention. The term "alkaline", as used in these claims, is intended to refer to either the true alkali metals, or to the metals of the alkaline earth group.

I claim:—

1. The method of producing an electric gaseous discharge device which comprises coating the electrodes thereof with an alkaline compound which is reducible to the oxide, attaching a small quantity of a metal having a high affinity for oxygen to one of said electrodes, sealing said electrodes into an envelope, evacuating said envelope while heating it to drive off substantially all occluded gases and vapors, filling said envelope with an attenuated atmosphere of rare gas, sealing off said envelope, and creating a high potential, high frequency discharge of steep wave front between said electrodes to reduce substantially all of said alkaline compound to the oxide.

2. The method of producing an electric gaseous discharge device which comprises coating the electrodes thereof with barium carbonate, attaching a piece of magnesium to one of said electrodes, sealing said electrodes into an envelope, evacuating said envelope while heating it to drive off substantially all occluded gases and vapors, filling said envelope with neon containing a small percentage of argon at a pressure of 40–50 m. m. of mercury, sealing off said envelope, and creating a high potential, high frequency discharge of steep wave front between said electrodes to reduce substantially all said barium carbonate to the oxide and to reduce some of said oxide to the metallic form.

3. The method of producing an electric gaseous discharge device which comprises coating the electrodes thereof with barium carbonate, strontium carbonate, and a carbonaceous substance, attaching a piece of magnesium to one of said electrodes, sealing said electrodes into an envelope, evacuating said envelope while heating it to drive off substantially all occluded gases and vapors, filling said envelope with neon contain-

ing about .7% of argon at a pressure of 40–50 m. m. of mercury, sealing off said envelope, and creating a high potential, high frequency discharge of steep wave front between said electrodes to reduce substantially all of said carbonates to the oxide and to reduce some of said oxide to the metallic form.

4. The method of producing an electric gaseous discharge device which comprises coating the electrodes thereof with an alkaline compound reducible to the oxide, attaching a small quantity of a metal having a high affinity for oxygen to one of said electrodes, sealing said electrodes into a vitreous tube of small diameter, evacuating said vitreous tube while heating it to drive off substantially all occluded gases and vapors, filling said envelope with an attenuated atmosphere of rare gas, closing the end of said vitreous tube, and creating a high potential, high frequency discharge of steep wave front between said electrodes to reduce substantially all of said alkaline compound to the oxide form, with a small quantity thereof further reduced to the metallic form.

5. The method of producing an electric gaseous discharge device which comprises coating the electrodes thereof with an alkaline compound reducible to the oxide, attaching a small quantity of a metal having a high affinity for oxygen to one of said electrodes, sealing said electrodes in an envelope, evacuating said envelope while heating it to drive off substantially all occluded gases and vapors, filling said envelope with an attenuated atmosphere of rare gas containing a small percentage of a common gas, sealing said envelope, and creating a high potential, high frequency discharge of steep wave front between said electrodes to reduce substantially all of said compound to the oxide, with a small amount thereof further reduced to the metallic form.

6. An electric gaseous discharge device comprising a tubular envelope of small diameter, electrodes sealed thereinto, at least one of said electrodes having a coating of barium oxide and barium thereon, and a gaseous atmosphere in said envelope consisting of a mixture of neon with .7% argon at a pressure of 40–50 m. m. of mercury.

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