

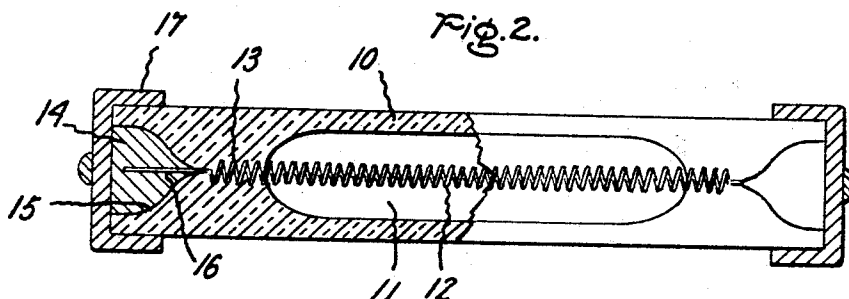
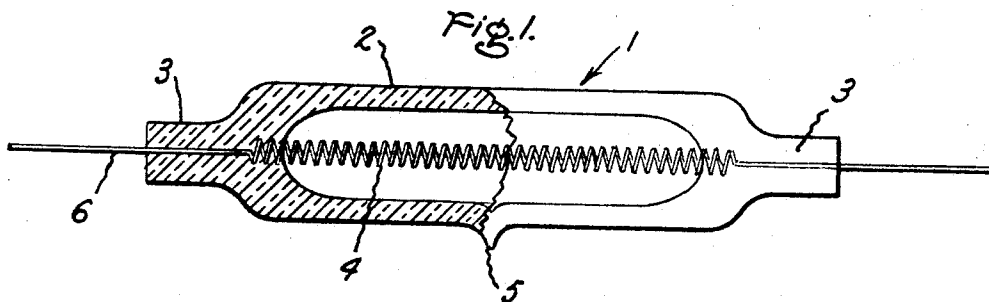
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ELECTRIC LAMP AND METHOD OF MANUFACTURE

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3,448,320
ELECTRIC LAMP AND METHOD OF
MANUFACTURE

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10 Claims

ABSTRACT OF THE DISCLOSURE

Incandescent lamps having incandescible filaments sealed through the exterior wall of a quartz envelope and making an intimate hermetic bond thereto are formed by passing the incandescent filament through a tubulation-type aperture therein, heating the wire to an elevated temperature, flushing the wire and the tubulation with a volume of inert gas sufficient to protect the incandescible filament against contamination from thermal decomposition products of the quartz tube and heating the quartz tube and the wire until the tube collapses about the wire to form an hermetic seal therebetween and in the absence of any intervening substance.

This application discloses improved electric lamps and similar structures utilizing an incandescent filament and is more specifically directed to such a structure in which a very thin filament is directly sealed through the ends of a quartz tubulation. This sealing is accomplished by carefully controlling the diameter of the wire, the temperature of the wire and the quartz during sealing, and the ambient atmosphere within which the seal is made to produce an intimate bonding of the quartz to the incandescent filament by a seal which does not crack, craze, or separate during or after operation of the device at temperatures up to 1000° C.

This application is related to my copending concurrently filed application, Ser. No. 601,927, and the copending concurrently filed application of R. C. Millikan and L. A. Osburg, Ser. No. 601,927.

For many years the incandescent lamp has been the standard source of illumination, particularly for low power applications wherein color rendition is of great importance. Unfortunately, theoretical and practical maximum efficiencies of an incandescent lamp are relatively low, since the radiation from an incandescent filament is substantially black-body radiation and only a minor fraction thereof lies within the visible spectrum, the greatest proportion thereof being dissipated in the form of heat. Because of its relatively small size and low cost, however, the incandescent lamp has been able to compete effectively with other light sources for the low voltage consumer market. Research efforts to improve the efficiency of incandescent lamps has nevertheless continued. The presently commercially available best example of the highest efficiency presently obtainable in incandescent lamp filaments is typically represented by lamps known as the Quartzline type of incandescent lamp such as those disclosed by Fridrich et al., U.S. Patent No. 2,883,571, issued Apr. 21, 1959, and assigned to the General Electric Company, and by other related patents disclosing and claiming improvements thereupon.

