Dec. 21, 1937. G. E. INMAN 2,103,033

ELECTRON EMISSIVE ELECTRODE

Filed Aug. 10, 1934

Fig. 4.

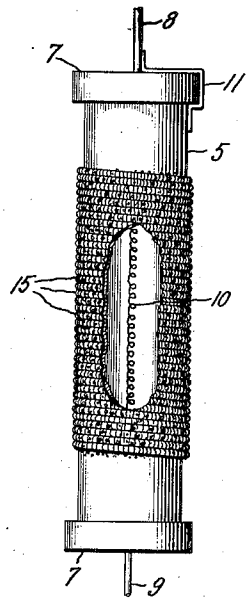


Fig. 1.

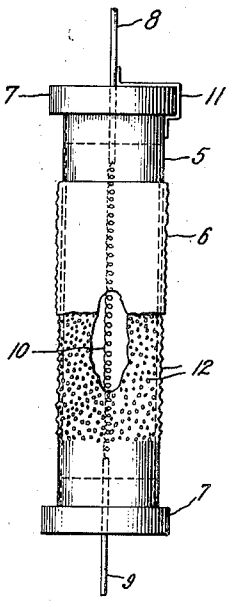


Fig. 2.

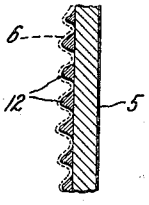
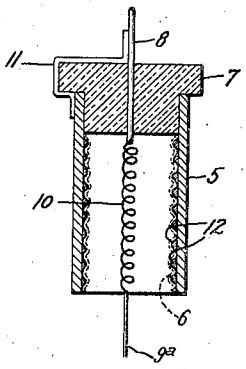


Fig. 3.



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UNITED STATES PATENT OFFICE

2,103,033

ELECTRON EMISSIVE ELECTRODE

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Application August 10, 1934, Serial No. 739,270

2 Claims. (Cl. 250—27.5)

My invention relates to electrodes suitable for gas or vapor electric discharge devices, and especially electron-emissive electrodes. Such electrodes of the unipotential type, in particular, have at their active surfaces material which emits electrons freely when heated, such as barium oxide or other suitable oxide; but after operation for some time this material may suffer serious loss of emissive power,—at least for a time,—as if it were progressively poisoned by something in the device. Such electrodes also "sputter" under the ionic impact of the electric discharge; and this discolors or blackens the envelope or bulb of the device. Blackening may also result from slight vaporization of electrode material by long use at high temperature. Loss of emissive power and sputtering have proved very objectionable in glow discharge devices used as lamps—referring especially to vapor lamps of the so-called "positive column low-pressure" or "cathodic glow" type that contain a vaporizable metal like sodium, cadmium, or mercury, and operate with very small (absolute) vapor pressure of the metal,—usually about 1 or 2 micron in the case of sodium and 1 or 2 mm. in the case of mercury. Such lamps may also contain a small amount of easily ionized gas like neon, argon, etc., whose partial pressure in the lamp is around 1 or 2 to 7 mm., to assist in starting the sodium or other vapor discharge. In devices operating on alternating current, the co-operating electrodes act alternately as cathodes and as anodes, and are both commonly called "cathodes."

I have found that the loss of emissive power above referred to can be practically prevented by providing the electrodes with much more emissive oxide or the like than heretofore, and that electrode sputtering and evaporation can be minimized by employing a metal such as tungsten or molybdenum in the electrodes, to receive the ionic impact. My invention permits of combining such use of tungsten metal in the electrode with a very liberal provision of emissive material, as well as of using one of these improvements without the other. Various other features and advantages of the invention will appear from the following description of species thereof, and from the drawing.

In the drawing, Fig. 1 is a side view of one form of electrode or cathode embodying the invention, on an enlarged scale, with a portion broken out, and with part of the electron-emissive coating removed; Fig. 2 is a fragmentary sectional view of part of the electrode base shown in Fig. 1, with its electron-emissive coating or surfacing, on a still larger scale; Fig. 3 shows an axial section through a different type of electrode from the one shown in Figs. 1 and 2; and Fig. 4 is a view similar to Fig. 1 illustrating a somewhat different construction.

The electrode shown in Fig. 1 is of the indirectly heated unipotential type such as known in the art. It comprises a base shown as a conductive (metal) tube 5, with an external coating or surfacing of electron-emissive material 6, such as barium oxide,—very usually containing an admixture of strontium oxide. For example, equal parts of barium and strontium oxides (by weight) may be used. Sometimes the base 5 is externally etched, in order that the slight roughness thus produced may make the material 6 stick better. In the ends of the tube 5 are externally shouldered plugs 7, 7, of refractory (insulative) material, such as lava. The plugs 7, 7 are centrally bored, and in the holes are (nickel) lead wires 8, 9. Inside the tube 5 is an (axial) heating resistance 10, such as a finely coiled tungsten filament, electrically connected between the leads 8, 9. The tubular base 5 is electrically connected to the lead 8 by a (nickel) strip 11. At present, nickel or the like is generally preferred as the material for the entire (tubular) base 5, because nickel seems to maintain active electron emission better than other materials, e. g., there is an alloy of nickel and cobalt known as "konel" that has similar properties, and is sometimes used instead of nickel alone. It has been suggested that some sort of interaction occurs between such nickel metal (nickel or the like) and the emissive oxide; and this seems plausible, because contact or direct proximity between them appears necessary to the favorable effect of the nickel metal.

