Feb. 25, 1958 T. E. FOULKE 2,824,985

GLOW DISCHARGE DEVICE

Filed Dec. 11, 1953

Fig. 1

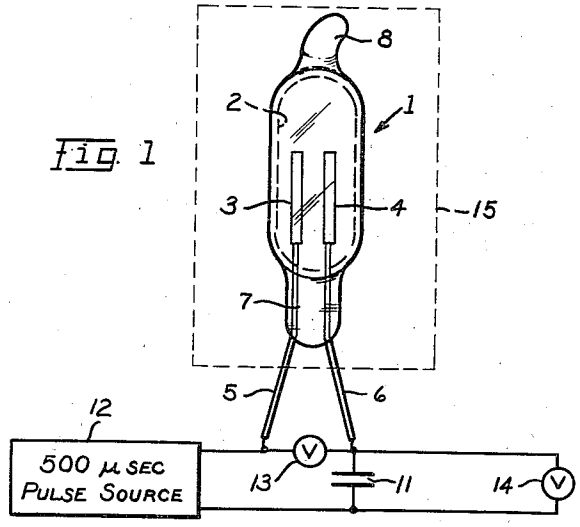


Fig. 2

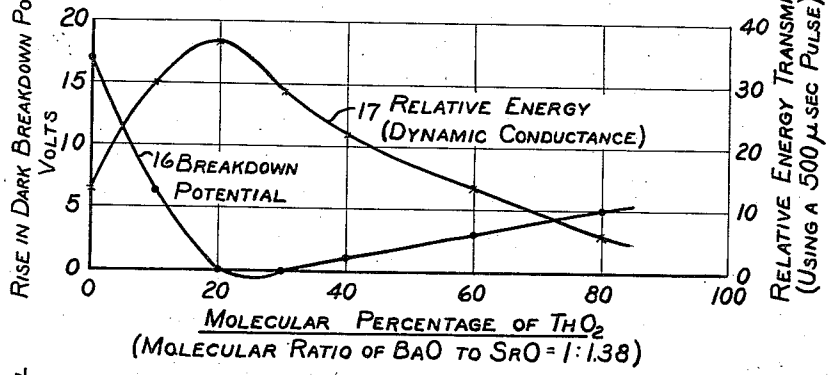
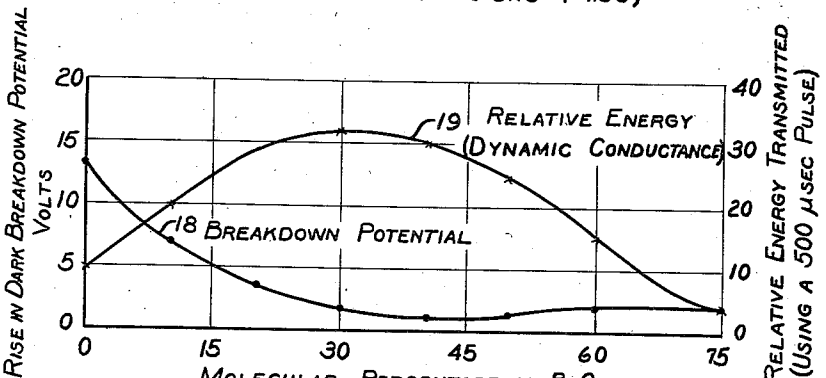


Fig. 3



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GLOW DISCHARGE DEVICE

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6 Claims. (Cl. 313—54)

This invention relates in general to electric discharge devices and more particularly to glow discharge devices having a pair of cold electrodes operating through field emission.

The invention finds particular application in miniature glow lamps or tubes such as exemplified by the series designated commercially NE and AR. One commercially available miniature glow lamp is rated at 1/25 watt. Neon glow lamps have starting or breakdown voltage ratings between 45 and 65 volts R. M. S. on alternating current, depending upon the pressure of the gas filling, whereas argon glow lamps have somewhat higher ratings. On direct current, the breakdown ratings are naturally higher, being between 60 and 90 volts. It has been observed that the breakdown voltage as between lamps of the same type may vary by as much as 20 percent about the average or rated value. Furthermore, the dark breakdown voltage, that is the breakdown voltage when the lamp or tube is located in an opaque enclosure, is usually considerably higher than the breakdown voltage when incident daylight or radiation from other lamps is striking the glow lamp. However, the most common application of miniature glow lamps up to the present time has been as visual indicators, for instance in alarms, automatic controls, household appliances, and wiring devices. For such applications, the performance characteristics are generally not critical and variations in breakdown potential within a limited range could readily be tolerated.

