GLOW DISCHARGE TUBE

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This invention relates generally to glow discharge tubes of the type utilized for luminous advertising signs and the like, and more particularly to progressively illuminating glow discharge tubes, in which the cathode is in the form of an elongate member along which the end of the cathode glow travels as the voltage applied to the tube is increased.

In this type of tube, application of a given critical voltage across the anode and cathode results in a luminous discharge from the tip of the cathode. As the current is gradually increased, the glow spreads rearwardly along the length of the cathode. It is a known fact that, as the current to a discharge tube, consisting of an anode and an extended cathode, is increased in this manner, the glow spreads along the length of the cathode in such a manner that (within limits of several feet of illumination) the current per unit area of the cathode remains constant while the voltage drop across the tube increases very little. This holds true, however, only so long as the forward end of the cathode area illuminated is not so far removed from the anode that an appreciable voltage drop exists through the positive column; and when an attempt is made to extend the illumination beyond several feet by raising the total current to the tube, the voltage across the tube is found to increase by reason of the drop across the positive column, accompanied by increase in current density in the portion of the cathode close to the anode. It is this increase in current density at the tip of the cathode which in practice limits the length of the cathode that can be illuminated, as a manifold increase in current density at the tip of the cathode causes the electrodes to disintegrate and the tube to become blackened at the anode end.

It is accordingly a primary object of the present invention to provide a progressively illuminating glow discharge tube in which substantially extended lengths of illumination may be obtained without deleterious effects on the electrodes or tube.

In accordance with the present invention the working length of the extended cathode is separated from the gas within the tube by an impedance sheath. This sheath may be either in the nature of a dielectric or of a comparatively high electrical resistance. The sheath may be of uniform impedance per unit length of cathode, or may decrease in impedance per unit length of cathode from the tip of the cathode toward its rearward end. The cathode itself may be either an equipotential member, or in other words, a highly electrically conductive member, as of copper, or it may be a uniform resistance member, as for example of a resistance of 200 ohms per centimeter (though this is not to be taken as limitative on the invention). It may also be tapered so as to increase in electrical resistance from the rearward portion toward its tip. Both of these variations have the effect of yielding an extended length of available illumination, as compared with the equipotential case.

All of these variant forms of the invention have the characteristic advantage over the unsheathed cathode type of tube that, for a given current density at the tip of the cathode, a larger voltage drop across the positive column is available, meaning a longer length of illumination for a given maximum desirable current density at the tip of the cathode. The various forms of the invention have different available total lengths of illumination, though all are superior in this respect to the unsheathed cathode type of tube.

The invention will be best understood without further preliminary discussion by referring now to the following detailed description of various illustrative forms of the invention, reference for this purpose being had to the accompanying drawing, in which:

Fig. 1 is a longitudinal section through a tube having its cathode enclosed by a uniform impedance sheath;

Fig. 2 is a cross-section on line 2—2 of Fig. 1;

Fig. 3 is a longitudinal section through a tube in which the cathode is enclosed by a tapered impedance sheath;

Fig. 4 is a cross-section on line 4—4 of Fig. 3;

Fig. 5 is a longitudinal section through a tube having a varying resistance cathode enclosed by a uniform sheath, this view being also illustrative of a tapered equipotential cathode enclosed by a tapering impedance sheath;

Fig. 6 is a cross-section on line 6—6 of Fig. 5;

Fig. 7 is a longitudinal section through a tube having a tapered cathode and a tapered impedance sheath;

Fig. 8 is a cross-section on line 8—8 of Fig. 7;

Fig. 9 is a longitudinal section through a tube having the cathode on the exterior thereof, the wall of the tube in this instance comprising a sheath or impedance separating the cathode from the gas and anode; and

Fig. 10 is a cross-section on line 10—18 of Fig. 9.

The impedance sheaths used on the cathode
element (or between the cathode and the gas) in the various forms of the tube are ordinarily of film like thickness, and the drawing is therefore to be taken as diagrammatic and as indicative of taping impedance rather than as illustrative of the sheath thicknesses that will be used in practice. The dimensional tapers as diagrammatically shown in certain forms of the impedance sheath, as well as the illustrated sheath thicknesses, are to be taken, therefore, as representative of taping impedance rather than as accurately illustrative of actual sheath dimensions. It will of course be evident that the impedance of the sheath per unit length of cathode may be varied either by varying the dimensions of the sheath, or by varying its composition along the cathode. And it will also be evident that, using a sheath of uniform thickness and uniform composition, the impedance of the sheath per unit length of cathode may be made to taper by employing a cathode of tapering dimensions, as in Figs. 5 and 6.

