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ELECTRIC SYSTEM EMBODYING COLD-CATHODE
GASEOUS DISCHARGE DEVICE
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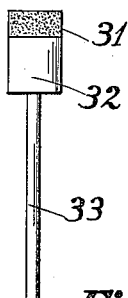


Fig. 1

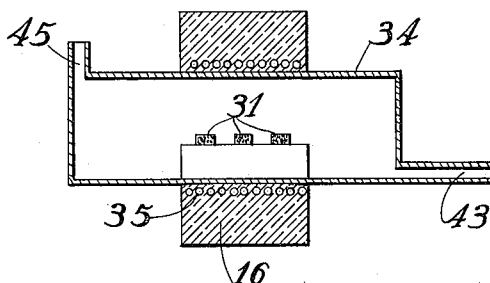


Fig. 2

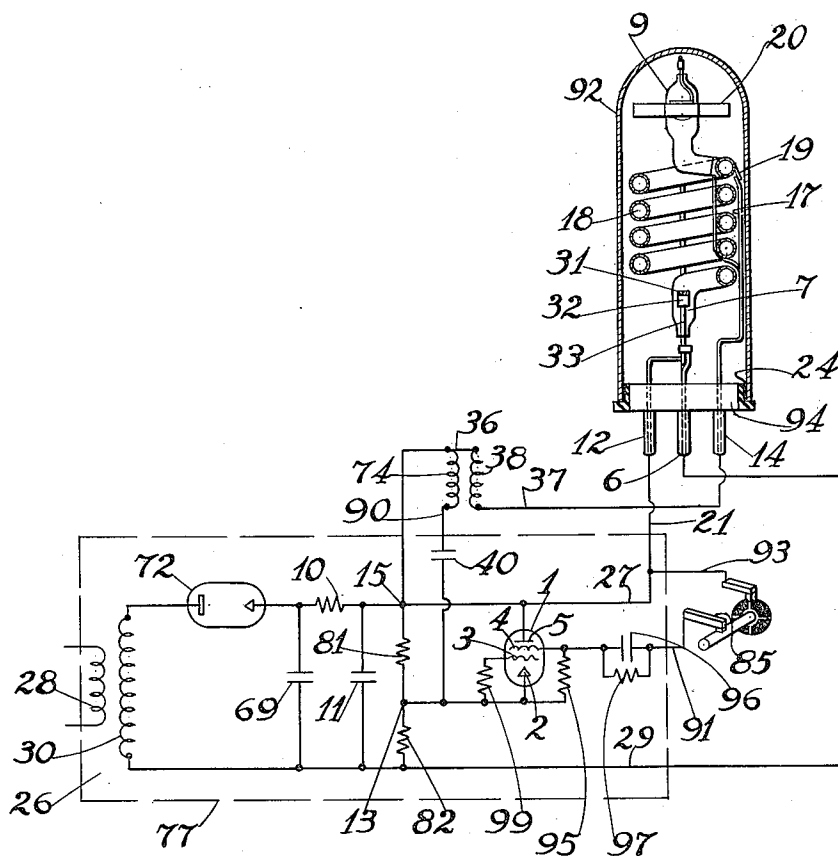


Fig. 3

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ELECTRIC SYSTEM EMBODYING COLD-CATHODE GASEOUS DISCHARGE DEVICE

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7 Claims. (Cl. 315—238)

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The present invention relates to electric systems embodying arc-discharge or gaseous-discharge tubes provided with cold cathodes the cathode emission of which is obtained from a small bright spot on the surface of the cathode, known as a cold-cathode spot. The present application is a continuation-in-part of application, Serial No. 538,467, filed June 2, 1944, now abandoned.

Tubes of the above-described character are used, for example, for the production of very intense short flashes of light, in stroboscopic work and photography, and for the control of heavy currents of brief duration. The duration of the current pulses, and the frequency with which they occur, depend on the application. In some work, there may be as many as several thousand pulses per second; in other applications, they may occur at intervals of minutes, or even hours. In what may be regarded as a typical application, the cathode may be called upon to deliver several thousands of amperes, during times ranging from 10^{-6} to 10^{-2} seconds. These currents may be obtained from a small electrode, perhaps $\frac{1}{8}$ inch in diameter and $\frac{1}{16}$ inch long.