In general, Quartzline type lamps are characterized by a thin cylindrical tube of quartz having a relatively long, longitudinal concentric tungsten filament, the diameter of which constitutes a substantial fraction of the diameter of the inner wall of the quartz tube, whereby the inner wall of the quartz envelope is operated at a relatively high temperature. Degeneration of the hot tungsten

filament is prevented by the presence, within the quartz envelope, of a low partial pressure of iodine in a buffer gas which, at the operating temperature of the filament is responsible for the presence of a regenerative iodine cycle which prevents accumulation of tungsten from the filament upon the interior bulb walls. This accumulation has the dual deleterious effect of lowering the transmissivity of the walls and causing the tungsten filament to be dissipated. Utilizing the iodine cycle, the tungsten on the bulb walls is recombined with iodine to form a tungsten-iodine compound which migrates to the hot filament, is decomposed and causes the tungsten to be redeposited upon the filament.

Although lamps such as those described hereinbefore are among the most efficient and long-lived incandescent lamps available today and are highly effective in competition with other light sources, the necessary steps which must be taken in order to achieve the high efficiencies and long life characteristic of the lamps result in production costs which are highly undesirable for commercial manufacture of such lamps. One such cost relates to the expensive double-welding process whereby the filament is welded to a foil of molybdenum which is then sealed through the quartz. A lead wire having mechanical strength and durability must be welded to the opposite end of the molybdenum foil, thus requiring four welds and the use of a fragile molybdenum foil in fabrication of the lamps. Additionally, such structure requires the utilization of an inordinately large quantity of quartz which is uneconomical.

Accordingly, it is an object of the present invention to provide high efficiency incandescent lamps wherein a simple, economical, and effective means is provided for sealing the incandescent filament through the quartz wall at the end thereof.

It is another object of the present invention to provide a method for simply and effectively directly sealing an incandescent filament through the end of a quartz envelope in an hermetic and mechanically strong seal which will not crack or craze under operating conditions.

Still another object of the invention is to provide lamps having improved quartz to refractory metal seals.

In accord with the present invention, I provide incandescent lamps having a quartz or quartz-like envelope and a refractory incandescent filament therein, wherein the incandescent filament is directly sealed through the wall of the quartz envelope without any intermediate element to facilitate the seal. Such seals directly between the incandescent filament and the quartz envelope may readily be made by keeping the diameter of the wire constituting the filament at a value of less than 0.004 inch, by out-gassing the filament wire prior to and during sealing to preclude the presence of any adsorbed gas thereupon and by continuously flushing the filament and the quartz during sealing to preclude the presence of any molecular or gaseous impurities evolved from either during heating to be interposed between the quartz and metal in the final seal.

The novel features believed characteristic of the present invention are set forth in the appended claims. The invention itself both as to its preferred embodiments and mode of operation, together with further objects and advantages thereof may best be understood with reference to the following detailed description taken in connection with the appended drawing in which:

FIGURE 1 is a vertical cross-sectional view of an incandescent lamp constructed in accord with the present invention, and

FIGURE 2 is a vertical cross-sectional view of an alternative embodiment of the device of FIGURE 1.

Since quartz was first used as an incandescent lamp envelope those skilled in the art have been attempting to make seals through quartz envelopes to incandescent

