

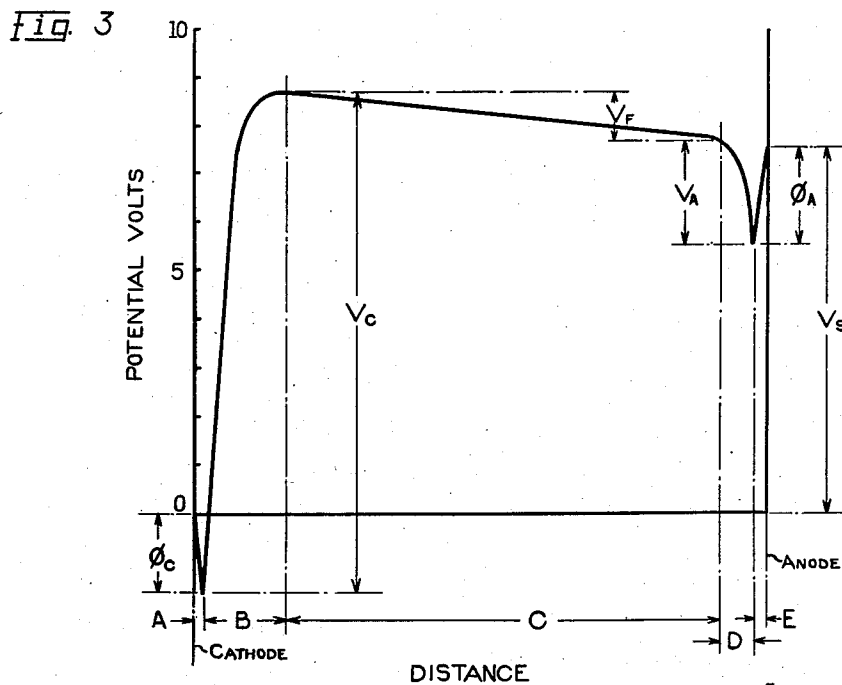
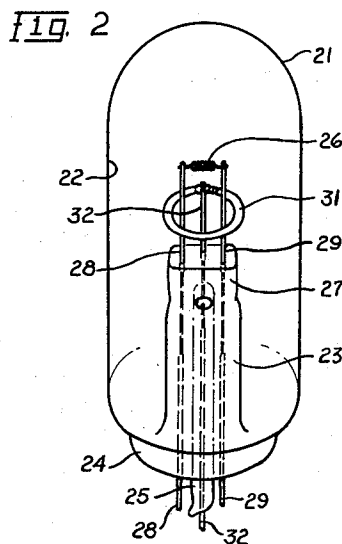
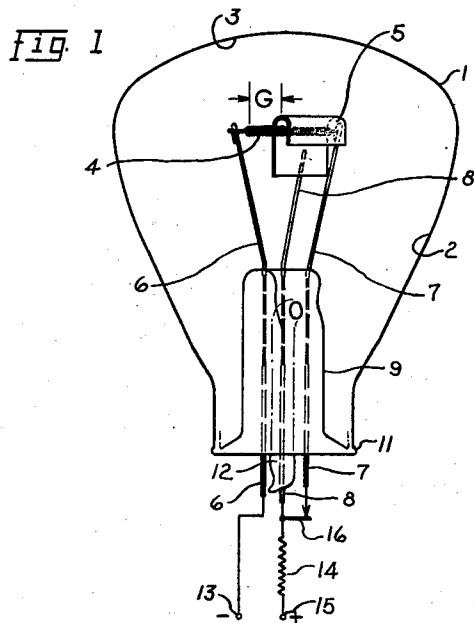
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ELECTRIC DISCHARGE DEVICE

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2,832,912

ELECTRIC DISCHARGE DEVICE

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This invention relates in general to gaseous electric discharge devices and more particularly to low voltage discharge lamps of relatively small wattage. The invention is more specifically concerned with discharge lamps of the cathode glow type having an operating voltage of the order of magnitude of the ionization potential of the ionizable medium.

An example of the type of discharge lamp with which the invention is most useful is that designated commercially RP12. This lamp may be characterized as a miniature, single-ended fluorescent lamp and is used for a source of ultraviolet radiation. One of its fields of application is in airplane or vehicle instrument panel lighting wherein it is necessary to dispense with cumbersome auxiliary equipment and wherein the available sources of power are generally of low voltage, for instance, 24 or 12 volts. The instrument dials or indicia in this application are coated with a fluorescent material which produces visible light upon irradiation by the ultraviolet radiation or black light from the lamp.