The life of tubes of the above-described character is usually limited by the erosion resulting from the sputtering away of the cathode material, due to the intense ion bombardment and heat in the region of the cathode spot. This sputtering is particularly severe when interrupting high currents in an inductive circuit, such as occur in very powerful flashlamps for photographic use.

Experiments with various metals as cathodes, under these conditions, indicated that the refractory material tungsten was the most resistant to sputtering; but that the sputtering rate of pure tungsten could be greatly reduced by a surface layer of low work-function, such as an oxide of one of the alkali, alkali-earth or rare-earth metals. In operation, however, these thin layers are quickly sputtered away again, exposing the base metal.

The sputtering rate of various metals, particularly tungsten, is greatly dependent also on the type of gas filling in the tube. The sputtering rate of tungsten in air, for example, may be as low as 2 to 3 milligrams per ampere-hour; while, for the rare gases, the sputtering rate may be as high as 70 to 80 milligrams per ampere-hour. The low sputtering rate obtained with air is dependent on the presence of the oxygen in the air; this oxygen produces thin oxide layers on

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the surface of the tungsten and this, in turn, lowers the sputtering rate.

In most tubes for the production of flashes of light and for control purposes, the presence of oxygen in the gas is undesirable from the standpoint of tube characteristics. Also, the oxygen disappears or cleans up rather rapidly, thus causing changes in the tube characteristics.

In some tubes for control purposes, it is desirable to fill the tubes with hydrogen, because of its very rapid de-ionization and high breakdown strength. The hydrogen precludes the formation of protective oxide layers and, hence, causes very rapid sputtering.

An object of the present invention is to provide a new and improved electric system embodying an arc-discharge or gaseous-discharge device provided with a cold cathode that, operated to produce a cold-cathode arc discharge, rather than as a thermionic cathode, shall be less subject to sputtering.

Other and further objects will be described hereinafter and will be particularly pointed out in the appended claims.

Toward the attainment of these ends, in accordance with a feature of the present invention, a suitable compound of low work-function, such as barium oxide, for facilitating the easy emission of electrons, is uniformly sintered and bound together into a unitary mass with a substance, such as tungsten, of high melting temperature, that is highly resistant to sputtering. Under some circumstances, a binding medium may be employed for soldering or otherwise binding the parts together; under other circumstances, no binding medium at all is necessary, in which event, the entire electrode may be constituted of a uniform mixture of tungsten with a suitable material of low work-function. A surface of the uniformly-sintered-and-bound-together mass is thereby continuously presented that combines the sputtering-resistant properties of tungsten with the properties of the said material of low work-function, regardless of the wearing away of the surface.

The invention will now be more fully described in connection with the accompanying drawings, in which Fig. 1 is a front elevation of a cathode electrode embodying the present invention; Fig. 2 is a diagrammatic view illustrating a sintering method; and Fig. 3 is a longitudinal section of a flash-lamp embodying the invention, shown connected into a preferred circuit.

The illustrated flash-tube embodies an elongated light-permeable gas-tight glass-bulb jacket

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or envelope 92, cemented at 24 to a flat insulating base plug 94 provided with three lead-in pin terminals 6, 14 and 12 projecting exteriorly thereof. A flash-lamp 18, that may be filled with an inert or reducing gas, such as krypton, hydrogen or any other suitable substantially non-oxygen-containing gas, is mounted in the envelope 92.

The flash-lamp 18 is shown helically coiled, and provided with two electrodes, constituted of a cathode 7 and an anode 9, connected, respectively, to the terminals 6 and 12. The parts are held permanently steady in correct position, and properly lined up, in the bulb 92, by means of suitable metal spreaders 20. One end of a high-voltage spark trigger or trip-wire electrode 17 is connected to the terminal 14, and its other end is soldered or otherwise joined to one or both ends of a metal ribbon or band support 19 that is mounted over a plurality of the coils or turns of the helical-tube flash-lamp 18.

