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INCANDESCENT LAMP WITH A TUNGSTEN FILAMENT WITH TANTALUM IMBEDDED IN THE SURFACE TO ACT AS A GETTINGER AGENT

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ABSTRACT OF THE DISCLOSURE

A coiled filament for electric incandescent lamps, especially those of microminiature size, is composed of a refractory metal wire such as tungsten substantially free of embedded carbon, iron and molybdenum surface layer impurities and containing tantalum diffused into and embedded in its surface layer in a small but effective amount serving as a getter but materially less than 300 parts per million of its surface layer composition.

This invention relates in general to electric incandescent lamps, and more particularly to coiled wire filament therefor and to a method of making such coiled filaments.

Electric incandescent lamps are normally characterized by a certain amount of bulb blackening which gradually develops during the operation of the lamp. This blackening has been attributed in the past mainly to the deposition on the bulb wall of particles of the filament material itself (usually tungsten) which are vaporized off the hot filament during operation of the lamp. This undesirable bulb blackening effect, and the reduced lamp light output resulting therefrom, has therefore placed a limitation on the minimum size of bulb that could be satisfactorily employed in a lamp for a given filament wattage or, stated conversely, has placed a limitation on the wattage of the filament that could be satisfactorily employed in a given size bulb. An especially undesirable effect, however, of this bulb blackening is that it has long prevented the manufacture heretofore of very small size, and particularly microminiature size coiled filament incandescent lamps (e.g., those employing bulbs of, for instance, around ½ inch diameter or so) which are of stable structure and substantially free of any tendency for the filament coils to twist or swirm out of shape, and are capable of producing an effective or useful amount of light output throughout a reasonable period of lamp operating life of at least several hundreds of hours, the bulbs of prior type miniaturized coil filament lamps of which attempted stable construction ordinarily becoming so heavily blackened within such a relatively short period of lamp operating time (e.g., as little as 48 hours or so) as to render the lamps in most cases practically useless thereafter.

In the manufacture, moreover, of coiled filaments for incandescent lamps, the refractory metal wire of which such filaments are customarily made (usual tungsten wire) is coiled on a mandrel wire and then heated or sintered on the mandrel, at an elevated temperature of, for example, in excess of 1500° C., in order to grow the grain structure of, i.e., recrystallize, the tungsten or other refractory metal to the desired degree and relieve the internal strains therein so as to, in effect, “set” the filament coil, after which the mandrel wire is then chemically dissolved out from the coiled filament wire. The higher the temperature at which the sintering of the coiled filament wire is carried out, the more uniform will be the resulting filament coils in respect to their operating characteristics and the less subject they will be to twisting during operation such as is likely to result in shorting out of the coil turns and premature failure of the filament.

An undesirable effect, however, heretofore experienced with such higher filament coil sintering temperatures has been the resulting significantly increased amount of blackening that is formed on the bulb wall of the lamp. It is an object of the invention, therefore, to provide an electric incandescent lamp having a greatly reduced amount of bulb blackening during its operating life and therefore greatly improved light maintenance.

Another object of the invention is to provide miniature coiled filament type electric incandescent lamps, having bulb sizes of as little as ½ inch in diameter or thereabouts, which are capable of producing a substantial amount of light output for an extended period of time and which are characterized by greatly reduced bulb blackening during their operative life and therefore greatly improved light maintenance.

Still another object of the invention is to provide a coiled filament for incandescent lamps having the desired degree of grain growth or recrystallization and substantially free of internal strains and resultant susceptibility to twisting and shorting out during operation, and which at the same time will produce a materially decreased amount of bulb blackening during operation of the lamp.

A further object of the invention is to provide a novel method of manufacturing incandescent lamp filament coils having improved operating characteristics and which produce a materially decreased amount of bulb blackening during lamp operation.

Briefly stated, in accordance with one aspect of the invention, the filament coils of electric incandescent lamps are wound or coiled on a tantalum mandrel and sintered thereon at a temperature above 1500° C. as a result of which they do not become contaminated with molybdenum, iron, or other surface layer embedded impurities to a degree such as would produce a significant amount of bulb blackening on vaporization thereof off the filament during lamp operation. Because of the comparatively low vapor pressure of tantalum, the amount of tantalum which diffuses into and becomes embedded in the surface layers of the filament coils from the tantalum mandrel during the sintering operation is insufficient even at comparatively higher sintering temperatures than those customarily employed heretofore, to produce any significant amount of bulb blackening during the operative life of the lamp. In addition, because the filament coils can be sintered at such comparatively higher sintering temperatures and thus recrystallized to a higher degree without causing diffusion thereinto of a significant amount of blackening-producing tantalum surface impurities, the resulting filament coils are therefore substantially free of internal strains and as a consequence possess uniform operating characteristics and are not subject to twisting during lamp life.

Further objects and advantages of the invention will appear from the following detailed description of species thereof and from the accompanying drawing.

In the drawing, FIG. 1 is an elevation of an electric incandescent lamp comprising the invention; FIG. 2 is a view illustrating the filament wire coiling step of the process of making coil filaments according to the invention; and FIG. 3 is a graph comparing the light maintenance of an electric incandescent lamp comprising the invention with that of prior type lamps.