lamp filament by a variety of methods. Since quartz has a temperature coefficient of expansion that is exceedingly different from that of most metals and particularly different from that of refractory metals, this has presented a very serious problem in instances in which the area of the final seal is to be subjected to high temperature. As described hereinbefore, the most effective and efficient incandescent lamps now utilize a configuration wherein the quartz including that portion thereof which constitutes the seal is operated at a substantially higher than room temperature during normal operation. For this reason the difference in thermal coefficients of expansion, if not in some way compensated for or otherwise avoided, results in seals which, when subjected to large temperature changes, degenerate by a separation of the metal from the quartz, resulting in the loss of hermetic sealing between the wire and the quartz. Due to the fragility of most incandescent filaments no attempt has ever been made to directly seal the incandescent filament through the quartz of incandescent lamp envelopes. Instead, workers in the prior art have generally relied upon the passage of the current carrying member through the quartz to effectuate a seal by virtue of an intermediate member which is connected to the incandescent filament on one end thereof and to the supporting lead at the other end thereof. As is mentioned hereinbefore, this is a costly, complicated and self-defeating approach since it requires four welds and an intermediate body which may have a number of configurations but which in general is difficult to work with and very expensive. Examples of the expedients taken in the prior art are as shown, for example, in the aforementioned Fridrich patent in which a refractory support member having a flattened end is utilized to form the seal and the filament is welded to the flattened end of the lead member.

Another approach is that set forth in Patent 1,271,245 to VonRecklinghausen in which one or more members having a portion thereof which is very small in one transverse dimension but very large in another transverse dimension, as for example by flattening a portion of the wire into a thin ribbon thus preserving the same total cross-section but maintaining at least one dimension thereof very small, attempts to seek release from the differential expansion problem. In yet another attempt sought by the prior art, Patent No. 1,922,536, Ericson sets forth an extremely complicated method whereby a thin intermediate member is sealed in a quartz tubulation and connected to at either end thereof to provide a seal. In yet another attempt to solve the differential expansion problem Patents Nos. 1,489,009 and 1,118,812 to Reynolds and Sand and Reynolds respectively, utilize a tungsten lead member with a lead coating thereupon which is sealed through a quartz member. In yet another attempt to solve through a quartz differential expansion problem, in Patent No. 832,302 to Ernst, an intermediate element comprising a thin tungsten wire sealed through a thin glass tubulation is provided for incorporation in a glass, hermetically sealed device by connecting a thin tungsten wire within a cylindrical glass tubulation and connecting the tubulation to a vacuum pump. Then, while the vacuum pump exhausts the tubulation to a low pressure, selected portions of the tubulations are heated so as to cause them to collapse around the glass and form a tight seal thereabout. Either end of the collapsed portion of the glass is then cut to provide an element comprising a thin piece of glass having a thin tungsten wire hermetically sealed thereto. This piece of glass may then be used as a seal in a glass envelope for a variety of uses.

In accord with the present invention I avoid the extremely complicated and expensive expedients of the prior art by the simple approach of directly sealing the filament through a quartz envelope under such conditions as to form a strong, temperature-resistant seal which does not degrade or separate from the wire during operation at temperatures even as high as 1000° C. for example.

The structure of the present invention is illustrated in one embodiment in FIGURE 1 of the drawing in which hermetically sealed envelope 1 includes a hollow cylindrical portion 2 with a closed tubular shaped end portion 3 at either end thereof. An incandescent filament 4 is located concentrically along the axis of envelope 1 and passes completely through end portions 3 thereof without interruption or termination. As illustrated in FIGURE 1, the coil of the filament is terminated and the filament assumes a configuration of a straight wire upon emerging from envelope 1. This is optional, however, and the filament may emerge from envelope 1 in the same configuration as it exists within cylindrical portion 2 thereof or as a straight wire as illustrated in FIGURE 1. Additionally, although the filament is illustrated in FIGURE 1 as being a single wire and including a single helical coil in the central portion thereof any conventional or convenient filament configuration as for example those set forth in the copending application of P. D. Johnson, Ser. No. 580,995, filed Sept. 21, 1966, the entire specification of which is incorporated herein by reference thereto, may be utilized provided that the elemental wire thereof from which the filament is fabricated meets the dimensional criteria set forth herein.