The apparatus may be used in conjunction with a control circuit 77, which may be of the nature more fully disclosed in Letters Patent 2,277,697, issued March 31, 1942, to Herbert E. Grier. The flash-lamp 18 may be connected, as there described, through the medium of the terminal pins 12 and 6, across a condenser 11. To this end, the terminal pin 12 may be connected to a terminal 15 at one side of the condenser 11 by conductors 21 and 27, and the terminal pin 6 may be connected to the other side of the condenser 11 by a conductor 29. The condenser 11 may be continuously charged through a variable current-limiting charging impedance 10 to a voltage of, say, 2000 volts from any direct-current supply. The preferred supply is shown as a transformer 26, the primary winding 28 of which may be connected to any desired source of alternating-current energy of the correct voltage and frequency, and the secondary winding 30 of which may be connected to the condenser 11 through a rectifier 72.

A filter condenser 69 may constitute part of the direct-current supply. The condenser 11 may be connected to the direct-current supply through the charging impedance 10. The arrangement is similar to that of Letters Patent 2,302,690, issued November 24, 1942, to Kenneth J. Germeshausen.

A trigger tube 1 may be connected to terminals 15 and 13, across a bleeder resistor 81, so as to be supplied with voltage therefrom. The bleeder resistor 81 is connected, in series with a bleeder resistor 82, across the condenser 11. The condenser 11 thus constitutes the main power-supply for the tube 1. The resistors 81 and 82 may be so proportioned that a desired voltage of, say, 300 volts shall appear across the terminals 13 and 15 of the resistor 81. To the terminals 13 and 15 there are also connected, in parallel with the tube 1, in series with a condenser 40, a primary winding 74 of a transformer 36. One side of the condenser 40 is connected to the terminal 13 and the other side, by way of a conductor 90, to the primary winding 74. The secondary winding 38 of the transformer 36 is connected, by a conductor 37, to the trip wire 17 to produce the high-voltage triggering spark.

The tube 1 may be of the cold-cathode gaseous-discharge type illustrated and described in Letters Patent 2,185,189, 2,201,166 and 2,201,167, issued to the said Kenneth J. Germeshausen on January 2, 1940, and May 21, 1940. It may comprise an evacuated glass envelope containing several electrodes, namely, a solid cold cathode 2, an anode or plate 5, and one or more grids, inner

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and outer grids being shown at 3 and 4, between the anode 5 and the cathode 2. An impedance 99 is shown connected between the cathode 2 and the grid 3 and an impedance 95 between the cathode 2 and the grid 4.

The flash-lamp 18 may be tripped by means of a hand-controlled switch (not shown), or, as illustrated and described in the said Letters Patent 2,277,697, by means of an automatically operated contactor 85, that is connected across the anode or plate 5 and the grid 4 by conductors 93 and 91 in series with a blocking condenser 96 and a leak resistor 97, in parallel. The contactor 85 may be actuated by the object being photographed. Further details, together with a fuller description of the circuit connections, are described in the said Letters Patent 2,277,697.

As further described in the said Letters Patent 2,277,697, a voltage surge of the secondary winding 38 of the transformer 36 is applied to the trigger electrode 17 of the tube 18. The high-voltage triggering spark ionizes the gas in the flash-tube 18, thereby causing it to become a conductor and permitting the condenser 11 to discharge through the flash-lamp 18 between its electrodes. The time taken for the circuit to function from the closing of the contactor 85 to the flash of light from the tube 18 is very brief, producing a very brilliant flash of light for a very brief period of time at any desired instant, for taking photographs.

Owing to the brief voltage pulse thus impressed by the condenser 11 between the anode 9 and the cold cathode 7, current passes between the anode 9 and the cathode 7 continually but interruptedly to set up continually discharges of arc characteristic between the cathode 7 and the anode 9. It is of amperage sufficiently high to produce a potential gradient on a relatively small area only of the before-described surface of the cathode 7 high enough to form a cathode spot on the cathode, in order to extract electrons from the cathode while the cathode remains "cold," at average low temperatures very substantially below the temperatures at which substantial thermionic emission may be produced from the cold cathode; and to produce a fall of cathode potential lower than that occurring in a glow discharge. A cold-cathode spot may thus be continually but interruptedly formed on the cathode. The average value of the said current is nevertheless so relatively low that the heat produced is insufficient to heat the cold cathode appreciably. It is sufficiently low, indeed, so that its root-mean-square value, that is, the heating current through the tube, is low enough so that the average temperature applied by the current to the cold cathode 7 is less than the temperature at which substantially incandescent thermionic cathode emission may be produced from the cold cathode 7. Repeatedly heavy currents of brief duration are thus produced.

