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ELECTRIC DISCHARGE DEVICE

Filed April 27, 1940

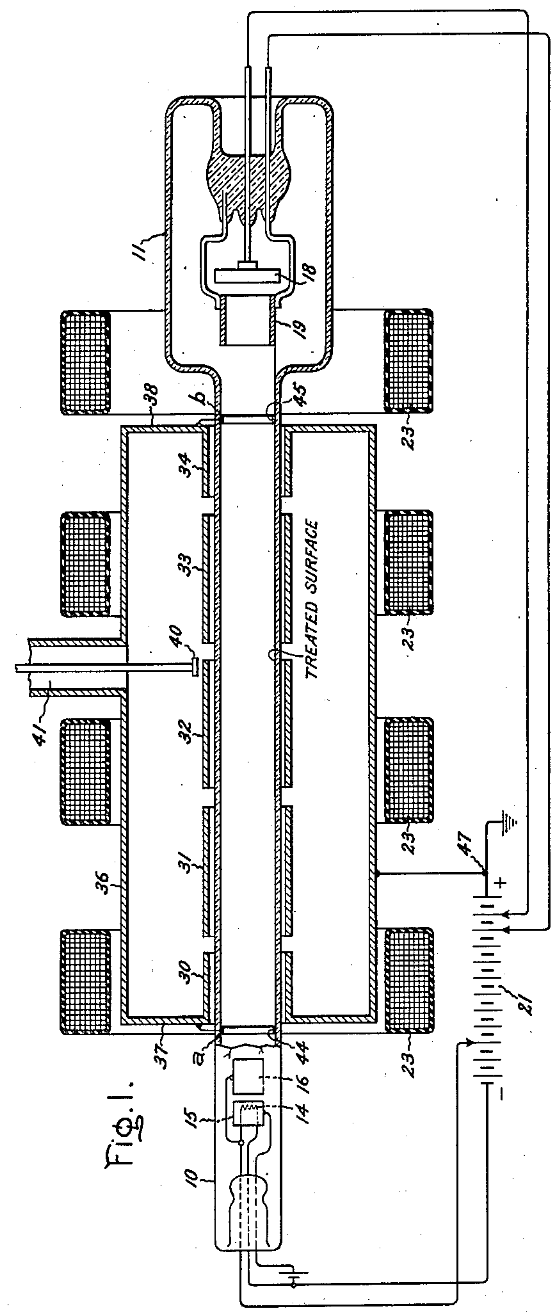

Fig. 1.

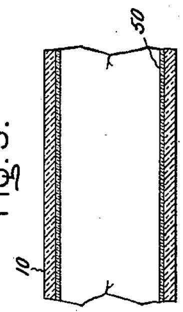

Fig. 3.

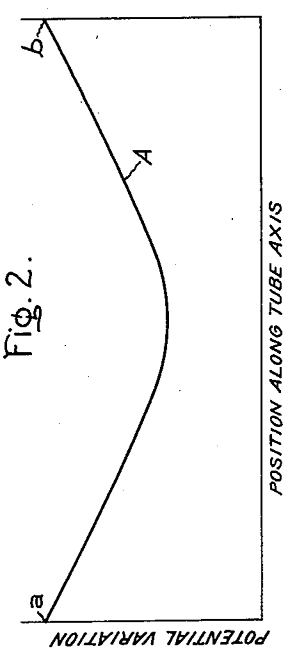

Fig. 2.

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UNITED STATES PATENT OFFICE

2,292,151

ELECTRIC DISCHARGE DEVICE

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Application April 27, 1940, Serial No. 332,022

3 Claims. (Cl. 250—155)

The present invention relates to electric discharge devices and more particularly to cathode ray tubes and similar devices in which an electron beam is required to be projected through an elongated tubular envelope of quartz glass or a similar material.