More recently such glow lamps have begun to find considerable application as circuit elements in electronic apparatus, for instance in electronic computers and other electronic control circuits. In one such application, an NE–2 neon glow lamp or tube is connected as a control impedance in series with a charge accumulating capacitor across a source of 500 microsecond pulses. Whenever a pulse exceeds a certain predetermined value corresponding to the breakdown voltage of the tube, current flows and charges the capacitor. For reliability of operation, it is essential that the breakdown voltage of the glow tube be constant and that the dark breakdown effect, that is the rise in breakdown voltage under dark conditions, be as low as possible. Furthermore, by reason of the relatively short time duration of the voltage pulses, it is essential that the tube achieve full conductance fairly quickly. This characteristic, which is related to the speed with which full ionization is achieved within the tube, may be referred to as the dynamic conductance. For electronic applications, it is generally desirable that the tube have the highest dynamic conductance which can be achieved.

Glow lamps or tubes commercially available up to the present time have generaly comprised a pair of electrodes sealed into a glass envelope containing a filling of an inert gas at a low pressure, for instance neon at 30 millimeters of mercury. The electrodes, which may consist merely of short lengths of wire in the smallest lamps or which may comprise suitably shaped pieces of sheet metal in the larger lamps, are coated with an electron emissive

mixture. This mixture has consisted of alkaline-earth oxides, generaly a mixture of barium and strontium oxides. With such discharge devices, it has been found that the breakdown in the dark may be as much as 20 percent higher than the breakdown in light. Furthermore, full ionization or conduction is achieved relatively slowly even under room illumination; in other words, the dynamic conductance is comparatively low, so that response to pulse signals is low and uncertain.

The object of the invention is to provide a new and improved glow discharge device having a rise in dark breakdown voltage substantially less than heretofore.

Another object is to provide a glow discharge device in which full ionization is reached more quickly after the initiation of breakdown.

A further object of the invention is to provide a glow discharge device having a dark breakdown voltage approaching that in light and having, for a given electrode configuration or size, a dynamic conductance substantially higher than heretofore possible.

In accordance with the invention, I have found that the addition of thorium oxide (or thoria) within a critical range, to an emission mixture containing barium oxide and strontium oxide within a certain range of proportions, achieves those objects. The tests which I have conducted have shown that an emission mixture containing approximately 15 to 40 mol percent thorium oxide (ThO_2), 10 to 55 mol percent barium oxide (BaO), with a balance of strontium oxide (SrO), provides a decided improvement. A glow discharge device having cold electrodes coated with this mixture shows both a reduction in the dark breakdown voltage rise and an increase in dynamic conductance. For best results, the proportion of thorium oxide should be between 15 to 30 percent; that of barium oxide, between 20 to 40 percent, and the balance strontium oxide. A mixture which is being used in commercial production of glow discharge lamps having operating characteristics in accordance with the stated objects of this invention contains approximately 23 percent ThO_2, 33 percent BaO, and 44 percent SrO. These percentages are mol percentages, that is based on the proportions of the constituents by molecular weight.

Further objects and advantages of this invention will become apparent by reference to the following description and the accompanying drawing. The features of novelty which characterize the invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

In the drawing:

Fig. 1 is a side view of a glow discharge lamp or tube embodying the invention and shown schematically connected in a suitable circuit.

Fig. 2 illustrates graphically the characteristics of the tube for various proportions of thorium oxide in the emission mix.

Fig. 3 illustrates graphically the characteristics of the tube for various proportions of barium oxide in the emission mix.