In accordance with a feature of the present invention, the cathode electrode may be constituted of 100 parts tungsten powder, 8 parts barium peroxide, and $\frac{1}{2}$ part cobalt powder by weight. The cobalt serves as a binder, and it may be replaced by nickel, copper, or any other suitable binder. Under certain circumstances, as hereinafter explained, the binder may be wholly omitted.

To insure thorough mixing, and to reduce the powders to small-particle size, these ingredients may be ball-milled for 12 to 24 hours, preferably in an inert vehicle, such as carbon tetrachloride.

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After milling and removal of the carbon tetrachloride by filtering, the resulting powder is pressed into the desired shape in molds (not shown) at pressures on the order of 20 to 40 tons per square inch. At these pressures, a very dense compact pill 31 is obtained, which is strong enough to be handled before sintering.

The electrode pills 31 are then placed in a refractory furnace 34, surrounded by an electrical heater 35, enclosed in heat insulating material 16.

The sintering may be carried out by heating in the furnace 34 in a vacuum, or an inert gas, to prevent oxidation or chemical combination with the materials of the electrode. It is preferred, however, to use a reducing atmosphere, such as hydrogen, since it will remove undesirable nickel and tungsten oxides, and allow better sintering. The hydrogen may be caused to flow into the furnace 34 by way of a gas inlet 43, and out of the furnace through an exit 45. The hydrogen is thus caused to flow through the furnace 34 and around the electrodes during the sintering process.

The electrodes are brought slowly to the sintering temperature. The barium peroxide decomposes, leaving barium oxide; and, at some higher temperature, depending on the composition of the electrode, the pill 31 will sinter into a very strong material.

The proportions of the tungsten, the barium oxide, and the cobalt may be varied over rather wide limits without seriously affecting the properties of the resulting sinter. In general, since the binder represents a relatively nonrefractory material, the quantity of binder should be kept as low as possible, consistent with good bonding and electrical conductivity of the resulting sinter.

The percentage of binder needed to secure good bonding will depend on the percentage of the material of low work-function employed and, to some extent, on how finely divided, uniformly sintered, and bound together the binder and the low-work-function material are. The percentage of binder will also depend on the sintering temperature.

Mixtures containing 100 parts tungsten, 10 parts barium peroxide, and 10 parts nickel or cobalt, or, say, 80 percent tungsten, 10 percent barium peroxide, and 10 percent cobalt, may be sintered satisfactorily at temperatures of approximately 800° C. to 1500° C., with an optimum temperature of 1000° C. to 1200° C. By reducing the barium peroxide to 1 percent or 2 percent, employing 98 percent to 99 percent tungsten, good sintering may be secured, without the use of any binder, at temperatures on the order of 1500° C. to 1600° C. or higher. The binder may thus not be needed at all; the tungsten and barium oxide or their equivalents are the substantially essential elements. If the mixture contains 91½ percent tungsten, 8 percent barium peroxide, and ½ percent cobalt, the sintering temperature employed may be 1500° C. or higher.

When the percentage of barium peroxide is much over 10, to say 15, the resulting sinter may prove to be weak mechanically, so as to wear very rapidly. If the percentage of barium peroxide should be reduced to a very low value, less than 1 percent to 2 percent, there would not be enough material of low work-function to produce the desired low wear rate.

The proportions will not be materially varied if molybdenum or tantalum be substituted for

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the tungsten as the refractory material highly resistant to the sputtering.

The major portion of the cold cathode may thus be constituted of a substance selected from the group consisting of tungsten, molybdenum and tantalum and a suitable material of low work-function.

In general, a high percentage of binder and a low percentage of barium peroxide will make a mechanically strong sample that is both ductile and workable. For the uses of the present invention, however, ductility is not important. It is therefore possible to use less binder and more barium peroxide or material of low work-function.

When the percentage of barium peroxide is above about 6, and the binder, as cobalt or nickel, is below 5 percent, the resulting sinter is relatively non-ductile. It should therefore be pressed and sintered into the desired form, as before described.