Referring to FIG. 1, the invention is there shown as embodied in an electric incandescent lamp of micro-miniature size and comprising a glass bulb or envelope having a size, in the case of the particular lamp illustrated, of the order of ½ inch or so in diameter. It should be understood, however, that the invention is applicable as well to electric incandescent lamps of any bulb size.
bulb or envelope 1 of the particular lamp illustrated is evacuated. However, if desired, and particularly in the case of larger size tantalum filament 9, the associated bulb 1 may be filled with a suitable inert gas such as argon, or mixtures thereof with other rare gases or with nitrogen, to a pressure preferably below atmospheric.

Sealed into one end of the bulb 1 are a pair of lead-in wires 2 and 3 which are electrically connected at their outer ends to the end contact 4 and the side shell contact 5, respectively, of a lamp base 6 which is suitably fastened to the said end of the bulb, as by conventional basing cement, for example. Interioally of the bulb, the inner ends of the lead-in wires 2, 3 are electrically connected to and support a coiled wire filament 7 disposed within the bulb 1. The filament 7 is formed of a suitable refractory metal such as tungsten, and it may be either of single coiled or multiple coiled form, e.g., coiled coil.

In accordance with the invention, the filament 7 is substantially free of carbon, iron and molybdenum surface layer impurities but contains tantalum diffused into and embedded in its surface layer in a small but effective amount to serve as a getter within the lamp bulb (i.e., for combining with and cleaning up any oxygen that may be present in the filament wire or bulb) but insufficient to cause, on its evaporation off the filament during lamp operation, any significant amount of blackening deposit on the lamp envelope during the operating life of the lamp. To this end, it has been found that the concentration of embedded tantalum at the surface of the wire filament should be materially less than about 300 parts, and preferably less than 100 parts per million of the surface composition of the wire filament. To satisfactorily perform its gettering action within the lamp bulb, however, the tantalum should be present in the surface layer of the filament wire 7 in an amount of at least a few parts per million of the surface composition of the wire filament.

In the manufacture of the filament 7 according to the invention, the tungsten or other refractory metal wire 8 of which the filament is to be constituted is first tightly wound or coiled to the desired pitch, or number of turns per inch, on a tantalum wire mandrel 9 of the desired wire size or diameter. As shown in FIG. 2, the filament wire 8 may consist of a continuous supply of the wire, as on a supply reel or spool 10 for example, and it may be wound or coiled on the tantalum wire mandrel 9, which also may consist of a continuous supply thereof on a supply reel 11, either in the form of a continuous coil or, as shown, in the form of an interrupted coil comprised of a series of coiled sections 12 separated apart by the coiled or straight wire sections 13. The coiling of the filament wire supply 8 on the tantalum wire mandrel 9 may be performed in any suitable manner, preferably by means of any conventional type automatic lamp filament coiling machine such as, for example, that shown and described in U.S. Patent 1,227,659, Quackenbush et al., dated May 29, 1917.

The filament wire 8 thus coiled on the tantalum wire mandrel 9 is then immersed in a hot hydrochloric acid bath, heated to a temperature around 80° C. for example, to remove any iron and nickel impurities that may be present on the surface of the filament wire. Following this cleaning operation, the coiled filament wire 8, while still in place on the tantalum wire mandrel 9, is then annealed in an inert atmosphere at a temperature above 900° C. and preferably around 1500° C. or thereabouts, after which the annealed coiled filament wire 8 is then cut in the central mandrel into individual filament lengths 7 of the desired length, as by severing the filament wire 8 and the associated tantalum wire mandrel 9 by means of metal cutting knives, for instance. The annealing of the coiled filament wire 8 on the wire mandrel 9 serves to relieve enough of the internal strains in the coiled filament wire 8 to prevent any uncoiling or unwinding thereof on the mandrel 9 when it is subsequently cut into the individual filament coil lengths 7. In the particular spaced-coiling adaptation shown in FIG. 2, the coiled filament wire 8 and the associated tantalum wire mandrel 9 are simultaneously cut approximately midway of the length of the straight sections 13 of the filament wire, at the cutting planes denoted by the dash-dot lines A, to thereby form the individual filament coils 7. Where filament coils 7 of multiple coiled, e.g., are desired, the annealed coiled filament wire 8 and associated tantalum wire mandrel 9, before the cutting thereof into the individual filament coil lengths 7, is in that case coiled again on a secondary mandrel (not shown) which, in accordance with the invention, is likewise made of tantalum. The coiled filament wire 8, while still in place on the primary and secondary tantalum wire mandrels, is then cleaned in a hot hydrochloric acid bath and again annealed, in the same manner as described above, following which it is then cut into individual coiled-coil filament lengths. The severed filament coils 7, while still in place on the cut lengths of tantalum wire mandrel 9, then are preferably again immersed in a heated hydrochloric acid bath, as before, to remove any iron or nickel impurities, or any other foreign matter that may have since deposited on the filament wire, as from the metal cutting knives employed to cut the coiled filament wire 8 into the individual filament coil lengths 7.