In the operation of devices of the character referred to, and especially where quartz (fused silica) is used as the envelope material, difficulty is frequently encountered due to the occurrence of wall-charging; that is to say, the accumulation of static charges on various portions of the envelope wall surface. Such charges tend to modify the potential distribution along the discharge path and may cause it to depart materially from the distribution normally maintained by the electrode elements of the device. An aspect of this phenomenon which is especially troublesome in the operation of beam tubes used as high frequency oscillators and the like lies in the occurrence of unpredictable variations from time to time in the amount of wall-charging, so that unstable and uncertain operation results. Under some circumstances the amount of wall-charging may become so great as actually to prevent the operation of the device in its normal and intended manner.

The difficulty stated in the foregoing may be overcome to a certain extent by arranging conductive electrode elements at the points at which objectionable wall-charging tends to occur. In many cases, however, this expedient is inconvenient in that the presence of the electrode elements and their lead-in connections interferes with the intended operation of the device as a whole.

In accordance with my present invention it is proposed to minimize wall-charging, in so far as the same occurs in discharge envelopes which consists principally of fused silica, by providing the interior surfaces of such envelopes with a superficial layer or glaze consisting of the fusion product of silica and an alkali-free oxide of a type which combines with silica to form a glass. While no completely satisfactory explanation of the efficacy of this expedient is now available, its utility has been established empirically, and a tentative explanation will be given at a later point herein.

The features which I desire to protect herein are pointed out with particularity in the appended claims. The invention itself, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the drawing, in which Fig. 1 shows in partial section a discharge device suitably embodying the invention, Fig. 2 is a graphical representation useful in explaining the invention, and Fig. 3 is an enlarged view of a fragmentary portion of Fig. 1.

Referring particularly to Fig. 1, the invention is illustrated in connection with a discharge device adapted to be used as an oscillator at ultra-high frequencies. The oscillator, itself, apart from the improvement in envelope structure to be described herein, is the invention of W. C. Hahn and is fully disclosed and claimed by him in his application Serial No. 276,172, filed May 27, 1939, and assigned to the same assignee as the present invention.

The arrangement shown comprises an electron beam tube which includes an evacuated envelope having an elongated tubular portion **10**. This portion, which is of uniform diameter along its length, connects at one end with a large electrode-containing portion **11**. In order to minimize power losses occurring in the envelope walls when the device is operated at ultra-high frequencies, the envelope is constituted of quartz glass (i. e. fused silica).

The tubular envelope portion **10** is provided at one end with means, such as a known type of electron gun, for producing an electron beam which passes axially of the envelope. The combination shown comprises a cathode **14**, which is indicated in dotted outline, and a focusing cylinder **15** for confining the electrons emitted from the cathode to a concentrated beam. The cylinder may either be connected directly to the cathode as shown or maintained a few volts positive or negative with respect to it. In order to accelerate the electrons to a desired extent there is provided an accelerating electrode **16** which is spaced from the cathode and which may be biased to a suitable positive potential, say, several hundred volts.

At the other end of the envelope there is provided an anode **18** which serves to collect the electron beam after it has traversed the tubular envelope portion **10**. A ring-like electrode **19**, in the nature of a suppressor grid, serves to prevent secondary electrons emitted by the anode **18** from returning to the discharge space.

In the operation of the device, the anode should be maintained at a potential one to several thousand volts above the cathode and the suppressor electrode **19** should be biased 50 to 100 volts negative with respect to the anode. These potential relationships may be established by means of a suitable voltage source conventionally represented as a battery 21. In order to maintain the beam in focus during its passage along the axis of the envelope, one may employ a series of magnetic focusing coils such as are indicated by the numeral 23.

The combination of elements so far described comprises means for producing a unidirectional beam of electrons. Outside the envelope there is provided an electrode system for generating ultra-high frequency oscillations by reaction with the beam.

The electrodes which make up the high frequency system include a series of sequentially arranged tubular conductive elements which surround the envelope and which are respectively numbered 30 to 34. These elements are concentrically enclosed by a one piece tubular structure 36 which is terminally connected with the end ones of the elements by means of transversely extending annular parts 37 and 38.

