# United States Patent [19]

**Kauer et al.**

[11] **3,868,159**

[45] **Feb. 25, 1975**


[54] **METHOD OF MANUFACTURING AN ELECTRIC INCANDESCENT LAMP HAVING A LONGER LIFETIME AND/OR A HIGHER LIGHT OUTPUT**


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[21] Appl. No.: **369,552**

[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** ..... **316/1,** 29/25.17

[51] **Int. Cl.** ..... **H01j 9/00**

[58] **Field of Search** ..... 316/1, 3, 15, 17, 18, 19, 316/20; 29/25.17, 25.18



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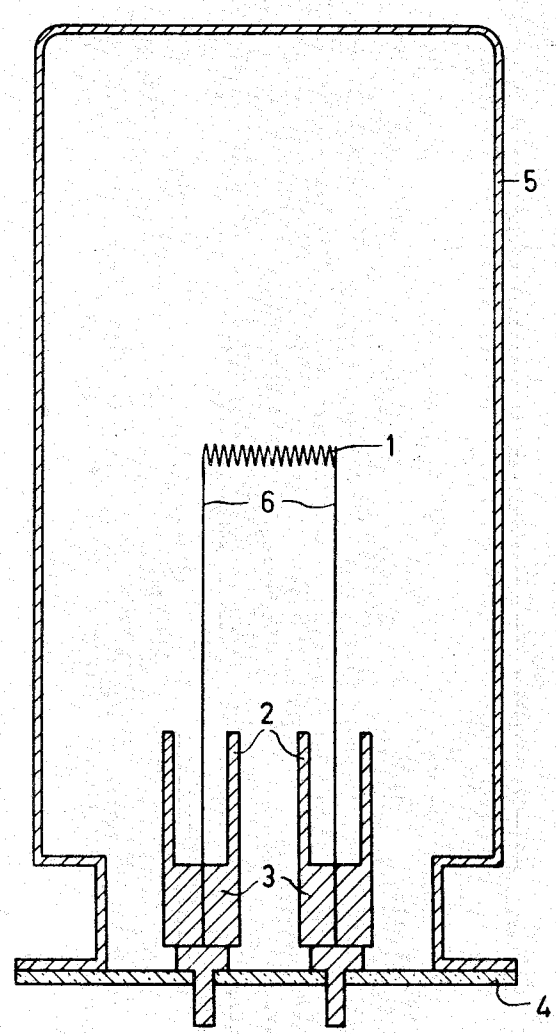
[57] **ABSTRACT**

The invention relates to a method of manufacturing a gas-filled electric incandescent lamp particularly a low-voltage incandescent lamp in which the wire diameter of the incandescent civil varies in different axial sections. The diameter of the tungsten wire is reduced at the end turns and is increased in the middle with the aid of a chemical cycle process either before or after mounting in the lamp in order to reduce the temperature differences between the turns in the middle and at the end of the coil during operation of the lamp at the prescribed operating voltage.