The extremely low voltage ratings of these lamps have entailed performance specifications extremely close to the design limits. The result has been that manufacture is very critical and frequently a large proportion of lamps, at times exceeding 50 percent, is found to be defective in failing to meet the maximum operating voltage specifications and must be rejected. The use of automatic machines in the production of such lamps required to operate on 12 volts or less has not been feasible, and up until the present time it has been strictly a bench exhaust proposition.

An object of the invention is to provide a new and improved low voltage electric discharge lamp having improved design characteristics making for a greater margin of tolerance in respect of established specifications and making the manufacture less critical.

Another object of the invention is to provide a low voltage electric discharge lamp of the cathode glow type which does not require an extremely critical exhaust and seasoning schedule in order to achieve substantially the lowest operating voltage of which the lamp is capable under optimum exhaust and seasoning conditions.

Yet another object of the invention is to provide a miniature electric discharge lamp of the cathode glow type having a lower operating voltage than heretofore possible.

In accordance with one feature of the invention, I have discovered that much of the shrinkage, that is, the production loss due to rejects, which has been experienced in the manufacture of lamps of the instant type in the past, has been due to the difficulty of achieving adequate exhaust or outgassing. The problem has been aggravated by reason of the fact that the lamps are single-ended, so that continuous flushing during the lehring or baking process to which the fluorescent coating on the bulb walls must be subjected has been impossible. One of the products evolved during the lehring is water vapor and if even a trace thereof is left in the bulb, it is decomposed by the discharge to produce hydrogen, which causes the oper-

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ating voltage of the lamp to rise markedly. The invention offers a solution to these difficulties by providing anodes for the lamps in the form of metal having the ability to getter the deleterious gas traces present in the lamp, and particularly the hydrogen. In the gettering action, the anode adsorbs or otherwise assimilates the deleterious gases present and reduces their pressure to insignificant levels.

In accordance with another feature of the invention, I have discovered that anodes made of titanium metal are particularly advantageous for lamps of the instant type. Titanium has the peculiar ability of adsorbing hydrogen most effectively at low temperatures, for instance, at room temperature, and of adsorbing other gases, such as oxygen, nitrogen, and carbon dioxide and monoxide at high temperatures, for instance, temperatures above 700° C. In the instant lamps, the gas which it is most important to adsorb or getter is hydrogen which is produced by decomposition of water vapor. There may also be minor traces of carbon dioxide and monoxide remaining from the lehring of the phosphor or evolved from the cathode during seasoning. The getter material is provided in the form of a titanium anode which is heated by the discharge in the operation of the lamp. The anode is of such configuration that the cooler portion remote from the arc getters or adsorbs hydrogen, and the hotter portion close to the arc adsorbs the other gases, namely carbon dioxide and monoxide, and other hydrocarbons present.

Low voltage cathode glow discharge lamps with titanium anodes in accordance with the invention have further been found to make possible lower operating voltage characteristics for such lamps than have hitherto been achieved. Quite unexpectedly, such operating voltages are lower than the lowest operating voltages formerly obtained with prior art lamps under optimum conditions of exhaust. This feature of the invention appears to be separate from and independent of the gettering action of the titanium and appears to be related to the electron emission and work function properties of the titanium, either considered by itself or in combination with coatings of other materials, such as barium, which may be formed thereon during operation of the lamps.

For further objects and advantages and for a better understanding of the invention, attention is now directed to the following description and accompanying drawings of preferred embodiments of the invention. The features believed to be novel will be more particularly pointed out in the appended claims.

In the drawings:

Fig. 1 is a pictorial view of a miniature fluorescent lamp embodying the invention along with a circuit for operating same;

Fig. 2 is a side view of an alternative construction of a miniature fluorescent lamp embodying the invention;

Fig. 3 is a graph illustrating internal potential conditions in lamps of the type illustrated in Figs. 1 and 2.

In Fig. 1, the particular lamp shown therein embodying a specific form of the present invention may be considered a modification of Patent 2,403,184—Lemmers. The lamp comprises a generally pear-shaped vitreous envelope 1 containing a suitable ionizable medium. The envelope may be coated internally with a fluorescent material and may be made of a vitreous material which is transparent to ultraviolet rays where such radiation is to be utilized externally of the envelope. In the illustrated lamp corresponding to the commercially available version, the conical side walls are comparatively thickly coated at 2 with phosphor, whereas the convex end wall at 3 is comparatively thinly coated. With this arrangement, the phosphor on the side walls serves both as a source and as a reflector of radiation which is transmitted through the convex end wall. The ionizable

medium may consist of a rare gas and a vaporizable metal. The preferred filling is argon at a pressure of a few millimeters of mercury, for instance, 3.5 to 4.5 mm., and a small quantity of mercury.