The sintered electrode 31 may be fastened to a steel or other support 32, by soldering or welding. The support 32 is joined to a rod 33 of tungsten or other material suitable for sealing into the bulb of the flashlamp 18. If the support 32 is of material with a low coefficient of expansion, such as tungsten or molybdenum, approximately matching that of the sinter, the sinter may be pressed onto the support, and sintered thereto, at the same time that the electrode 31 is sintered.

Instead of the barium peroxide, barium carbonate, strontium carbonate, calcium carbonate, or mixtures of these three carbonates may be used as the source of material of low work-function. What is sought after is the barium, the strontium, or the calcium oxide. Other compounds of barium, strontium and calcium that will break down to yield the oxide, on sintering, may therefore equally be used. A substance selected from the group consisting of the oxides of barium, strontium and calcium has been found to be very satisfactory.

In general, the oxides or other compounds of the rare-earth or alkaline-earth groups of elements, classed as materials of low work-function, will reduce the sputtering rate. Not all the alkali, alkali-earth and rare-earth compounds may, however, be employed effectively. Sodium, potassium and caesium compounds, for example, are too volatile to use effectively at the high temperatures of these sinters; they might become lost during the sintering process. Oxides of thorium, aluminum and beryllium, again, reduce the sputtering rate of tungsten. They are not, however, nearly so effective as barium.

With a cathode of this type, the rate of wear is very low, on the order of 1 to 2 milligrams per ampere-hour even for gas fillings containing no oxygen, such as the rare gases, or hydrogen.

The use of these sintered electrodes in flashlamps of the type shown in Fig. 3 has resulted in a great improvement in life. The life of these tubes was previously limited by darkening of the glass, due to sputtered material from the cathode, resulting in a serious loss of light after about 20,000 flashes. With the sintered electrode of the present invention, on the other hand, there is no appreciable darkening, even after more than 100,000 flashes; and this despite the fact that the emission of the cold-cathode electrode is of the order of thousands of amperes per square centimeter. In other cases, lamps or control tubes that were impractical with other electrodes, due

to electrode wear, have been made successfully with the new sintered electrode of the present invention.

Modifications will occur to persons skilled in the art, and all such are considered to fall within the spirit and scope of the invention, as defined in the appended claims.

What is claimed is:

1. An electric system having, in combination, a gaseous-discharge device having an envelope containing a gas in which are disposed an anode and a cold cathode the major portion of which and of a surface thereof are constituted of a substance selected from the group consisting of tungsten, molybdenum and tantalum uniformly sintered and bound together into a unitary mass with an oxygen-containing compound selected from the group consisting of barium, strontium and calcium, a relatively small cold-cathode spot being adapted to be formed on the said surface to produce the emission of electrons from the cold cathode at temperatures very substantially below the temperatures at which substantial thermionic emission may be produced from the cold cathode, and means for impressing between the anode and the cathode a brief voltage pulse of magnitude sufficient to form the relatively small cold-cathode spot on the said surface of the cold cathode but insufficient to heat the cold cathode to a temperature at which substantial thermionic emission may be produced from the cold cathode, thereby to pass an electric discharge between the anode and the cathode through the gas.

2. An electric system having, in combination, a gaseous-discharge device having an envelope containing a gas in which are disposed an anode and a cold cathode the major portion of which and of a surface thereof are constituted of a substance selected from the group consisting of tungsten, molybdenum and tantalum uniformly sintered and bound together into a unitary mass with an oxygen-containing compound selected from the group consisting of barium, strontium and calcium and with a binder, a relatively small cold-cathode spot being adapted to be formed on the said surface to produce the emission of electrons from the cold cathode at temperatures very substantially below the temperatures at which substantial thermionic emission may be produced from the cold cathode, and means for impressing between the anode and the cathode a brief voltage pulse of magnitude sufficient to form the relatively small cold-cathode spot on the said surface of the cold cathode but insufficient to heat the cold cathode to a temperature at which substantial thermionic emission may be produced from the cold cathode, thereby to pass an electric discharge between the anode and the cathode through the gas.