I find that an effective strong seal may be made between a tungsten filament and a quartz envelope if the elemental wire comprising the incandescent filament is less than 0.004" in diameter, if the wire is heated to a white heat prior to and during sealing to force the evolution therefrom of any adsorbed gasses, and if means are provided to remove all material ejected from the filament during the heating thereof and to prevent material ejected from the quartz from migrating to and contaminating the filament prior to or during sealing. The incandescent filament 4 may conveniently be of any refractory material suitable for operation at incandescent temperatures, as for example tungsten, molybdenum, rhenium, but for purposes of simplicity in this application will be referred to as a tungsten wire. I find that if the tungsten wire is 0.004" or less in cross-sectional diameter, the seal formed with quartz may be operated repeatedly and for many hours at a temperature up to 1000° C., for example, and repeatedly cooled back to room temperature without degradation of the seal. I believe this is possible due to the distribution of stresses along the radial and tangential directions of the circular cross-section of the wire is such that the difference between thermal coefficient of expansion and of the quartz and tungsten does not cause a separation between the two, provided the initial bond is between the two directly and there is no interposed impurity layer which tends to weaken the same. As a practical matter, I find that for the construction of useful commercial incandescent lamps a filament wire diameter of 0.0005" represents the practical low limit with which one can make lamps in accord with the present invention.

Prior workers in the art have attempted to form effective tungsten to quartz seals by deliberately forming upon the surface of the tungsten an oxide coating of several monolayers thickness or greater, which had the purpose of providing a resilient means for taking up for differential expansion. To the contrary, I find that such interposed oxide layers are extremely deleterious and tend only to form an easy source of cleavage between the tungsten and quartz upon differential expansion or contraction. Accordingly, I provide my tungsten filament in a substantially unoxidized state by conventional prior heat treatment and out-gassing the heat and filament during sealing to a temperature of from 1750 to 2200° C., which is a white heat, to remove any surface adsorbed gasses thereon.

Although the heating of the tungsten filament may be accomplished by passing an electric current therethrough, I prefer to heat the filament by the passage of a flow of extremely hot gas longitudinally along the filament during sealing. This has the added advantage of not only heating

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the filament but also removing therefrom any impurities evolved by heating and serving as a buffer to prevent the deposition thereupon of any impurities evolved from the quartz. The gas utilized to heat the filament is preferably a gas which does not react with quartz or tungsten as for example nitrogen or one of the noble gasses. The pressure at which the flushing gas is utilized may be any value in excess of 1 mm. of mercury pressure although in general as the velocity of the flushing gas decreases it is preferred that the pressure of the gas increases. This is because, as stated hereinbefore, one essential function of the flushing gas is to shield the tungsten filament from any impurities evolved from the quartz during heating in sealing.

When quartz is heated to its softening point to the extent that it can be expected to contract around, and seal with, a tungsten filament, as for example, a temperature of 1750 to 2200° water vapor is evolved therefrom. Water vapor in the presence of a hot tungsten filament can set up a deleterious cycle whereby the water molecules migrate to the tungsten, are decomposed thereat, forming tungsten oxide and a tungsten compound which migrates back to the quartz, removing tungsten from the filament. This cycle is very detrimental in the formation of tungsten filaments and, therefore, it is exceedingly important that, when the quartz is heated in the formation of the seal the water vapor evolved from the quartz be prevented from reaching the tungsten filament. This may be achieved by the passage of high velocity gas between the two even at reduced pressures of for example 1 mm. of mercury of the flushing gas. The same objectives may, however, be achieved at lower flushing velocities or even for brief periods of time at which the velocity of the gas between the quartz and the tungsten is essentially zero, as for example, just prior to making of the final seal in a closed system, unless some other orifice is provided to allow for a path for flushing of the gas. In this instance, it is highly desirable that a very high pressure of a high molecular weight inert or noble gas such as argon or krypton be provided in order that the mean free path of the water molecules be very short as compared with the distance between the quartz and the tungsten.

As an example of a pressure distance relationship which satisfies this mean free path requirement it is sufficient, utilizing a 0.002" wire in a 0.040" inside diameter quartz tubulation that the pressure of the flushing gas or the interposed gas, even without flushing, be approximately 10 mm. of mercury. This yields a mean free path of the water molecule of approximately 0.0005", which clearly makes it highly improbable that any water molecule may reach the tungsten filament.