The lamp contains a cathode 4 and an anode 5, the cathode being mounted on leads 6, 7 and the anode on lead 8. The leads extend through a conventional stem 9 sealed peripherally at 11 to the bulb and including an exhaust tube 12. The cathode 4 is preferably formed as a triple-coiled tungsten filament of the type now common in tubular elongated fluorescent lamps. The filament is coated with electron-emissive material such as alkaline-earth oxide, for instance, a mixture of barium and strontium oxides.

The instant invention is more particularly concerned with the anode 5, which, in the prior art, was generally made of molybdenum or nickel. In this preferred embodiment, the anode is made of titanium. Commercially pure titanium metal consisting of 99.5 percent titanium has been found suitable. Titanium alloys may also be used, for instance alloys consisting of titanium for the major part and of iron, molybdenum or chromium for the remainder. In general, the improved results appear to depend on the presence of the titanium, whether by itself or in alloy form. For the instant lamp rated at about 3 watts, and having a sealing length of approximately 1 7/8 inches and a maximum diameter of approximately 1 1/2 inches, the anode may consist of a strip of commercially pure titanium 12 mil thick, 6 millimeters wide, and 11 millimeters long. As shown in the drawing and in accordance with the teachings of the aforementioned Lemmers patent, the anode may be substantially U-shaped, the bent portion having a diameter of about 3 millimeters, whereby the distance between the outer surface of the coiled cathode 4 and the inner surface of the anode 5 is approximately 1 millimeter.

Prior to mounting in the envelopes, the titanium anodes must be outgassed in order to condition them as getters. This may be done by vacuum firing the anodes in quartz or quartz-like glass e. g. Vycor brand of Corning Glass Works) tubes at about 1050° C. for 30 minutes. At this temperature, hydrogen is driven out, whereas other gases, such as oxygen and nitrogen, diffuse inward into the metal from the surface layers. At lower temperatures, the process of hydrogen evolution slows down considerably, and temperatures below approximately 800° C. do not cause diffusion of surface layers of oxygen and nitrogen into the metal. On the other hand, very high temperatures are to be avoided, because they cause appreciable vaporization of titanium in a vacuum. The anodes may be left exposed to the ambient air for considerable lengths of time after degassing without observable decrease in gettering ability. However, anodes which have been exposed to the air for more than a week should preferably be outgassed anew for best results.

In the prior art lamps of this type having molybdenum anodes, in order to hold the operating voltage of the lamp under the specification limit of 9.0 volts maximum, it was necessary to subject the lamp to a special and critical seasoning schedule. According to this schedule, after assembly of the lamp, the cathode is initially outgassed at about 1100° C. by connecting it across a suitable source of voltage. This heating decomposes to oxides the mixture consisting of carbonates of alkaline-earth metals, for instance, barium and strontium carbonates, suspended in a suitable binder, such as nitrocellulose, with which the cathode is coated. The heating is continued until no more carbon dioxide is evolved. The lamp is then seasoned by passing a higher current through the cathode to maintain it at a temperature of approximately 1300° C. for 2 to 6 minutes. Thereafter the seasoning may be completed by operating the lamp with arc current for 5 to 10 minutes.

While the above-described seasoning treatment is beneficial and desirable in lamps with titanium anodes em-

bodying my invention, it is not nearly as necessary. In fact, I have found that lamps in accordance with the invention may be seasoned to an operating voltage of less than 8.0 volts on the average by operating with arc current for approximately 1 minute and without any other treatment. However, with such a short seasoning time, the cathodes are not always sufficiently activated to provide reliable dimming throughout the range of the lamp. For completely reliable dimming and starting, I prefer a schedule consisting of operation with arc current for approximately 5 minutes followed by seasoning consisting of cathode heating to 1300° without arc current for a period of approximately 1.5 minutes.