Reference is first directed to the tube depicted in Figs. 1 and 2. Numeral 10 designates an elongated vessel or tube, filled with a suitable gas, as for instance neon. An anode 11 extends through and is sealed in one end of the tube, and a cathode 12, extending through and sealed in the opposite end of the tube, extends substantially the length of the tube, its forward end or tip being separated by a suitable gap from the opposed tip of the relatively short anode. In accordance with one form of the invention, both anode 11 and extended cathode 12 may be of relatively conductive metal, as copper, the cathode thus constituting for all practical purposes an equipotential electrode. While for simplicity the tube is indicated in Fig. 1 as relatively short, it will in practice normally be a number of feet in length, and may be bent or curved into letters or other sign configurations. The entire working length of the cathode is surrounded by an impedance sheath 13, and as here shown, this sheath extends entirely to the base or rearward end of the cathode. It is essential in all cases that the tip or forward end of the cathode be enclosed by this sheath, or be separated in some manner from the gas within the tube. Typical of the invention, though without expressing a limitation thereon, it may be stated that the cathode may be a round wire or rod from .1 to 1.00 mm. in diameter, though it is not at all necessary that the cathode be round in cross-section, nor is it essential that the cathode extend concentrically of the tube, as here specifically illustrated.

The impedance may be either of a dielectric or a high electrical resistance nature. A suitable resistance sheath may comprise a carbon-bearing composition of appropriate electrical resistance. Typical forms of dielectric sheaths are silicate or oxide coatings of dielectric characteristics. An oxide thickness of 10^{-4} cm. is appropriate to provide desirable impedance values at commercial frequencies. However, this is not to be taken in a restrictive sense, since with currents of appropriate frequencies, dielectric walls or sheaths of other thickness dimensions may be used. Fig. 9, for example, shows a form of the invention in which the dielectric wall is of a substantially greater thickness dimension. The expression Impedance sheath as hereinafter and in the claims described, will it will therefore, be either a dielectric or a high resistance sheath, either of which may be used in any of the forms of the invention shown in Figs. 1 to 8, inclusive.

Upon application of a certain critical potential across terminal leads 16 and 17 connected to anode 11 and cathode 12, a glow discharge will take place from the tip of cathode 12 to the anode. As the potential is then gradually raised, this glow spreads or progresses rearwardly along the length of the sheathed cathode. Any appropriate source of variable potential electric current may be connected to leads 16 and 17.

The length of the cathode which can be illuminated is limited in practice by the highest current density allowable at the forward end of the cathode, it being recalled that if the current density at the tip of the cathode is excessive, disintegration of the cathode will result. For an equipotential sheathed cathode the total voltage drop is divided between the cathode fall, the positive column and the current times impedance across an area of sheath under consideration. This holds for the total voltage drop between the anode and any area of the cathode, which total voltage is in this case the same for all areas at any one time, since the cathode is an equipotential. Thus designing the composition of an area on the cathode close to the anode where the current density is high to that of an area far removed where the current density is low, and assuming that the cathode falls are approximately equal, it follows that the positive column drop for the area far removed is equal to the positive column drop for the area near the anode plus a term equal to the difference of the current-times-impedance term at the near area and the current-times-impedance term at the far area. It is this difference term, which is present only because of the impedance sheath, that increases the available positive column drop, as compared with an unsheathed extended cathode. Since this difference depends directly on the tendency of the discharge tube to pass greater currents through areas near the anode than those farther away, it follows that there results a greater positive column drop and hence an extended length of illumination for a given critical current at the anode end.

Figs. 3 and 4 show a tube 10 having an anode 11 like that of Figs. 1 and 2, but in which the sheath, designated at 13a, tapers in impedance from the tip of the cathode 12a in a rearward direction. The impedance of the sheath at the tip of the cathode is therefore greater than the impedance of the sheath at a given point on the cathode somewhat distant from the tip, therefore increasing the difference of the voltage drop across the sheath at the tip and the voltage drop across the sheath at said given point, which results in a greatly increased positive column drop and a correspondingly extended length of illumination.