**7 Claims, 3 Drawing Figures**



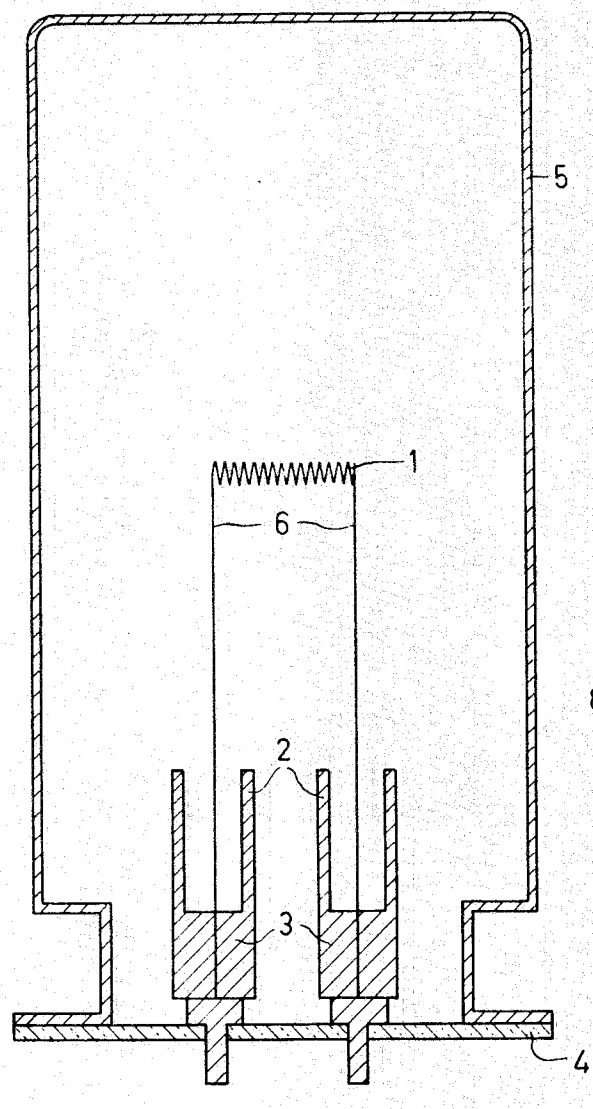



Fig. 1

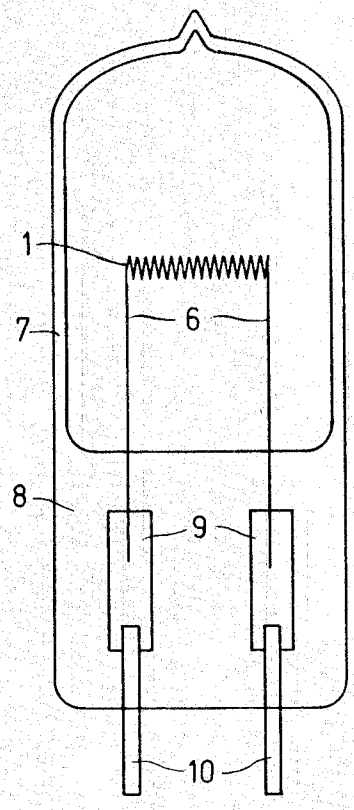



Fig. 2

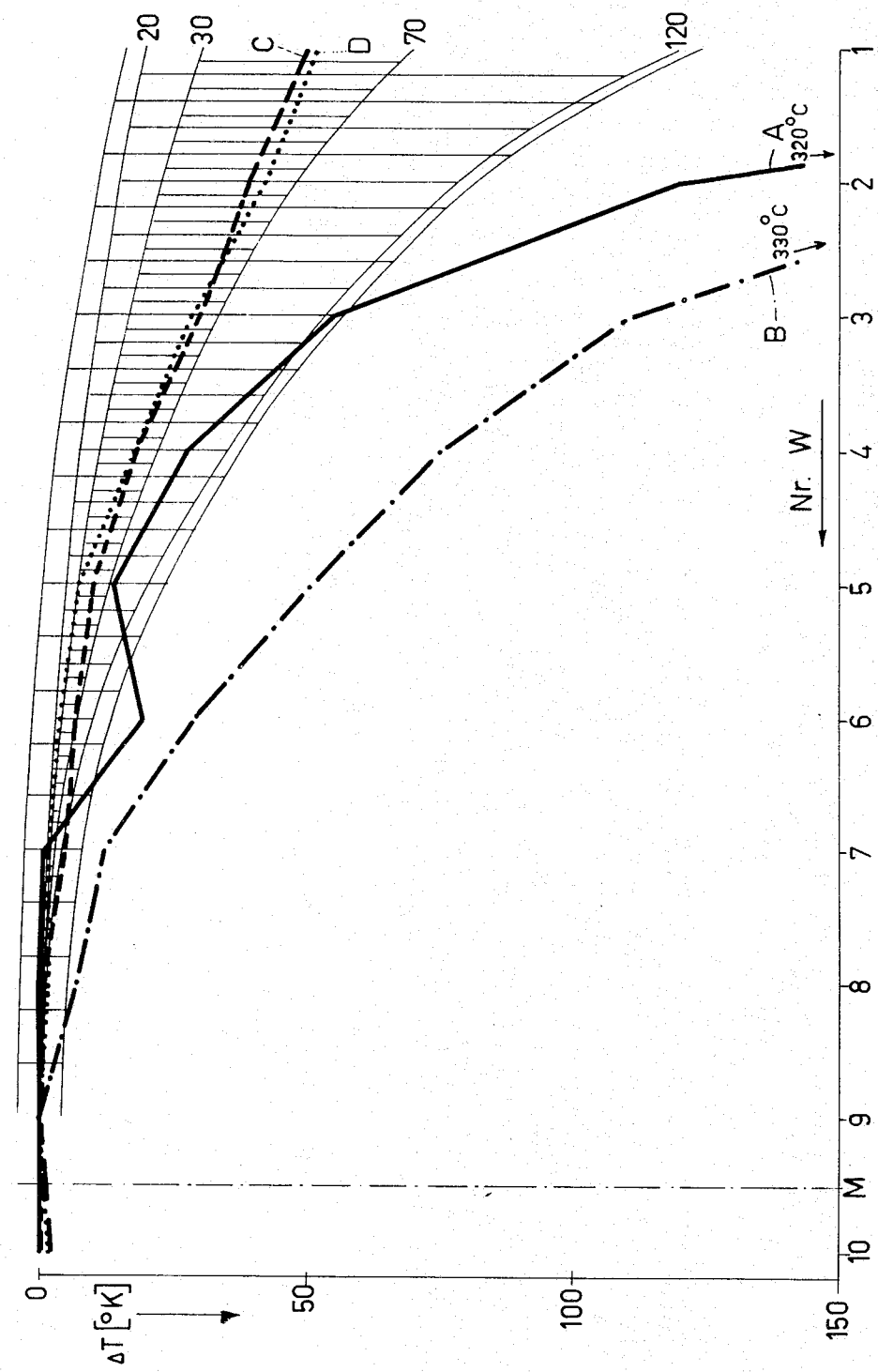



Fig. 3

# METHOD OF MANUFACTURING AN ELECTRIC INCANDESCENT LAMP HAVING A LONGER LIFETIME AND/OR A HIGHER LIGHT OUTPUT

Low-voltage lamps are in this connection to be understood especially heavy-loaded electric incandescent lamps whose operating voltage is generally below 42 V. Examples of such lamps are many types of projection lamps, motorcar lamps, etc. in which a high luminance is important. The lamps may comprise a reactive transport gas such as iodine and bromine and bromine compounds such as hydrocarbonbromides, hydrobromic acid, boronbromide, etc. These lamps generally have a coiled filament which consists of a comparatively low number of turns. By removal of heat through the ends of the coiled filament the temperature of the end turns may be several hundred °C lower than the temperature of the turns in the middle of the coiled filament. Consequently the luminance along the coiled filament is not constant for which reason in projection lamps sometimes only the light emitted by the central turns is used in order to obtain an optimum uniform light intensity on the image surface. It has already been attempted to equalize the luminance distribution along the coiled filament by pre-operation in a halogen-containing gas atmosphere. It was always the aim in such methods of pretreatment to reach a full temperature homogeneization along the filament.

However, in practice, such pre-operation treatments did not find general acceptance. This is caused presumably by the fact that such pre-treatments led to considerably shorter lifetimes.