Titanium at room temperature appears to be able to absorb as much as 5 micron-liters per milligram and maintain the hydrogen pressure surrounding the metal below 10⁻² micron of mercury. A micron-liter per milligram is defined as 1 liter of gas at a pressure of 1 micron being adsorbed into 1 milligram of metal. I have found that the anode which has been described, namely, a strip 12 mil thick, 6 millimeters wide and 11 millimeters long is more than adequate as regards absorption capacity for the lamp described. However, since the titanium strip in its operation as an anode becomes heated by the discharge, its dimensions must be correlated to the arc intensity to achieve at the hottest point an operating temperature above 700° C. in order to absorb gases such as nitrogen and carbon dioxide, but having sufficient cooler portions under 700° C. from which hydrogen will not be evolved. A temperature in the neighborhood of 800° C. for the hottest point has been found satisfactory. On the other hand, I found that a titanium anode of the same dimensions, but having a thickness of 5 mils does not have as good gettering ability as that having a thickness of 12 mils. This may be due in part to excessive contamination of the thinner strip as a result of the additional rolling and milling required. Even though such thin anodes are subsequently outgassed, and adsorbed surface gases, such as nitrogen and oxygen driven to the interior, there is greater relative contamination volume-wise for equal surface contamination. In testing lamps made with the thinner titanium anodes, it has been found that the operating voltage averages approximately 0.5 volt higher than with lamps having 12 mil thick titanium anodes.

In order to achieve the lowest possible operating voltage with the lamp which has been described, the gap G between the activated end of the cathode to which the negative potential is applied and the nearest edge of the anode is greater than 2 millimeters and less than 5 millimeters in accordance with the teachings of the aforementioned Lemmers patent. In the illustrated embodiment, the gap is approximately 3 millimeters. In the operation of the lamp, lead 6 is connected to the negative terminal 13 of a suitable voltage source, such as a 12-volt storage battery, and lead 8 to the anode is connected through a ballasting resistance 14 to the positive terminal 15. Switch 16 permits connecting the filament in shunt with the discharge path at starting whereby to achieve preheating of the cathode. The close spacing of the anode and cathode results in ready starting of a glow discharge upon opening of switch 16, this discharge occurring between the anode and the point on the cathode or filament at which the cathode spot appears. The cathode spot forms at the most negative point having substantially the electron emissivity of the rest of the cathode. This point occurs in the turn adjacent lead wire 6, so that the discharge is formed across the gap G. For the lamp which has been described, ballast 14 may have a resistance of about 10 ohms.

Comparison of substantial lots of RP12 type lamps having titanium anodes in accordance with the invention with prior art lamps having molybdenum anodes under equivalent seasoning conditions shows that the improved lamps average as much as 15 percent lower arc voltage. For instance, with a seasoning schedule consisting of

operation with cathode current alone for 1 minute and then operation with arc current for 1 minute, the improved lamps develop an arc voltage of 7.5 volts, whereas the prior art lamps develop an arc voltage of 9.1 volts. By increasing the seasoning schedule with the prior art lamps to operation with cathode current for 3 minutes and then with arc current for 3 minutes, the arc voltage drops to 8.5 volts. To achieve a further lowering of the arc voltage with the prior art lamps is not feasible under practicable factory processes. Thus, the improved lamps in accordance with the invention provide a definite advantage in ease of manufacture and leave a much wider margin of tolerance in respect of the design specifications which, for the 3-watt RP12 lamp, are a maximum arc voltage of 9 and a starting voltage of 12 volts.

Over and above the improvements which have been noted above, and which are ascribable in part to the gettering action of the titanium, it has been found that the operating voltage with the titanium anode lamps may be made lower than that which may be achieved with prior art lamps, even under optimum processing. For instance, titanium anode lamps have been made having operating voltages as low as 6.5 volts, whereas with prior art molybdenum anode lamps the operating voltage can only with great difficulty be made as low as 8 volts. As regards maintenance, that is, the extent to which initial luminous output is maintained throughout life, the titanium anode lamps show measurable superiority.

By using different gas mixtures and filling pressures in RP12 type lamps with titanium anodes in accordance with the invention, it is possible to achieve remarkably low operating voltages. Thus, for instance, a group of lamps similar to that of Fig. 1 but using, for the starting gas, xenon at 3.5 millimeters had an average operating voltage of 5.0 volts. The spread in operating voltage as between 12 lamps which were made and tested was from 4.0 to 5.8 volts. Some of these lamps would be operable on 6 volts, thereby indicating feasibility of use on regular 6-volt automobile systems.

The excess in the lowering of operating voltage with titanium anodes over and above that due to the gettering action of the titanium is not perfectly understood. The observed phenomenon may be explained on the basis of the following theory which, it is to be clearly understood, is offered as a probable explanation only. Referring to Fig. 3, the curve therein is plotted with cathode-to-anode distance as abscissa and potential as ordinate. The abscissa or x-axis scale has been grossly exaggerated and the whole curve is intended as qualitative only and not as quantitative.