In a lamp, a pair of such electrodes are used; and the lead 8 of each is connected to a current supply lead (not shown) of the lamp, and their leads 9, 9 may be interconnected by a refractory (molybdenum) lead (not shown), so that their heating resistances 10, 10 are in series with one another and in parallel with the discharge between the electrodes.

As thus far described, the device and its construction are no part of my present invention. They have been described in detail for purposes of illustration, and as a background for the explanation of my invention. They may, of course, be widely varied in practice, or even radically changed.

To receive and resist the ionic impact with a minimum of sputtering, I employ tungsten metal (tungsten or molybdenum) in the electrode. It

is not necessary, however, to make the electrode base 5 entirely of such tungsten metal, which would be both difficult and expensive: on the contrary, an overlay 12 of tungsten or molybdenum on a base 5 of other suitable (conductive) material will suffice. There are special advantages in an open, pervious overlay of tungsten metal on a base of metal which tends to maintain electron emission from the oxide,—even though such metal be subject to sputtering,—like nickel metal.

To increase the amount of emissive material on the electrode, I increase the effective surface of the electrode base 5 to afford a greater area for the material to adhere to. One way of doing this is to make the base 5 not merely rough enough to hold the emissive material 6 better, like an etched surface, but irregular or "scabrous" (with projections and hollows of some magnitude in comparison with the emissive particles, however tiny considered by themselves) to such a degree that the applied coat or surfacing of emissive material will adhere to the surface of the inequalities. In this way, more emissive material 6 will adhere than to a plain or etched surface—whether the emissive material merely follows and reproduces all the inequalities of the surface, like a very light snow on an old, worn cobblestone pavement, or whether it masks and obliterates the inequalities, like a deep snow.

The measures just set forth can readily be combined in a tungsten metal overlay 12 of suitable character. One such type of overlay 12 can be produced by applying coarse tungsten powder (e. g., between 50 and 60 mesh per in., more or less) rather sparingly to a nickel metal base 5, and heating or "baking" it on in an atmosphere of hydrogen at a temperature of about 1200° C. To make the tungsten particles adhere more firmly to the base 5, a small amount (such as some ten per cent, more or less) of nickel oxide powder (NiO) is preferably mixed with a liquid such as amyl acetate, and this mixture painted or sprayed on the base 5. A small amount of binding material such as nitrocellulose may be added to the amyl acetate before mixing the nickel oxide therewith. While the coating or amyl acetate with nickel oxide is still damp on the base 5, the tungsten powder is sprayed or dusted on. Commercial tungstic acid powder (WO_3) may be used instead of nickel oxide, in similar amount and in a similar way. Either of these oxides is reduced by the hydrogen, and the liberated metal seems to "cement" the coarse grains of tungsten powder to the base 5. (Such cementing oxides must not be confused with the electron-emissive oxide which is afterward applied to the base.) At 1200° C., the vapor tension of nickel in the furnace is quite appreciable, and the tungsten particles or grains "solder" or "sinter" to the nickel metal so that they do not easily rub loose. Or using tungsten powder alone, it may be mixed with a weak solution of a temporary binder (such as nitrocellulose in amyl acetate, for example) and painted on the base 5. I prefer not to apply enough material to form a continuous, coherent coating, nor even enough to conceal the surface of the nickel metal with a single layer of grains touching one another like the pebbles in a pebble-dash stucco, but rather to have a "sprinkling" of grains 12 slightly separated, as suggested in Figs. 1 and 2. Molybdenum powder (with or without MoO_3 or NiO) can be applied in similar ways with like results.

Thus the base 5 is "toothed" and rendered scabrous with the attached tiny tungsten metal particles 12 projecting from the nickel metal surface, which remains exposed and visible amongst them. Necessarily, the size of the projections 12 is exaggerated in Figs. 1 and 2, in order to make them clearly visible.

I prefer to coat the scabrous base 5 with emissive oxides 6 by applying carbonates or hydrides and afterward converting them to oxides. For this purpose, powdered barium carbonate (alone or with admixture of strontium carbonate) may be mixed with a weak solution of a temporary binder (such as nitrocellulose in amyl acetate) and sprayed on the base 5. The carbonate may be broken down to oxide by heating the electrodes sufficiently in exhausting the device in which they are used, which can be done by overheating the electrode-heating filaments 10 and overrunning the device with an abnormally high glow discharge current. The depth or thickness of the emissive coating 6 may vary considerably; but I prefer an oxide surfacing like that shown in Fig. 2, which is so thin as to adhere in the hollows and inequalities of the base 5 without filling them up or masking the projections 12 formed by the tungsten metal particles, rather than a heavier coating such as suggested in Fig. 1, which masks and equalizes the projections and the hollows.