An object of the invention is to provide a method of manufacturing an electric incandescent lamp, particularly a low-voltage incandescent lamp having a longer lifetime and/or a higher luminance which is as uniform as possible. According to the invention this goal is achieved by a method in which the filament is pre-operated until the temperature $T_1$ of the end turns of the filament is 20° to 120°K lower than the temperature $T_2$ of the central turn in an atmosphere which comprises a gas which is reactive relative to tungsten.

The invention is based on the following recognitions obtained during experiments which led to the present invention. In the conventional low-voltage lamps the temperature of the end turns is often 200° to 400°K lower than the temperature in the middle of the filament. Such a coiled filament will burn through in the central hotter part of the filament. When the temperature along the filament body is completely equalized the filament burns through at one of the ends. An extension of the lifetime does not occur, on the contrary the lifetime is generally drastically shortened. Hitherto it has not been taken into account that at equal temperature the tungsten transport due to radial evaporation in the middle of the coiled filament is approximately 50 percent of the quantity of tungsten evaporating at the ends of the filament. This phenomena is presumably to be ascribed to the fact that in the middle of the coiled filament only that part of the filament turn projecting outwards contributes to the radial tungsten transport, whereas at the ends and particularly also at the transition to the non-coiled straight part the entire volume of the filament contributes to this transport.



