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THERMIONIC CATHODE FOR ELECTRIC DISCHARGE DEVICES

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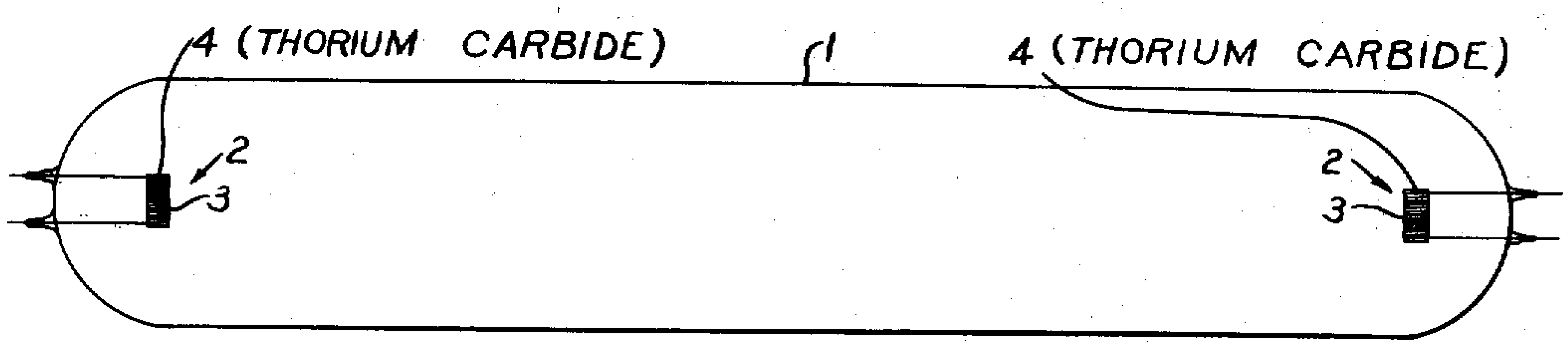

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THERMIONIC CATHODE FOR ELECTRIC DISCHARGE DEVICES

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1 Claim. (Cl. 313—346)

This invention relates to electric discharge devices comprising thermionic cathodes and to thermionic cathods for use in such devices.

According to one aspect of the invention, in an electric discharge device of the kind referred to the electron-emissive material of each said thermionic cathode consists wholly or mainly of thorium carbide.

According to another aspect of the invention a thermionic cathode for use in an electric discharge device of the kind referred to either consists of thorium carbide or includes thorium carbide as part or the whole of the electron-emissive material of the cathode.

Thermionic cathodes in accordance with the invention may be employed, for example, in various types of electric discharge lamps. Examples of particular types of lamps for which such cathodes are particularly suitable are high pressure metal vapor lamps (and especially such lamps whose envelopes contain a filling of mercury or of a mixture of mercury and one or more other metals such as cadmium, zinc or thallium) adapted to operate at a pressure of at least one atmosphere, and lamps having a filling of a rare gas such as xenon at a pressure of about one atmosphere when the lamp is cold.

In thermionic cathodes according to the invention, the electron-emissive material is usually supported by a body of refractory metal, preferably tungsten or tantalum. Thus, for a discharge lamp, the cathode may comprise a tungsten or tantalum sheet, wire helix, or rod, coated with thorium carbide, or a tungsten or tantalum wire helix, drilled rod, or sheet enclosure, containing a sintered pellet or rod of thorium carbide, or a block of tungsten or tantalum provided at one end with recesses containing thorium carbide. However, in some cases the cathode may consist only of a sintered pellet consisting wholly or mainly of thorium carbide, without any supporting metal body.

The coatings, rods or pellets of the emissive material may contain tungsten and/or tantalum in admixture with the thorium carbide, such addition of refractory metal being particularly desirable in the case of the form of electrode, last mentioned in the preceding paragraph, wherein the emissive material is not associated with a metal support. The emissive material may be prepared by sintering an intimate mixture of thorium powder and finely divided carbon in the proportions required to produce the thorium carbide, if desired with tungsten powder or tantalum powder.

We have found that the thorium carbide emissive material has a tendency to react with the metal support in some cases, especially when the latter consists of tantalum. Therefore in cathodes which include a metal support, this preferably consists of tungsen, or if it consists of tantalum the surface in contact with the thorium carbide material is advantageously coated with tungsten or tungsten carbide or carburised to form a surface layer of tantalum carbide, before the thorium carbide material is coated onto the support or otherwise brought into contact therewith.

In the preferred method of manufacturing the electron-emissive material for a cathode according to the invention, a mixture of thorium powder and finely divided carbon in the proportions within the range of 20:1 to 8:1 by weight, preferably of 232 parts by weight of thorium to 24 parts by weight of carbon, together with tungsten or tantalum powder if desired, is made into a paste with a solution of nitrocellulose in a volatile solvent. This paste may be applied as a coating, for example by painting, spraying or by electrophoresis, onto a sheet, wire helix, or rod of tungsten or tantalum or may be inserted into recesses within a block of tungsten or tantalum, and the whole cathode then heated to such a temperature that the solvent in the paste evaporates, the thorium and carbon combine to form thorium carbide, and the emissive material is sintered to form a coherent mass, the nitrocellulose functioning as a binder. A suitable sintering temperature is of the order of 1900° K. to 2000° K. Alternatively, the paste may be extruded to form a rod or pellet which is then heated as aforesaid, the sintered rod or pellet subsequently being inserted into a tungsten or tantalum wire helix, drilled rod or sheet enclosure to complete the formation of a cathode, or being employed alone as a cathode without any metal support.