Referring to Fig. 1, there is shown a glow discharge device 1 corresponding generally to the neon glow lamp designated commercially NE–2. The device comprises a vitreous envelope 2 in which is mounted a pair of wire electrodes 3, 4 welded on the inner ends of leads 5, 6 sealed into a press 7 at the lower end of the tube. Electrodes 3, 4 may consist of nickel coated with an electron emissive mixture such as will be described herein. The leads 5, 6 are preferably of "dumet" wire, that is copper-sheathed nickel-iron wire which seals readily into glass. The tube contains a filling of an inert gas at a low pressure, for instance neon or argon at pressures from 20 to 200 millimeters of mercury, and is tipped off at its upper

end 8. The device or tube 1 has been illustrated in the drawing approximately three times full size; the actual dimensions are approximately ¼ inch for the diameter and ⅞ inch for the over-all length of the bulb. In the illustrated tube which constitutes a preferred embodiment of the invention, the electrodes are closely spaced, the distance between them being less than the minimum inside dimension of the envelope.

In accordance with the invention, electrodes 3, 4 are coated with an electron emissive coating of barium and strontium oxides having added thereto thorium oxide in the range of proportions stated earlier herein. The active coating is preferably produced by applying to the electrodes a mixture of barium and strontium carbonates together with thorium oxide in a suitable binder, such as nitrocellulose dissolved in a suitable vehicle such as amyl and butyl acetate. Where the application is by spraying rather than by dipping, the vehicle may contain a higher proportion of butyl acetate in order to increase the rate of evaporization. The electrodes are then sealed into the tube by fusing the glass about the leads in the press 7 and the envelope is then thoroughly exhausted through the as yet open upper end of the tube. While the tube is still on the exhaust schedule, electrodes 3, 4 are heated, for instance by an electric induction furnace, to a temperature sufficient to decompose the carbonate to the oxide, the carbon dioxide and other gases being exhausted as evolved. During this heating of the electrodes, the nitrocellulose binder is also reduced to carbon. The gaseous filling is then admitted and the device is sealed off by tipping off the glass tube 8 with a hot flame.

As previously stated, the filling consists of an inert gas or a mixture of inert gases at a low pressure. A suitable filling consists of neon at 30 millimeters' pressure; if a lower breakdown potential is desired for the lamp, a small percentage of argon may be added to the neon, for instance 0.8 percent argon. When higher breakdown voltages are desired, the argon content and pressure are increased substantially.

After tipping off, the lamp may be subjected to the treatment described in my Patent 1,965,589 for further lowering the work function of the electrodes and achieving a longer life for the lamp. In this process, the leads 5, 6 are connected to a source of steep wave-front, high frequency oscillations such as are produced by the discharge of an inductance through a condenser. These oscillations cause discharges within the lamp of sufficient energy to break up the barium, strontium, thorium oxides, leaving metals cemented to the electrode surface by oxygen and resulting in a composite metal oxide surface. The bombardment of electrodes 3, 4 is carried on until there is a uniform corona thereon.

The dependency of the characteristics of the glow tube upon the relative proportions of barium oxide, strontium oxide, and thorium oxide in the emissive coating is illustrated in Figs. 2 and 3. The characteristics considered are those observed upon connecting the tube in the circuit schematically illustrated in Fig. 1. Device or tube 1 is connected in series with a capacitor 11 across a source of rectangular pulses of 500 microsecond time duration, this source being represented by the block 12. A volt meter 13 connected across the leads 5, 6 measures the breakdown voltage of the tube. A volt meter 14 connected across capacitor 11 measures the voltage to which the capacitor is charged by the pulse energy transmitted through the tube. Since the energy stored in a capacitor is proportional to the square of the voltage to which the capacitor is charged, the relative energy transmitted by the tube is readily measured by squaring the voltage recorded by volt meter 14. It will be appreciated, however, that other circuit arrangements may be used to measure the energy transmitted by the tube, for instance a resistance and thermocouple. The characteristics of the tube which are illustrated in Figs. 2 and 3

are dark operating characteristics; they are obtained with device 1 filled with inert gas to a pressure above 100 millimeters of mercury, specifically of the order of 130 millimeters of mercury, and enclosed in a substantially light-tight compartment which has been represented schematically by the dotted rectangle 15.