Considering the cathode proper as being at zero reference potential, there occurs firstly over the region A a negative potential fall corresponding to ϕ_C , the work function of the cathode. It will be appreciated that the distance A is atomic in dimensions, corresponding to the range of the interplay of forces between the atoms in the metal and the electrons issuing therefrom.

Over the next region B, there occurs a positive fall in potential generally known as the cathode fall and denoted by V_C . In this region, a relatively high positive fall is required to accelerate the electrons through the negative space charge surrounding the cathode. The electrons are accelerated sufficiently that a substantial proportion acquires energy in excess of 10.4 electron volts, the ionizing potential of mercury vapor, thereby producing ionizing collisions with resultant generation of resonance radiation. In the next region C, there is a negative potential fall denoted by V_F and corresponding to the Faraday dark space.

In the next region D, there occurs the anode fall V_A which may be either positive or negative, depending upon whether the electrons must be accelerated or decelerated in order to reach the anode in the required numbers to sustain the discharge phenomenon. In most discharge lamps where the size of the anode is much less than the

cross section of the discharge column, electrons must be accelerated in order to reach the anode in sufficient quantities and the anode fall is positive. In the instant case, indications are that the anode fall is negative and it has been so shown in the curve of Fig. 2. The sign of the anode fall appears also to bear some relation to the electron emissivity or work function of the anode.

In the last region E, which like region A is atomic in dimensions, there occurs a positive potential fall denoted ϕ_A and corresponding to the work function of the anode. It will be observed that ϕ_C , the voltage drop corresponding to the work function of the cathode, and ϕ_A , the voltage drop corresponding to the work function of the anode, tend to cancel each other and will effect cancellation when they are equal. This aspect of the discharge phenomenon may also be explained on the contact potential theory whereby a positive external potential gradient appears between the metal of lower work function and that of higher work function. The positive fall due to the work function of the anode thus adds to the other potential falls within the discharge space in determining the total potential that must be applied by the external circuit in order to maintain the given discharge condition. The practical conclusion is that lowering the work function of the anode reduces the voltage V_S which must be applied by the external circuit in order to maintain the discharge.

Applying the above theoretical considerations to the instant lamp, the work function of titanium as determined by the contact method is 4.14 volts, whereas that of molybdenum is 4.48 volts. On the basis merely of the work function of the pure metal, it will thus be seen that a decrease in anode work function of 0.34 volt may be expected. However, probably the effective work function is not that of the pure metal, that is, of titanium, but that of a coating of an activating substance on the titanium serving as a base metal. Such coating may consist of a molecular layer of barium vaporized from the cathode and deposited on the anode. Possibly the difference in work function of such a layer when deposited on titanium as compared with a similar layer deposited on molybdenum is even greater than the difference in work functions of pure titanium and molybdenum.

Referring to Fig. 2, there is shown another single-ended cathode glow fluorescent lamp embodying the invention and corresponding to the lamp designated commercially 2W-T6. This lamp likewise finds application as a source of ultra-violet radiation or black light suitable for use with fluorescent instrument panels. The lamp comprises a generally tubular envelope 21 coated internally with a fluorescent material 22 responsive to the 2537 Å. resonance radiation of mercury and producing radiation in the long ultraviolet spectrum. The lamp is of the single-ended type having a conventional stem 23 sealed peripherally at 24 to the lower end of the bulb, and including an exhaust tube 25 through which the lamp is exhausted in the usual fashion. The cathode 26 is a triple-coiled tungsten filament coated with an electron-emissive material such as a mixture of barium and strontium oxides. It is supported above the stem press 27 on lead wires 28, 29 sealed therethrough and extending downwardly through the stem. In accordance with the invention the anode is made of titanium metal. It is here formed as a ring 31 supported on the upper end of lead wire 32 sealed through the press, and is symmetrically located relative to the cathode in a plane transverse to the longitudinal axis of the lamp and intermediate the filament and the upper end of the press. The ionizable filling within the lamp comprises a small quantity of mercury and an inert gas at a pressure of a few millimeters of mercury, for instance, argon at a pressure of approximately 4 millimeters.

The prior art lamps corresponding to Fig. 2 and designated commercially 2W-T6 have a nominal rating of 2 watts and an operating voltage specification of 11.5 volts

maximum. These lamps have a sealing length of approximately $1\frac{1}{8}$ inches and a bulb diameter of approximately $\frac{3}{4}$ inch. The substitution of titanium for molybdenum as the anode material has resulted in a decided reduction in the criticality of the seasoning schedule, and also in a reduction of the average operating voltage by approximately 1 volt.