While the most convenient method of preparing the emissive material is usually that, described above, which comprises heating thorium and carbon together so that the thorium carbide is formed in situ, in some cases, if desired, thorium carbide may be coated directly onto the metal support or inserted into recesses in the supporting metal body.

The advantageous properties of a cathode according to the invention may be illustrated by comparison with those of certain known types of thermionic cathodes, considering the data relating to the emission of the various types of cathodes in vacuo. The amount of the electron emission in vacuo from any thermionic cathode may be specified by means of the constants A and ϕ in the well-known Richardson equation for thermionic emission:

$$I=AT^2e^{-\phi/kT}$$

where I is the emission in amps./cm.^{2}, T is the temperature of the cathode in degrees K, and k is Boltzmann's constant. For cathodes in which the emissive material is thorium carbide, the work function ϕ is of the order of 3.4 electron volts, and values of A between 1500 and 2500 are obtained. Thus, a D.C. emission of about 2 amps./cm.^{2} can be obtained when the cathodes are run at a temperature of 1800° K., and this emission is maintained in general for several thousand hours.

For cathodes utilizing thorium as the emissive material, the constant ϕ is of the same order, and initially the constant A and the emission are substantially the same, as in the case of cathodes in which the emissive material is thorium carbide, but the value of A drops rapidly to about 60–70 and the emission falls off considerably within about 10 hours. The considerably longer effective life of the cathodes in accordance with the invention is due firstly to the fact that with these cathodes there is much less evaporation of the emissive material than with cathodes utilizing thorium as the emissive material, and secondly to the fact that the melting point of thorium carbide is high compared with that of thorium so that thorium carbide retains its rough texture and high effective area better than thorium.

Thermionic cathodes using thorium oxide as the emissive material are also known, and for these the values of the work function ϕ and the constant A in the Richardson equation are of the order of $\phi=2.6$ electron volts and $A=3$. For such cathodes, the emission at the lower end of the range of suitable operating temperatures is of the same order as that of the cathodes according to the invention, but at the upper end of the range the emission is substantially lower than for the cathodes according to the invention. For example, for cathodes using thorium oxide as the emissive material, a D.C. emission of 0.5 amp./cm.^{2} can be obtained at an operating temperature of 1800° K., being maintained for several thousands of hours.

It will be appreciated that the data cited above are only applicable for emission taking place in vacuo and that the conditions in a gas discharge device such as a lamp are somewhat different, since the emission of any emissive material may be effectively considerably greater in a gas than in a vacuum. However, the above figures will serve also as a basis for comparison as far as gas discharge devices are concerned, since materials with high thermionic emission can in general be operated at higher current density under gas discharge conditions than materials with low thermionic emission.

One form of thermionic cathode in accordance with the invention, and a particular discharge device in accordance with the invention incorporating two such cathodes, will now be described by way of example in connection with the drawing wherein the single figure is an elevation of such a device.

The discharge device is a high pressure mercury vapor lamp for alternating current operation, adapted to develop a pressure of about one atmosphere in operation and to dissipate about 400 watts at a current of 3 amperes. The lamp is of tubular form, having a glass envelope 1 of 34 millimeters diameter and having an arc length of 160 millimeters between the two electrodes 2, 2 which are identical in form.

Each electrode 2 consists of a helix 3 of tungsten wire 0.4 millimeter in diameter, wound to 125% pitch on a 3 millimeter mandrel and consisting of 14 turns of wire, and within the helix and fitting closely thereto a preformed rod 4 of thorium carbide. The thorium carbide rod 4 is prepared by extruding a paste consisting of thorium powder and finely divided carbon, in the proportions of 232 parts and 24 parts by weight respectively, and nitrocellulose dissolved in a volatile solvent, and heating the extruded rod in vacuo at a temperature of 1900° K. to 2000° K. The electrodes 2 are disposed within the lamp envelope 1 in such a position that the axis of each helix lies at right angles to the axis of the discharge.

An additional advantage of thermionic cathodes comprising thorium carbide as the emissive material lies in the fact that they are resistant to oxidation and therefore may be used in demountable discharge devices without the necessity of replacing the cathode each time the device is opened to atmospheric pressure.

While the most convenient method of preparing the emissive material is usually that described above, which comprises sintering thorium and carbon together so that the thorium carbide is formed in situ on a metal support, in some cases, if desired, preformed thorium carbide may be coated directly onto the metal support or inserted into one or more recesses in the supporting metal body, the cathode then being heated to sinter the thorium carbide coating onto the support. When preformed thorium carbide is used, either with or without a support, it is advantageous to mix a small proportion, for example 5% to 10% by weight, of a powdered refractory metal, such as tungsten and/or tantalum with the thorium carbide: the presence of the refractory metal facilitates the sintering and results in the formation of a more coherent product, while the small proportion mentioned does not cause any objectionable degree of decomposition of the thorium carbide or detract appreciably from its electron emissive properties.

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

An electric discharge device comprising thermionic cathodes including electron-emissive material, consisting mainly of thorium carbide, carried on a tantalum support having on the surface in contact with the thorium carbide material a protective coating composed of a member of the group consisting of tungsten, tungsten carbide and tantalum carbide.

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