It has been found that in case of a reduction of the temperature difference between the middle and the ends of the filament to less than 120°K an extension of the lifetime and an increase in the light output can be found. Temperature difference of less than 20°K do not, however, result in an extension of the lifetime. Temperature differences of between 30° and 70°K yield the greatest improvements. It was found that in gas-filled incandescent lamps having coiled tungsten filaments an axial transport of tungsten from turn to turn takes place during operation in addition to the already mentioned radial tungsten transport. In case of temperature differences of approximately 5°K between two juxtaposed turns this transport form turn to turn is already larger than the radial transport at a filament temperature of approxiimately 3000°K bringing about the loss of mass of the filament body. In filaments having comparatively short and thick wires such as are used in high-loaded low-voltage incandescent lamps the temperature from turn to turn decreases, however, by more than 5°K as a result of the strong heat dissipation through the supply conductors. By complete equalisation of the temperature of the coiled filament, this axial transport would not occur, but in such a case the radial transport from the end turns as described would result in a considerably shorter lifetime. It has been found that for the required temperature decrease in the direction of the two end turns of from 20° to 120°K particularly between 30° and 70°K, the radial tungsten losses of the end turns correspond to the total loss of the turn in the middle of the filament body, which loss is composed of radial and axial transport, so that in addition to a more uniform luminance at a constant temperature $T_2$ of the middle of the filament an increase in the light output and an extension of the lifetime $\tau$ are obtained. Furthermore it has been found that the largest extension of the lifetime is obtained when the mass losses of each individual turn between the middle and the ends of the filament likewise equals the loss of the central turn and hence that of the end turns because evidently the unfavourable formation of local differences in cross-section and in temperature (so-called "hot-spots") is counteracted thereby. Such mass losses which are uniform for all turns are achieved in the ideal case when the temperature variation $T(x)$ along the filament axis $x$ from the middle of the filament $X = O$ and the temperature $T_2$ to the ends of the filaments $x = L$ and the temperature $T_1$ satisfies the following equation:

$$T(x) = T_2 \left\{ 1 - \left[ 1 - \left( \frac{T_1}{T_2} \right)^{\gamma} \right] \frac{e^{x/a} - \left(1 + x/a\right)}{e^{1/a} - \left(1 + 1/a\right)} \right\}^{1/\gamma}$$

The exponent $\gamma$ is dependent on the temperature: $\gamma = 10{,}35.10^4.1/T$ in which for T the mean value between $T_1$ and $T_2$ can be assumed. For the temperature range of between approximately 2,800°K and 3,600°K $\gamma$ thus has a value of between **38** and **29** and in the temperature range about 3,300°K which is conventional for low-voltage lamps $\gamma$ may be adjusted at **32.** In the formula $a$ corresponds to the radius of the quasi-stationary layer of gas (Langmuir-layer) surrounding the filament. In the above-mentioned temperature range of between approximately 2,800°K and 3,600°K this radius may assume a value of between 1 and 4 mm. For the temperature range about 3,300°K the radius is approximately 2 mm.

The incandescent lamp according to the invention may be manufactured by pre-operating the lamp with the mounted filament body or by pre-operating the fila-

ment body prior to mounting, the filament body being in an atmosphere comprising fluorine or chlorine.

Fluorine is preferred. Only when using fluorine is it possible to preoperate the filament body at a temperature which can also be achieved later during operation at the operating voltage which has been found to be favourable in the experiments for adjusting a given temperature profile and hence a long lifetime. With fluorine at temperatures of the filament body of about 3,300°K which are conventionally used in the present-day high-loaded low-voltage incandescent lamps tungsten is transported from comparatively cold spots to hotter spots of the filament body. With chlorine this is only the case at temperatures of less than approximately 2,700°K. In addition the pretreatment with fluorine has technological advantages relative to a pretreatment with chlorine. When using chlorine all parts of the equipment coming in contact with the reaction gas must be maintained at a temperature of at least 200°C because at low temperatures the less volatile tungsten chlorides condense and hence are withdrawn from the reaction or may give rise to clogging of the gas ducts. When using fluorine these difficulties do not occur because all reaction products occurring in the treatment with fluorine are gaseous at room temperature. In addition the transport process in the presence of fluorine is considerably faster than in the presence of chlorine. Furthermore it has been found that already during a short pre-operation of only a few minutes in a fluorine-containing atmosphere the surface of the filament is smoothed and that also small temperature inhomogeneities are greatly reduced. This is not the case when pre-operating in a chlorine-containing atmosphere because for small temperature differences the tungsten transport from cold to hot proceeds so slowly that even for treatment periods of more than one hour no noticeable homogenization can be observed. By suitably choosing the partial pressures of fluorine and inert gas as well as of the time and the operating temperature the pre-operation in a fluorine containing atmosphere results in a profile of the temperature along the filament which lies in a region which is bounded by two curves obtained with the above-mentioned equation for which $T_1$ is 20° and 120°K lower than $T_2$ respectively. The temperature may, however, lie up to 4°K outside said region computed with said equation.