It has been shown in the Hahn application Serial No. 276,172 previously referred to that an electrode system such as that described may be made to develop self-sustained oscillations provided the electron transit time through the elements 30 to 34 inclusive is properly correlated to the desired frequency of operation of the oscillator, and provided further that the lumped capacitance existing across the various gaps which separate the elements is properly related to the distributed constants of the elements and the surrounding conductive shell 36. When the foregoing requirements are complied with the electrode structure acts as a resonant standing wave system which is maintained in excited condition by its reaction with the beam at the interelectrode gaps. Power may be taken from the system for external utilization by the provision of a member 40 which is capacitively coupled to one of the electrode elements near its extremity and which is associated with a concentric conductor transmission line 41 appropriate for the transfer of high frequency energy.

In the design of a system such as that described above it is ordinarily convenient to start with an intended beam velocity. The dimensions of the electrode parts and their spacings are then determined in such fashion as to be correlated to the assumed velocity and to produce the transit time relationships which are necessary to the desired operation of the device. It is apparent, therefore, that in order that the intended operation of the device shall obtain, it is necessary that the beam velocity shall remain at the assumed value.

To some extent, the condition specified in the preceding paragraph can be realized by positioning conductive members 44 and 45 within the envelope at the boundaries of the high frequency electrode system and by connecting such electrode to a voltage which corresponds to the desired beam velocity. (In the present case the desired voltage relationship is established by connecting the members 44 and 45 directly to the high frequency electrode structure and by tying the latter to the grounded positive terminal of the battery 21 as indicated at 47.) It is found, however, that even with these precautions, the occurrence of charging of the wall surfaces of the envelope tends to produce considerable variation of the potential distribution between the conducting members 44 and 45 and thus to cause a departure of the average beam velocity from the desired value.

The nature of this phenomenon is indicated graphically in Fig. 2, in which curve A shows the variation of potential which may occur between the regions *a* and *b* (Fig. 1) where the potential level is definitely fixed by the presence of the conductive members 44 and 45. In cases where quartz glass is used as the envelope material the amount of this variation may become so great after a relatively limited period of operation as to make impossible the further operation of the tube in its intended manner. The complete explanation of this phenomenon is not known, but it is believed to be controlled at least in part by the secondary emission characteristics of the envelope surface. In the case of quartz glass, however, it appears that the greater part of the difficulty may arise from the trapping of electrons in the substance of the glass itself. More specifically, on this point, it is thought that electrons from the electron beam penetrate the molecular structure of the glass. Due to the extremely low volume conductivity of this material, such trapped electrons are unable to escape by flowing through the envelope wall to nearby conducting parts, as would be possible in connection with many so-called insulating substances.

In accordance with my present invention, at least this aspect of wall-charging is overcome by providing the interior surface of the envelope between the electrodes 44 and 45 with a superficial layer 50 (see Fig. 3) which is more highly conducting than the quartz glass itself. A very great limitation is imposed on the character of the materials which may be used in this connection, however, by the fact that it is to be used in a situation where high frequency fields exist. As a result of this latter circumstance the material employed must be of such character that its total high frequency losses are not greatly in excess of those of quartz itself, lest such losses produce undue interference with the operation of the device as a whole. These diverse requirements are fulfilled in accordance with the present invention by forming the superficial layer referred to of the fusion product of silica and an oxide which is adapted to form a glass when combined with silica. The particular oxides deemed suitable for use in this connection include phosphorus pentoxide (P_2O_5), boric oxide (B_2O_3), and lead oxide (PbO), or combinations of these materials. It is especially important that the glass-forming material employed be free of alkalies such as Na_2O_3 and K_2O_3, which are frequently associated with glasses, since it is found that the presence of such alkalies tends to raise the high frequency losses of the resultant fusion product to an insupportable degree.