3. An electric system having, in combination, a gaseous-discharge device having an envelope containing a gas in which are disposed an anode and a cold cathode the major portion of which and of a surface thereof are constituted of about 85 to 99 parts tungsten uniformly sintered and bound together into a unitary mass with about 15 parts to 1 part, respectively, of barium oxide, a relatively small cold-cathode spot being adapted to be formed on the said surface to produce the emission of electrons from the cold cathode at temperatures very substantially below the temperatures at which substantial thermionic emission may be produced from the cold cathode, and means for impressing between the anode and the

cathode a brief voltage pulse of magnitude sufficient to form the relatively small cold-cathode spot on the said surface of the cold cathode but insufficient to heat the cold cathode to a temperature at which substantial thermionic emission may be produced from the cold cathode, thereby to pass an electric discharge between the anode and the cathode through the gas.

4. An electric system having, in combination, a gaseous-discharge device having an envelope containing a gas in which are disposed an anode and a cold cathode the major portion of which and of a surface thereof are constituted of about 85 to 99 parts tungsten uniformly sintered and bound together into a unitary mass with about 15 parts to 1 part, respectively, of barium oxide and with about 1 per cent of nickel, a relatively small cold-cathode spot being adapted to be formed on the said surface to produce the emission of electrons from the cold cathode at temperatures very substantially below the temperatures at which substantial thermionic emission may be produced from the cold cathode, and means for impressing between the anode and the cathode a brief voltage pulse of magnitude sufficient to form the relatively small cold-cathode spot on the said surface of the cold cathode but insufficient to heat the cold cathode to a temperature at which substantial thermionic emission may be produced from the cold cathode, thereby to pass an electric discharge between the anode and the cathode through the gas.

5. An electric system having, in combination, a gaseous-discharge device having an envelope containing a gas in which are disposed an anode and a cold cathode the major portion of which and of a surface thereof are constituted of a substance selected from the group consisting of tungsten, molybdenum and tantalum uniformly sintered and bound together into a unitary mass with an oxygen-containing compound selected from the group consisting of barium, strontium and calcium, a relatively small cathode spot being adapted to be formed on the said surface to produce the emission of electrons from the cold cathode at temperatures very substantially below the temperatures at which substantial thermionic emission may be produced from the cold cathode, a condenser, means connecting the condenser to the anode and the cathode, means for charging the condenser, and means for discharging the condenser between the anode and the cathode to impress therebetween a brief voltage pulse of magnitude sufficient to form the relatively small cold-cathode spot on the said surface of the cold cathode but insufficiently to heat the cold cathode to a temperature at which substantial thermionic emission may be produced from the cold cathode, thereby to pass an electric discharge between the anode and the cathode through the gas.

6. An electric system having, in combination, a gaseous-discharge device having an envelope containing a gas in which are disposed an anode and a cold cathode the major portion of which and of a surface thereof are constituted of about 85 to 99 parts tungsten uniformly sintered and bound together into a unitary mass with about 15 parts to 1 part, respectively, of barium oxide, a relatively small cold-cathode spot being adapted to be formed on the said surface to produce the emission of electrons from the cold cathode at temperatures very substantially below the temperatures at which substantial thermionic emission may be produced from the cold cathode, a condenser, means for connecting the condenser to the anode and the cathode, means

for charging the condenser, and means for discharging the condenser between the anode and the cathode to impress therebetween a brief voltage pulse of magnitude sufficient to form the relatively small cold-cathode spot on the said surface of the cold cathode but insufficient to heat the cold cathode to a temperature at which substantial thermionic emission may be produced from the cold cathode, thereby to pass an electric discharge between the anode and the cathode through the gas.

7. An electric system having, in combination, a gaseous-discharge device having an envelope containing a gas in which are disposed an anode and a cold cathode the major portion of which and of a surface thereof are constituted of about 85 to 99 parts tungsten uniformly sintered and bound together into a unitary mass with about 15 parts to 1 part, respectively, of barium oxide and with about 1 per cent of nickel, a relatively small cold-cathode spot being adapted to be formed on the said surface to produce the emission of electrons from the cold cathode at temperatures very substantially below the temperatures at which substantial thermionic emission may be produced from the cold cathode, a condenser, means for connecting the condenser to the anode and the cathode, means for charging the condenser, and means for discharging the condenser between the anode and the cathode to

impress therebetween a brief voltage pulse of magnitude sufficient to form the relatively small cold-cathode spot on the said surface of the cold cathode but insufficient to heat the cold cathode to a temperature at which substantial thermionic emission may be produced from the cold cathode, thereby to pass an electric discharge between the anode and the cathode through the gas.

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