The curves of Fig. 2 show the variation in characteristics of the tube for a mol percentage of thorium oxide in the coating varying from 0 to 80 percent, the mol ratio of barium oxide to strontium oxide remaining constant at 1 to 1.38. Curve 16 shows the rise in dark breakdown potential, that is the increase in breakdown potential when the device is placed in a dark enclosure over the breakdown potential in room illumination. Curve 17 shows the relative energy from a 500 microsecond pulse transmitted through the device, this being a measure of the dynamic conductance. It will be observed that in the region from 15 to 40 mol percent of thorium oxide, the rise in dark breakdown potential is quite low and the dynamic conductance of the device is high. The fortuitous concurrence of these characteristics provides a device having vastly improved performance in respect of the objects of the present invention.

In Fig. 3, the curves illustrate the variation in characteristics as the mol percentage of barium oxide is varied from 0 to 75 percent, the mol percentage of thorium oxide being maintained constant at 25 percent, and the balance being made up of strontium oxide. Here again it will be observed that the lowest rise in dark breakdown potential, shown by curve 18, and the highest dynamic conductance, shown by curve 19, occur simultaneously in the region between 10 and 55 mol percent barium oxide. Considering the curves of Figs. 2 and 3 simultaneously, it is apparent that for best results the thorium oxide should lie between 15 to 30 percent and the barium oxide between 20 to 40 percent. A mixture containing, by molecular proportions, 22.5 percent thorium oxide, 33.2 percent barium oxide and 44.3 percent strontium oxide, has been found to give the lowest shrinkage, that is the lowest proportion of defective lamps which must be rejected.

While a glow tube or lamp embodying the invention has been described in detail, it is to be understood that this embodiment is intended as illustrative and not as limitative of the invention. Obviously, the electrode coating mixture which has been described can be used in lamps and discharge devices differing widely in size and configuration from that which has been described. Accordingly, the scope of the invention is to be determined by the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A gaseous electric glow discharge device comprising an envelope containing an inert gas at a pressure of from approximately 70 to 200 millimeters of mercury and a pair of closely spaced cold electrodes sealed therein, and an electron-emissive coating on said electrodes containing 15 to 30 mol percent thorium oxide, 20 to 40 mol percent barium oxide, and with the balance consisting of strontium oxide.

2. A gaseous electric glow discharge device having a low dark breakdown rise and high dynamic conductance comprising an envelope containing an inert gas at a pressure of from approximately 70 to 200 millimeters of mercury and a pair of closely spaced cold electrodes sealed therein, and an electron-emissive coating on said electrodes containing approximately 23 mol percent thorium oxide, 33 mol percent barium oxide and 44 mol percent strontium oxide.

3. A gaseous electric glow discharge device having a low dark breakdown rise and a high dynamic conductance comprising a generally cylindrical vitreous envelope of approximately ¼ inch diameter and ⅞ inch in length containing an inert gas at a pressure of 70–200 millimeters of mercury and a pair of closely spaced cold elec-

trodes sealed therein, said electrodes consisting of metal wires disposed substantially parallel to the longitudinal axis of said envelope, and an electron-emissive coating on said electrodes consisting of approximately 23 mol percent thorium oxide, 33 mol percent barium oxide and 44 mol percent strontium oxide.

4. A gaseous electric glow discharge device comprising an envelope containing an inert gas at a low pressure above 100 millimeters of mercury and a pair of closely spaced cold electrodes sealed therein, and an electron-emissive coating on said electrodes containing 15 to 30 mol percent thorium oxide, 20 to 40 mol percent barium oxide, and with the balance consisting of strontium oxide.

5. A gaseous electric glow discharge device comprising an envelope containing an inert gas at a pressure of the order of 130 millimeters of mercury and a pair of closely spaced cold electrodes sealed therein, and an electron-emissive coating on said electrodes containing 15 to 30 mol percent thorium oxide, 20 to 40 mol percent

barium oxide, and with the balance consisting of strontium oxide.

6. A gaseous electric glow discharge device comprising an envelope containing an inert gas at a low pressure above 100 millimeters of mercury and a pair of closely spaced cold electrodes sealed therein, and an electron-emissive coating on said electrodes containing approximately 23 mol percent thorium oxide, 33 mol percent barium oxide, and 44 percent strontium oxide.

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