Phosphorus pentoxide represents a preferred material for use in this connection in view of its high degree of effectiveness in preventing wall-charging and in stabilizing the potential level of the parts of the envelope wall surface which are glazed therewith and which are separated from the conductive parts of the apparatus. A suitable mode of applying this material to the wall surface consists in the following:

A water solution containing 50 per cent P_2O_5 is made by dissolving powdered phosphorus pentoxide in water. This solution is run into the cleaned quartz glass tube so as to form a film of the solution. (Quartz glass cleaned with chromic acid allows a uniformly wetted surface to be attained.) The quartz glass so coated should be heated in an oxygen-hydrogen flame to evaporate the water and to fuse the P_2O_5 into the quartz. The superficial layer thus formed is integral with the quartz glass.

The other oxides which have been mentioned may be applied by a technique generally similar to that described in the foregoing, although, of course, other techniques may be used.

The effectiveness of the invention is thought to depend upon the relatively higher conductivity of the glaze applied to the quartz glass as compared to the conductivity of the quartz glass itself. Due to this conductivity it appears the electrons which penetrate the structure of the glaze are not trapped as in the case of the unglazed quartz, but are continuously released due to their ability to flow through the relatively conductive substance of the glaze. (It should be understood that the word "conductive" is a purely relative term and that the conductivity of the coatings referred to herein, while higher than that of quartz glass, is neverthless many thousand times lower than the conductivity of a typical metallic substance.) Some additional improvement with respect to decrease in wall charge may be obtained by additionally coating the glazed surface of the quartz glass with magnesium oxide or related substances so as to modify the secondary emission property thereof in the manner described in the application, Serial No. 301,629 of Victor H. Fraenckel which was filed October 27, 1939, and which is assigned to the same assignee as the present invention.

While my invention has been described by reference to a particular structural embodiment thereof it will be understood that it has a great number of other applications. I, therefore, aim in the appended claims to cover all uses of the invention which come within the true scope of the foregoing disclosure.

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

1. A discharge device comprising an elongated envelope formed of fused silica, means within said envelope for producing an electron stream axially of the envelope, conductive means within the envelope for fixing the potential level at a particular point along the envelope axis, a high frequency electrode system located in proximity to the walls of the envelope in a region bounded at one extremity by said conductive means, said electrode system being effective during normal operation of the device to produce high frequency fields adapted to modulate the electron stream, and a superficial coating covering the interior surface of the envelope over an area which includes the region subtended by the high frequency electrode system and by the said conductive means, said coating being effective to lessen the wall-charging tendencies of the envelope surface and comprising a layer which consists of the fusion product of silica and an alkali-free oxide of the group which includes P_2O_5, B_2O_3, and PbO.

2. A discharge device comprising an elongated tubular envelope formed of fused silica, means within said envelope for producing an electron stream axially of the envelope, conductive means within the envelope for fixing the potential level at spaced points along the envelope axis, a high frequency electrode system outside the envelope in a region between the said spaced points, said electrode system being effective during normal operation of the device to produce high frequency fields extending through the wall of the envelope to modulate the electron stream, and a superficial coating covering the interior surface of the envelope between the said spaced points for modifying the wall-charging properties of the envelope, said coating comprising a layer which consists of the fusion product of silica and an alkali-free oxide of the group which includes P_2O_5, B_2O_3, and PbO.

3. A discharge device comprising an elongated tubular envelope formed of fused silica, means within said envelope for producing an electron stream axially of the envelope, means including a pair of axially spaced annular electrodes within the envelope and in contact with the interior surface of the envelope at displaced points for fixing the potential level at such points, a high frequency electrode system outside the envelope in a region between the said annular electrodes, said electrode system being effective during normal operation of the device to produce high frequency fields extending through the wall of the envelope to modulate the electron stream, and a superficial layer covering the interior surface of the envelope in a region extending between the said annular electrodes for modifying the wall-charging properties of the envelope, said layer comprising the fusion product of silica and phosphorous pentoxide.

LOUIS NAVIAS.