By virtue of the foregoing discussion, it should be readily understood that it is not practical or desirable to attempt to form seals between tungsten and quartz by this or any other method wherein the substitution of a vacuum environment for an inert gas environment (often considered equivalent in related arts) is made. This is because, if a vacuum is established within the distance between the filament and the quartz and the quartz is heated to cause the softening thereof, under vacuum conditions the mean free path of water vapor evolved from the quartz becomes exceedingly long and the probability of water reaching the tungsten filament and setting up a water cycle, which causes the deposition of the layer of tungsten oxide upon the tungsten filament, is very great. Accordingly the last thing to be considered in the formation of such seals would be the evacuation of the region between the tungsten and the quartz during sealing.

In forming lamps in accord with the present invention, it is convenient to take a section of quartz tubing as illustrated in FIGURE 1 of the drawing, having an outside diameter of approximately 10 mm. and an inside diameter of approximately 8 mm. with a "necked down" end section on either end thereof having an outside diameter of approximately 8 mm. and an inside diameter of approximately 2 mm. Conveniently, the inside diameter of the

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constricted end portion of at least one of the ends of the quartz tube is made large enough to accommodate the outside diameter of the configuration of the coil of filament 4. Since the filament need be inserted in only one end this requirement need be present at only the end from which the filament is inserted.

Also conveniently, the quartz tube may be provided with an exhaust-type tubulation at the center thereof for provision of a ready path of flushing for the second seal after the first seal is made and for evacuation or filling, as for example with low pressure iodine, of the enclosure within the envelope or raising or lowering of the pressure thereof, as desired. After sealing both ends and after whatever operation is desired to be performed through this tubulation is performed, the tubulation is closed off, leaving a nipple 5 which completes the hermetic sealing of the envelope. It is to be appreciated, however, that such a tubulation and remaining nipple are in accord with only one feature of the invention and the lamps in accord with the invention may be fabricated without such tubulation.

Assuming such a tubulation is present, fabrication of the lamp of FIGURE 1 may be as follows. The quartz tube, as described above, has a conveniently coiled or coiled-coil helical filament which may or may not have straightened ends but which, for convenience of description, will be assumed to have straightened ends as illustrated in FIGURE 1, is inserted therein through the larger diameter end portion 3 and the straightened end portion 6 is caused to emerge from the other end portion 3. The quartz tube is then placed in a suitable fixture and a jet of argon, for example, at a pressure of, for example 10 mm. of mercury is directed into the aperture within the first end 3 to cause the flushing of the entire interior of the envelope with argon gas. The flow of flushing gas and low internal pressure are maintained by any appropriate suction device. This gas is heated to an elevated temperature by external torching or other application of heat to the quartz so as to cause the temperature of the filament to be raised to a temperature of from 1750 to 2200° C. At temperatures below 1750° insufficient out-gassing and desorption of surface adsorbed gas particles is present and it is difficult to make good seals. At temperatures in excess of 2200° C. the effects upon the quartz envelope are such as to preclude its maintaining its structural rigidity. I have found that it is preferable, both from the point of view of forming optimum degassed tungsten surfaces and for maintaining the structural rigidity of the quartz during fusing, to cause the gas heating to provide a filament temperature of from 1800 to 2000° C. After the filament has reached this temperature, as measured by an optical pyrometer, the quartz is heated more intensely, which may for example be a second jet of high temperature gas directed thereabout, as for example from a peripheral nozzle located thereabout, or by an annular resistive heater encircling region 3, or by plasma torch or focussed laser heating to cause the temperature of the quartz to be raised above 2200° C., causing the quartz to collapse about the tungsten filament and form an hermetic seal therewith.