Fig. 3 shows an electrode of indirectly heated unipotential type and of another already known form. It is open at one end and has its electron-emissive material 6 inside, instead of outside as in Fig. 1. It has a comparatively short base tube 5 (of nickel metal) with a shouldered refractory (insulative) plug 7, of lava, for example, in one end only, and a (nickel) current lead 8 in the central bore of the plug 7 connected to one end of the (axial) helically coiled tungsten heating filament 10 inside the tube 5. To the other end of this heating resistance 10 is connected a (molybdenum) current lead 9*a*; and a (nickel) strip 11 connects lead 8 to tubular base 5.

A tungsten metal overlay 12 is shown on the inner surface of the base 5 instead of on its outer surface, but is otherwise similar to that shown in Figs. 1 and 2. It consists of a sprinkling of grains of coarse tungsten powder applied and affixed as already described, so that they do not entirely cover the nickel metal of the base 5. The surfacing of emissive material 6 is similar to that shown in Fig. 2, and may be similarly applied.

A sodium vapor lamp or other such glow discharge device equipped with electrodes such as shown in Figs. 1–3 and herein described will operate like one with ordinary electrodes; but the tungsten metal bears the brunt of ionic impacts with less sputtering than nickel metal, and the bulb of the device blackens less. Owing to the increased amount of emissive material that can adhere to the surface of the base 5 as augmented by the projections, the serious reduction in electron-emission above referred to does not occur during the useful life of the device. As the emissive material is gradually used up or leaves the electrodes during the life of the device in which they are used, it first exposes the outermost projecting points of tungsten metal: i. e., tungsten metal is left bare, rather than nickel metal, which would sputter, evaporate, and blacken the bulb of the device more quickly than tungsten metal. The bare tungsten metal points, moreover, provide useful anode surface. And while the nickel metal is protected and sputtering largely pre-

vented by the tungsten metal, yet the immediate presence of the nickel in close proximity to the emissive oxide—even in contact with the oxide between the tungsten metal particles, when the latter are separated as shown in Figs. 1 and 2—has the favorable effect already mentioned of maintaining active electron-emission from the oxide. There is also less vaporization of nickel in the heating to convert the carbonate to oxide during exhaust than with ordinary nickel-base electrodes, and hence less blackening of the bulb from this source. Afterward, in the operation of the device, the oxide gradually sinters a little, and even seems to impregnate the nickel metal where it is in contact with it. This renders the oxide surfacing as a whole stronger and more adhesive to the base.

To be effectively "scabrous" for my purpose, the base 5 need not be so harshly rough or sharp-toothed as with the affixed grains of tungsten metal 12 just described, inasmuch as more rounded tiny projections may give all the surface required for adhesion of ample amounts of emissive material. For example, the base 5 may have a multitude of parallel ridges 15, which may be rounded as in Fig. 4 to present a corduroy-like rimosity, and may themselves be also individually rimose, open, or foraminous. Such ridges 15 may be embodied in a tungsten overlay or superstructure preferably open between them to the underlying nickel metal, when the base 5 is nickel or the like. A simple way of doing this is to use for the wire-like round 15 wound on the base 5 a hollow open form such as a fine-wound coil or helix of tungsten metal wire of filamentary gauge. By winding this under sufficient tension to open its convolutions about as indicated by the curved lines in Fig. 4, a very large amount of interstitial surface can be provided within and between the tiny projections formed by the individual filament convolutions, in addition to the interstitial surface represented by the major corduroy rimosities. The tungsten metal winding 15 may be united to the metal base 5 by spot-welding in various places. Preferably, the emissive material will be applied sparingly to preserve the separateness of the corduroy ridges, and even to leave open the intervals amongst the outer portions of the filament convolutions, away from the nickel metal base 5. The amount of oxide in the foraminous superstructure can readily be controlled in spraying on the carbonate as described in connection with Figs. 1 and 2.

In the operation of a lamp equipped with the Fig. 4 electrodes just described, all the advantages of the Fig. 1 electrodes are fully and even more amply realized. In addition, there is more emissive material, and more tungsten metal, and the tungsten metal is better disposed to shield and protect the nickel metal from ionic impacts.

While the use of tungsten metal in the projections provided to increase the surface for carrying emissive material is preferred, it will be understood that other suitable metal might be used for the purpose,—and even nickel metal,—with a corresponding sacrifice of the special advantages of tungsten metal. Likewise, tungsten metal might be applied to an electrode base 5 so as to shield it from ionic impacts, more or less, without materially increasing its surface or the amount of electron-emissive material that it could carry.

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

1. A unipotential glow discharge electrode comprising a hollow nickel base scabrous with discrete tiny tungsten projections, a filamentary heater mounted in said base, and a thin surfacing on said base of electron-emissive oxide material adherent in the inequalities, the depth of said material being substantially uniform over the entire discharge supporting surface of said electrode.

2. A unipotential glow discharge electrode comprising a hollow nickel base toothed with discrete tungsten metal particles, and thus rendered scabrous, a filamentary heater mounted in said base and electron-emissive oxide material adherent in the inequalities of said base, the depth of said material being substantially uniform over the entire discharge supporting surface of said electrode.

GEORGE E. INMAN.