Assuming a maximum impedance per sq. cm. of 1,500,000 ohms, a tube of 300 cm. in length may have a linear tapered resistance sheath of 5,000 ohms per cm. taper. For longer tubes, the taper should be less. It will be understood that the tapered impedance sheath 13a of Figs. 3 and 4 may be formed of either a high electrical resistance material or a dielectric.

Figs. 1 and 2 are also illustrative of a modification, in which the cathode, enclosed by a uniform sheath 13, is composed of a suitable metallic or refractory material. For example, such a cathode may be composed of any suitable carbon bearing composition or a metallic alloy of the indicated electrical resistance characteristics.

For a maximum current of 50 milliamperes, the
resistance of the cathode should not be greater than 300 ohms/cm. to assure a sharply demarcated end as the tube approaches complete illumination.

Figs. 3 and 4 are also illustrative of another form of the invention involving use of a uniform electrical resistance cathode, as described in the preceding paragraph, enclosed by a tapering impedance sheath. This form combines the advantages of resistance electrodes with tapering impedance sheaths.

In Figs. 5 and 6 is shown a tube 10 having an anode 11 and a tapering resistance cathode 12b, the cathode diverging from its tip toward its rearward end, its electrical resistance therefore decreasing in a rearward direction. While a tapering resistance cathode may also be formed by varying its composition, or in other ways, it is perhaps made up most simply by varying its cross-sectional area, as here illustrated. The tapered resistance cathode is enclosed by an impedance sheath 13b, which may be of uniform impedance per unit length. The cathode will be understood to be formed of electrical resistance material, for instance of the same material as the uniform resistance cathode mentioned above. As a typical example, though without limiting intent, it may be stated that such a cathode might vary from 1000 ohms/cm. at its tip to 100 ohms/cm. at its connection end. This provision results in a substantial increase in positive column drop, and therefore in the possible length of illumination.

Figs. 7 and 8 show a tube 10 having an anode 11 and a resistance cathode 12c enclosed by an impedance sheath 13c, the resistance of the cathode and the impedance of the sheath both tapering from the forward toward the rearward end of the cathode. This form of the invention combines features of the forms of Figs. 3 and 4, and Figs. 5 and 6.

Figs. 9 and 10 show a form of the invention in which the cathode 20, which may be either an equipotential or an electrical resistance element, is placed outside the tube 21, being here shown as mounted directly on the side wall of the tube and extending substantially the length of the tube. To afford the necessary capacitance between the cathode and the gas within the tube, the cathode is transversely curved and arranged so as to have an appreciable transverse arc of contact with the tube. The anode 22 is again placed within the tube, as in the other forms. The wall of the tube separating the cathode from the gas and the anode functions to provide an impedance drop, just as in the case of the impedance sheath of the other forms. Thus it will be evident that in a broad aspect of the invention, it is not essential that the impedance element be an enclosing sheath, but only that the impedance element separate the working length of the cathode from the gas and the anode, so as to provide an impedance in series with the gas path to the anode.

Thus, for a given permissible current density at the tip of the cathode, all of the various forms of the invention provide an increased voltage drop across the positive column, and therefore an extended length of available illumination, over what is possible with an unsealed cathode.

It is of course to be understood that the forms here shown are illustrative of rather than restrictive on the broad invention, and that various changes in design, structure and arrangement may be made without departing from the spirit and scope of the broad invention or of the appended claims.

We claim:

1. A gaseous glow discharge tube of extended length having a cathode inside the tube and extending lengthwise thereof, an anode in one end of the tube spaced from one end of said cathode, and an impedance sheath completely surrounding the working length of said cathode, said impedance sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

2. A gaseous glow discharge tube of extended length having an equipotential cathode inside the tube and extending lengthwise thereof, an anode in one end of the tube spaced from one end of said cathode, and an impedance sheath completely surrounding the working length of said cathode, said impedance sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

3. A gaseous glow discharge tube of extended length having an equipotential cathode inside the tube and extending lengthwise thereof, an anode in one end of the tube spaced from one end of said cathode, and a uniform impedance sheath completely surrounding the working length of said cathode, said impedance sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

4. A gaseous glow discharge tube of extended length having a resistance cathode inside the tube and extending lengthwise thereof, an anode in one end of the tube spaced from one end of said cathode, and an impedance sheath completely surrounding the working length of said cathode, said impedance sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