Fluorine may be introduced into the lamp as such or in the form of a compound. Suitable compounds, some of which are more easy to handle than fluorine, are, for example, tungsten hexafluoride ($WF_6$), tungsten oxyfluoride ($WOF_4$) nitrogen fluorides ($NF_3$, $N_2F_4$), fluorides of phosphorus and arsenic, sulphur hexafluoride ($SF_6$), oxygen fluoride ($OF_2$), selenium hexafluoride ($SeF_6$), tellerium hexafluoride ($TeF_6$), halogen fluorides, fluorides of rare gases such as, for example, xenon fluorides.

The partial pressure of these compounds is preferably chosen to be such that in case of a complete decomposition of the compound the partial pressure of fluorine at room temperature should be between approximately 0.1 and 20 Torr. Also when using fluorine the partial pressure is preferably chosen to be within these limits. In case of partial pressures of less than 0.1 Torr the required pre-operation time considerably increases and in case of partial pressures of more than 20 Torr the reactions proceed too vigorously and the process becomes uncontrollable.

The partial pressure of the inert gas is preferably between approximately 0.1 and 10 atmospheres. The pre-operating temperature must be approximately between 2,800° and 3,600°K. Under these circumstances the pre-operation time is approximately 1 minute to 20 minutes.

When pre-operating in a chlorine-containing atmosphere such a quantity of a volatile chlorine compound is preferably added to the gas atmosphere that in case of complete decomposition the partial pressure at room temperature of chlorine would be between 10 and 100 Torr. When using chlorine in an elemtary form the partial pressure is likewise chosen to be between these limits. The partial pressure of the inert gas is preferably between approximately 0.1 and 10 atmospheres. The pre-operation temperature must be approximately between 1,700° and 2,700°K. Under these circumstances the pre-operation period is approximately 10 to 100 minutes.

The lamps with a filament treated according to the invention may be filled with the conventional rare gases such as argon or krypton or may also comprise a chemical transport gas such as iodine or bromine or bromine compounds (HBr, Alkyl bromines or $BBr_3$).

The invention and its advantages relating to the lifetime and the light output will hereinafter be described in greater detail with reference to an example and the accompanying drawings.

FIG. 1 diagrammatically shows in a cross-section a pre-operation device

FIG. 2 shows a complete lamp having a preoperated filament and

FIG. 3 shows some curves which state the relation between the filament temperature and the number of turns in lamps treated in accordance with the invention and not treated in accordance with the invention.

## EXAMPLE

Tungsten filaments **1** were pre-operated in a pre-operation device diagrammatically shown in a cross-section in FIG. **1.** The device contained two nickel electrodes **3** provided with nickel tubes **2** which were secured to a base plate **4** of electrically non-conducting material, in which electrodes the filament ends **6** were inserted. The gas space was enclosed within an envelope **5** of nickel.

The filaments **1** had 18 turns. The wire thickness was 0.17 mm and the filament length was 5 mm. The straight wire ends **6** were protected from quick attack by fluorine over a length of approximately 5 mm by the nickel tubes **2** (inner diameter 2 mm). The envelope **5** comprised a gas mixture of argon (partial pressure 200 Torr) and nitrogen fluoride ($NF_3$) (partial pressure 3 Torr). The filaments were operated for 2 minutes at a temperature of approximately 3,450°K of the central turns. The filament thus pretreated were cut off at a length of the straight wire ends **6** of 10.5 mm and, as shown in FIG. **2,** provided in a quartz envelope. The lamp was provided with a pinched base **8** in which molybdenum foils **9** had been sealed which at one end were connected to the wire ends **6** and at the other end to current supply conductors **10.** The lamps were filled with a gas mixture of krypton (partial pressure 5 atm.) and methylenedibromide ($CH_2Br_2$) (partial pressure 13 Torr). In the same manner lamps having the same filaments which were, however, not pre-treated were manufactured for the purpose of comparison of the quality.

The curves A and B in FIG. 3 show temperature profiles (pertaining to one half of a filament each) of non-treated filaments. The curves C and D show temperature profiles of filaments treated in accordance with the invention (also pertaining to one half of a filament). The temperature profiles C and D satisfy the temperature requirements very good while the non pre-treated temperature profiles show a temperature profile deviating therefrom. In the Figure the reference N*r* W shows the number of the relevant turn, Δ T(°K) shows the temperature difference in °K and M shows the middle of the filament.