The quartz may be caused to collapse about the filament and seal thereto by applying a constrictive force thereto. Such a force may, for example, be supplied by pressure differential of, for example several pounds per square inch, caused by pumping the flushing gas out from the quartz envelope through the tubulation at nipple 5, as described above, so that the pressure within the envelope is slightly less than outside the envelope. Alternatively, the end 3 may be mechanically squeezed by any suitable means. After one end of envelope 1 has been sealed, the process is repeated with the other end, the high temperature gas which is injected into the restricted diameter end portion 3 escaping through the tubulation at the center of the tube to allow free flushing of the device. After the second end portion has collapsed about the tungsten filament to cause the formation of an

hermetic seal, the center tubulation is sealed off (after any desired filling or pressure change therethrough) leaving nipple 5, and the incandescent lamp fabrication is completed.

In accord with another embodiment of the present invention, substantially the same procedure is utilized, as described above, with the exception that no center tubulation is provided and the second seal is made at a higher pressure of inert gas, as for example, approximately 1 atmosphere, thus relying upon the high pressure of inert gas molecules in the vicinity of the filament and the quartz to which it is to be sealed to reduce the mean free path of water evolved from the quartz so as to preclude the presence of a water cycle and the deposition of tungsten oxide upon the tungsten filament.

In FIGURE 2 of the drawing there is illustrated a lamp constructed in accord with another embodiment of the invention. In FIGURE 2, the lamp comprises a cylindrical quartz member 10 having a central aperture 11 therein for the accommodation of a filament 12 which passes concentrically therethrough. At either end of opening 11, the quartz constituting cylinder 10 has been collapsed about filament 12, forming seal regions 13, which seals were made substantially as described with respect to the formation of the device of FIGURE 1. The respective ends of cylindrical quartz tubulation 10 include re-entrant openings 14, which are filled with an electrical contact-making and mechanically support-producing filling 15 of a suitable metal, as for example nickel, which is readily adaptable for making electrical contact to the emerging filament lead 16. The ends of the tubulation 10 are closed with metallic caps 17, which may conveniently be made of nickel and which are suitably soldered nickel inserts 15 within tubulation 10. Electrical contact to the lamp may then be made to end caps 17 to provide for the flow of electric current through filament 12 to produce incandescence therein and the subsequent emission of suitable and useful light. The structural characteristics and suitable methods for forming the filling 15 in re-entrant portions 14 of envelope 10 are described in greater detail and claimed in the copending, concurrently filed application of R. C. Millikan and L. A. Osburg, application Ser. No. 601,927, which is assigned to the assignee of the present invention.

In describing the formation of the lamps of the present invention, I have indicated a preference for nonreactive gasses as the medium for flushing the quartz tubulation and for heating the tungsten wire. Although this is the case, it is possible to form lamps in accord with the present invention using low pressure atmospheric air for these purposes. In this instance, provided the pressure of the air is low enough, as for example from 10 to 100 mm. of mercury, substantially little oxide is allowed to form upon the surface of the tungsten filament. Even if a very small amount of oxide does form as for example a monolayer, the solubility of tungsten oxide in quartz is sufficient so that a very small amount of oxide may be absorbed within the quartz immediately upon making contact thereto, thus allowing the quartz to make intimate contact with the metallic tungsten of the filament which facilitates the formation of good seals in accord with the present invention.

From the foregoing it will be evident that I have disclosed improved incandescent lamps utilizing refractory metal filaments which are simple, inexpensive and easy to manufacture and wherein a refractory metal filament having a metal wire diameter of not to exceed 0.004" is directly sealed through a quartz envelope wall without the interposition of any intermediate member or any welding thereto. This sealing is accomplished by the heating of the refractory filament to a white heat of 1750° to 2200° C. and a flushing with hot gas to remove evolved impurities or, in the alternative, the presence of a high pressure gas to see that impurities evolved from either the tungsten or the quartz do not return to the

tungsten to cause the formation of deleterious coatings thereupon.