While certain specific embodiments of the invention have been illustrated and described in detail, these are intended as illustrative and not as limitative of the invention. Obviously, the invention is applicable to lamps and discharge devices differing widely in shape, size and ratings from those which have been considered herein, and the necessary modifications will readily be seen upon applying the principles which have been elucidated herein. The appended claims are intended to cover any such modifications coming within the true spirit and scope of the invention.

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

1. A low voltage gaseous electric discharge device of the cathode glow type having an operating voltage of the order of magnitude of the ionizing potential of the ionizable medium utilized within it, comprising an envelope filled with said ionizable medium and having sealed therein a thermionic filamentary activated cathode, and an anode consisting essentially of titanium metal located in close proximity to the cathode.

2. A gaseous electric discharge device having an operating voltage of the order of magnitude of the ionizing potential of mercury comprising an envelope having an ionizable medium therein comprising an inert starting gas at a low pressure and a small quantity of mercury, a thermionic filamentary activated cathode sealed within said envelope, and an anode sealed within said envelope and located in proximity to said cathode and consisting essentially of titanium metal.

3. An electric discharge device having an operating voltage of the order of magnitude of the ionizing potential of mercury comprising an envelope having an ionizable medium therein comprising an inert starting gas at a pressure of a few millimeters and a small quantity of mercury, a thermionic filamentary cathode activated with alkaline-earth oxides sealed within said envelope, and an anode sealed within said envelope and located in proximity to said cathode and consisting essentially of titanium metal.

4. A gaseous electric discharge device of the low pressure cathode glow type having an operating voltage in the neighborhood of the ionizing potential of mercury, comprising a sealed envelope containing an ionizable gaseous medium including an inert starting gas at a pressure of a few millimeters and a small quantity of mercury, a pair of lead wires extending into said envelope and supporting on their ends a thermionic filamentary cathode coated with oxides of alkaline-earth metals, and another lead wire extending into said envelope and supporting on its end a strip of titanium metal disposed to curve around said filamentary cathode in close proximity thereto.

5. A gaseous electric discharge device of the low pres-

sure cathode glow type having an operating voltage in the neighborhood of the ionizing potential of mercury, comprising a sealed envelope containing an ionizable gaseous medium including an inert starting gas at a pressure of a few millimeters and a small quantity of mercury, a pair of lead wires extending into said envelope and supporting on their ends a thermionic filamentary cathode coated with oxides of alkaline-earth metals, and another lead wire extending into said envelope and supporting on its end a strip of titanium metal disposed to curve around said cathode in close proximity thereto and spaced from the negative end of said cathode a distance greater than two but less than five millimeters.

6. A miniature fluorescent lamp of the low pressure cathode glow type having an operating voltage in the neighborhood of the ionizing potential of mercury, comprising a sealed vitreous envelope coated internally with a phosphor and containing an ionizable gaseous medium comprising an inert starting gas at a pressure of a few millimeters and a small quantity of mercury, a thermionic filamentary cathode coated with alkaline-earth oxides sealed within said envelope, and an anode of titanium metal sealed within said envelope and located in close proximity to said cathode.

7. A miniature fluorescent lamp of the low pressure cathode glow type having an operating voltage in the neighborhood of the ionizing potential of mercury, comprising a sealed vitreous envelope coated internally with a phosphor and containing an ionizable gaseous medium comprising an inert starting gas at a pressure of a few millimeters and a small quantity of mercury, a thermionic filamentary cathode coated with alkaline-earth oxides sealed within said envelope, and an anode of titanium metal sealed within said envelope and located in close proximity to said cathode and proportioned to attain in normal operation a temperature at the hottest point between 700 and 1000° C. and with cooler portions below 700° C.

8. A miniature fluorescent lamp of the low pressure cathode glow type having an operating voltage less than 9 volts and a rating of a few watts comprising a sealed single-ended vitreous envelope coated internally with a phosphor and containing an ionizable gaseous medium comprising argon at a pressure of a few millimeters and a small quantity of mercury, a thermionic filamentary cathode coated with alkaline-earth oxides sealed within said envelope, and an anode of titanium metal sealed within said envelope and consisting of a strip disposed to curve around said cathode in close proximity thereto and proportioned in size to attain in normal operation a temperature between 700 and 1000° C. at the hottest point.

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