The resultant light-technical advantages of the lamps C and D having pre-treated filaments with respect to those having non pre-treated filaments A and B are apparent from the Table below in which the measured light values and the lifetimes of the four experimental lamps are stated. All lamps were examined at the same operating temperature $T_m$ (temperature of the middle of the filament). The electrical power N, the luminous flux I, the light output I/N, the temperature difference Δ T between the middle and the ends of the filament and the lifetime $\tau$ until the wire burnt through were measured. The measuring results are representative of many investigations.

TABLE

| Test lamp | $T_m$ in °K | N in Watt | I in lm | I/N | (°K) $T_2$-$T_1$ | $\tau$ in min |
|---|---|---|---|---|---|---|
| A | 3450 | 74.4 | 2270 | 30.5 | 320 | 3250 |
| B | 3450 | 74.5 | 2280 | 30.6 | 330 | 3420 |
| C | 3450 | 88.2 | 2840 | 32.2 | 50 | 10500 |
| D | 3450 | 88.1 | 2820 | 32.0 | 50 | 8000 |

The advantages obtained by the invention thus especially consist in that with the aid of comparatively simple steps an extension of the lifetime and a higher and more uniform luminance of gas-filled incandescent lamps can be obtained.

What is claimed is:

**1.** A method of manufacturing a gas-filled electric incandescent lamp, particularly a low-voltage incandescent lamp in which the wire diameter of the filament body consisting of a coiled tungsten wire varies in different axial sections of said coil, said diameter being reduced at the end turns and increased in the middle with the aid of a chemical cycle process either before or after mounting in the lamp so as to reduce the temperature differences between the turns in the middle and at the end of the filament during operation of the lamp at the prescribed operating voltage, said method comprises mounting said filament and in an atmosphere comprising a gas which is reactive with respect to tungsten and pre-operating said filament until the temperature $T_1$ of the end turns of the filament is 20 to 120°K lower than the temperature $T_2$ of the central turns.

**2.** A method as claimed in claim **1**, wherein said pre-operating step is continued until the temperature $T_1$ of the end turns of the filament is 30° to 70°K lower than the temperature $T_2$ of the central turns.

**3.** A method as claimed in claim **1**, wherein said pre-operating step is performed in an atmosphere containing a chemical selected from the group consisting of fluorine in an elementary form, chlorine in an elementary form, a fluorine compound, and a chlorine compound.

**4.** A method as claimed in claim **1**, wherein said pre-operating step takes approximately 1 to 20 minutes in an atmosphere comprising fluorine having a partial pressure of between 0.1 and 20 Torr and an inert gas having a partial pressure of between 10 and $10^4$ Torr at a temperature $T_2$ of the central turns of between 2,800° and 3,600°K.

**5.** A method as claimed in claim **1**, wherein said pre-operating step lasts 10 to 100 minutes in an atmosphere comprising chlorine having a partial pressure of between 10 and 100 Torr and an inert gas having a partial pressure of between 10 and $10^4$ Torr at a temperature $T_2$ of the central turns of between 1,700°K and 2,700°K.

**6.** A method as claimed in claim **1**, wherein said pre-operating step is performed in a fluorine-containing atmosphere until the temperature variation of the middle of the filament [(X = O, $T_2$)] to the ends [(X) = L, $T_1$] is within a temperature range which is limited by two curves given by the equation below:

$$T(x) = T_2 \left\{ 1 - \left[ 1 - \left( \frac{T_1}{T_2} \right)^{\gamma} \right] \frac{e^{x/a} - (1 + x/a)}{e^{1/a} - (1 + 1/a)} \right\}^{1/\gamma} \pm 4°K$$

in which for one boundary curve $T_2 - T_1 = 20°K$ and for the other boundary curve $T_2 - T_1$ is 120°K while $\gamma = 10{,}35.10^4 \cdot 2/(T_2 + T_1)$ and *a* corresponds to the radius of the gas layer surrounding the filament.

**7.** A method as claimed in claim **6**, wherein $T_2 - T_1 = 30°K$ for one boundary curve and $T_2 - T_1 = 70°K$ for the other boundary curve.

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# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,868,159 Dated February 25, 1975

Inventor(s) Erhard Kauer, Johann Schroder, Horst Horster

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Title page, Section 30 change "2231520" to

--P.2231520.4--

Claim 6, line 50 Change "$2/(T_2+_{T1})$ to --$2/(T_2 + T_1)$--

Signed and Sealed this

*twenty-ninth* Day of *July 1975*

[SEAL]

*Attest:*

RUTH C. MASON
*Attesting Officer*

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*Commissioner of Patents and Trademarks*