One lamp in accord with the invention was made with a 3" long quartz tube of 0.250" O.D. and 0.150 I.D. and an exhaust tubulation of 0.100 O.D. at the longitudinal center thereof. A 0.002" diameter tungsten wire having a helical coil having a diameter of 0.050" and a length of 1" was suspended along the longitudinal axis of the quartz tube and extending along its entire length. One end of the tube was closed by an O ring and an end clamp and the other end was connected temporarily to a source of dry nitrogen at a pressure of 10 mm. of Hg. A mechanical fore pump was connected to the exhaust tubulation and operated to draw the nitrogen through one end of the quartz tube at a flow rate equivalent to 1 cc. per second at conditions of standard temperature and pressure. Heat was applied to the quartz wall about 1" from the end with a pair of oxyhydrogen torches at a rate sufficiently slow to allow the tungsten wire to come to a temperature of 1800° C. before the quartz was deformed. This was accomplished by a 2 minute heating cycle. After 2 minutes of heating the softened quartz was drawn by the pressure differential into contact with the tungsten wire and the seal was made. The procedure was repeated with the nitrogen source connected to the other end to produce the second seal. The exhaust tubulation was then heated until it softened and sealed over completely. The resultant lamp was as is illustrated in FIGURE 1.

Although the desirability for the improvements achieved by the present invention are of particular importance in Quartzline type incandescent lamps utilizing iodine or other halogen regenerative cycle, it should be appreciated that the invention set forth herein is applicable to the generalized structure of quartz and quartz-like lamp envelopes and is not limited to lamp envelopes containing any particular gaseous filling. Similarly although for convenience the invention has been described in connection with pure quartz envelopes it should be appreciated that the invention may be practiced with any light-transmissive vitreous predominantly silica material as for example, Vycor (95% SiO) which is predominantly silica and has a quartz-like low thermal coefficient of expansion which renders the passage of metallic electrical lead wires therethrough a problem of such magnitude as is described herein and which may be solved by the principles of the present invention.

While the invention has been described herein with respect to specific embodiments and examples thereof it will be appreciated that many modifications and changes will readily occur to those skilled in the art. Accordingly I intend by the appended claims to cover all such modifications and changes as fall 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. An incandescent lamp comprising:

(a) an hermetically sealed envelope of a vitreous light-transmissive high silica material having a low quartz-like coefficient of thermal expansion;

(b) a refractory metallic wire incandescable filament supported within said envelope and sealed directly through said envelope without interruption or deformation and emerging as a current conductor exterior of the hermetically sealed portion of said envelope;

(b₁) said filament being sealed through said envelope by intimate contact between said metal and the material of said envelope in the absence of intervening substance.

2. The lamp of claim 1 wherein the wire from which said filament is formed has a cross-sectional diameter of approximately 0.0005" to 0.004".

3. The lamp of claim 2 wherein said wire is tungsten.

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4. The lamp of claim 2 wherein a lamp envelope is quartz.

5. The lamp of claim 3 wherein the lamp envelope is Vycor.

6. The lamp of claim 3 wherein the lamp envelope is in the form of an elongated cylindrical tube and said filament is in the form of an axial coiled helix, said helix occupying a substantial portion of the interior cross-sectional area of said tube.

7. The method of making an incandescent lamp which comprises:

(a) providing an envelope of a vitreous light-transmissive high silica material having a low quartz-like coefficient of thermal expansion having at least one constricted end portion with an aperture therein;

(b) disposing a refractory metallic incandesible filament within said envelope with an end of said filament extending through said aperture;

(c) heating said filament to a temperature of approximately 1750° C. to 2200° C. in an inert gas atmosphere to outgas the surface thereof, said gas being present in pressures sufficient to prevent contamination of the surface of said filament by thermal decomposition products of said high silica material; and

(d) heating said constricted end portion above the softening point thereof to cause the envelope end

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to constrict about said filament while maintaining said filament at said elevated temperature to form an intimate, hermetic seal therewith.

8. The method of claim 7 wherein said filament is heated by a flow of heated inert gas at a pressure of in excess of 10 mm. of mercury.

9. The method of claim 8 wherein the inert gas is argon at a pressure of 10 mm. of mercury to one atmosphere.

10. The method of claim 8 wherein the inert gas is pure dry nitrogen at a pressure of 10 mm. of mercury to one atmosphere.

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