5. A gaseous glow discharge tube of extended length having a uniform resistance cathode inside the tube and extending lengthwise thereof, an anode in one end of the tube spaced from one end of said cathode, and an impedance sheath completely surrounding the working length of said cathode, said impedance sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

6. A gaseous glow discharge tube of extended length having a uniform resistance cathode inside the tube and extending lengthwise thereof, an anode in one end of the tube spaced from one end of said cathode, and a uniform impedance sheath completely surrounding the working length of said cathode, said impedance sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

7. A gaseous glow discharge tube of extended length having an anode in one end thereof, a cathode inside and extending lengthwise of said tube, the forward end of said cathode being...
8. A gaseous glow discharge tube of extended length having an anode in one end thereof, a cathode within and extending lengthwise of said tube, the forward end of said cathode being spaced by a gap from said anode, said cathode being of decreasing resistance per unit length from its end adjacent said anode toward its end remote from said anode, and an impedance sheath completely surrounding the working length of said cathode, said impedance sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

10. A gaseous glow discharge tube of extended length having an anode in one end thereof, a cathode within and extending lengthwise of said tube, the forward end of said cathode being spaced by a gap from said anode, said cathode being of decreasing resistance per unit length from its end adjacent said anode toward its end remote from said anode, and an impedance sheath completely surrounding the working length of said cathode, said impedance sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

12. A gaseous glow discharge tube of extended length having an anode in one end thereof, a resistance cathode within and extending lengthwise of said tube, the forward end of said cathode being spaced by a gap from said anode, and an impedance sheath completely surrounding the working length of said cathode, said sheath decreasing in impedance from the forward end toward the rearward portion of the cathode, and said impedance sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

13. A gaseous glow discharge tube of extended length having an anode in one end thereof, a uniform resistance cathode within and extending lengthwise of said tube, the forward end of said cathode being spaced by a gap from said anode, and an impedance sheath completely surrounding the working length of said cathode, said sheath decreasing in impedance from the forward end toward the rearward portion of the cathode, and said impedance sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

14. A gaseous glow discharge tube of extended length having a cathode within and extending lengthwise thereof, an anode in one end of the tube spaced from one end of said cathode, and a high electrical resistance sheath completely surrounding the working length of said cathode, said sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

15. A gaseous glow discharge tube of extended length having a cathode within and extending lengthwise thereof, an anode in one end of the tube spaced from one end of said cathode, and a dielectric sheath completely surrounding the working length of said cathode, said dielectric sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

16. A gaseous glow discharge tube of extended length having an equipotential cathode within and extending lengthwise thereof, an anode in one end of the tube spaced from one end of said cathode, and a dielectric sheath completely surrounding the working length of said cathode, said dielectric wall increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.
completely surrounding the working length of said cathode, said dielectric sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

19. A gaseous glow discharge tube of extended length having an anode in one end thereof, a cathode within and extending lengthwise of said tube, the forward end of said cathode being spaced by a gap from said anode, said cathode being of decreasing resistance per unit length from its end adjacent said anode toward its end remote from said anode, and a dielectric sheath completely surrounding the working length of said cathode, said dielectric sheath decreasing in impedance from the forward end toward the rearward portion of the cathode, and said dielectric sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

20. A gaseous glow discharge tube of extended length having an anode in one end thereof, a cathode within and extending lengthwise of said tube, the forward end of said cathode being spaced by a gap from said anode, and a dielectric sheath completely surrounding the working length of said cathode, said dielectric sheath decreasing in impedance from the forward end toward the rearward portion of the cathode, and said dielectric sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

21. A gaseous glow discharge tube of extended length having an anode in one end thereof, an equipotential cathode within and extending lengthwise of said tube, the forward end of said cathode being spaced by a gap from said anode, and a dielectric sheath completely surrounding the working length of said cathode, said dielectric sheath decreasing in impedance from the forward end toward the rearward portion of the cathode, and said dielectric sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

22. A gaseous glow discharge tube of extended length having an anode in one end thereof, a resistance cathode within and extending lengthwise of said tube, the forward end of said cathode being spaced by a gap from said anode, and a dielectric sheath completely surrounding the working length of said cathode, said dielectric sheath decreasing in impedance from the forward end toward the rearward portion of the cathode, and said dielectric sheath increasing the available length of illumination along the extended cathode by increasing the positive column drop at points far removed from the anode as compared with points near the anode.

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