After they have been thus cleaned, the individual filament coils 7, with the tantalum wire mandrels 9 still in place therein, are then sintered, under vacuum, at the required sintering temperature and for the required period of time, generally from 10 minutes to a few hours, to recrystallize the tantalum wire or other refractory metal of which the filament coils are made to the desired degree, and to also relieve the internal strains remaining in the filament wire, the filament coils 7 thereby being "set" so as to retain their coiled form, and not uncoil, when the wire mandrels are subsequently removed therefrom. The sintering of the filament coils 7 may be carried out in a vacuum furnace under a high degree of vacuum of, for example, around 10⁻⁶ pounds per square inch or higher. The temperature at which the filament coils 7 are sintered may range anywhere from around 1600° to 2500° C. or thereabouts, depending on the degree of grain growth of the filament metal, and relieve the internal strains therein to a greater degree, as a consequence of which the filament coils 7 are considerably more uniform in their physical and operating characteristics and less subject to twisting and resultant shorting out of the coil turns during lamp operation. The choice of sintering temperature employed, however, will depend on the degree of brittleness of the tungsten or other refractory metal filament coil 7 which can be tolerated in the particular lamp application, it being well known that the higher the sintering temperature the lesser the degree of brittleness of the tungsten filament coil at room temperature. Thus, for filaments of very small wire size, it is necessary to employ sintering temperatures within the lower regions of the above stated temperature range because such small wire size filaments become exceedingly brittle, and therefore difficult to handle without breakage, at the higher sintering temperatures.

After the filament coils 7 with their respective tantalum wire mandrels 9 still in place therein have been thus sintered, the tantalum wire mandrels are then suitably removed from the filament coils. The removal of the tantalum wire mandrels is preferably accomplished by chemically dissolving the tantalum wire mandrels, as customary practice heretofore in the manufacture of incandescent lamp filament coils. For this purpose, the filament coils 7
may be immersed in a hydrofluoric acid bath heated to a temperature near the boiling point thereof, for example around 80° C., or so. Thereupon, the filament coils 7 are suitably cleaned, as by rinsing them in distilled water for instance, after which they are then stored in glass or other suitable containers in readiness for use in the manufacture of incandescent lamps comprising the invention.

As clearly evident from the curves designated A and B in the chart shown in FIG. 3, the light maintenance of electric incandescent lamps comprising the invention, provided with tantalum mandrel wound filament coils 7, is greatly improved over that of corresponding, previously manufactured lamps provided with filament coils wound on molybdenum or steel mandrels. The curves A and B in FIG. 3 are the plots of the percent of initial light output, at various hours of lamp burning time, of lamps provided with tantalum mandrel wound filament coils and molybdenum mandrel wound filament coils, respectively, the lamps being of substantially the same physical construction throughout except for the tungsten filament coils and having substantially the same initial light output at zero burning hours. The particular lamps represented by the curves A and B in FIG. 3 are of the T 9% microminiature bulb size, employing a small tubular bulb 2 having a diameter of 5% of one-eighth inch, i.e., 5/4 inch, and a length of about 3/4 inch, and provided with tungsten filament coils 7 of 5 volt .06 ampere rating, which have been sintered at approximately 1600°C.

Referring to the curves shown in FIG. 3, it will be seen that during the initial lamp seasoning time of around 20 hours or so of operation, during which time the tungsten filament of the filament coil 7 is further recrystallized, the light output of lamps comprising the invention provided with tantalum mandrel wound tungsten filament coils (curve A) increases by about 15 to 20% or so and thereafter remains substantially constant. In contrast thereto, the light output of lamps provided with molybdenum mandrel wound tungsten filament coils (curve B) undergoes an appreciable initial decrease amounting to about 15 to 20% (due mainly to the deposit on the bulb wall of the molybdenum surface impurities rapidly vaporized off the filament) during the initial lamp seasoning time of around 20 hours or so, and thereafter continues to progressively fall off and decrease during the operating life of the lamp so that at 2000 hours, for example, the light output is only around 60% or so of the initial light output. Thus, at 2000 hours of burning time, the light output of lamps comprising the invention is almost twice that of lamps conventionally made employing molybdenum mandrel wound tungsten filament coils. This, of course, is a most important and highly desirable advantage and has made possible, and commercially practical, the production of microminiature and other smaller size incandescent lamps which are of stable character and are capable of producing an effective or useful amount of light for a relatively long period of operating time ranging up to hundreds, and even thousands, of hours.

The improved light maintenance of incandescent lamps according to the invention, as compared to prior type incandescent lamps which are generally provided with filament coils which have been wound on molybdenum or steel mandrels, is due mainly to the fact that the filament coils 7 according to the invention are substantially free of molybdenum, iron and carbon surface layer embedded impurities such as are normally found in significant amounts into filament coils wound on molybdenum or steel mandrel wire and which heretofore accounted for the major portion of the bulb blackening produced in the lamp, these impurities vaporizing out of the filament wire during lamp operation and depositing on the inside wall of the lamp bulb. As a result, a blackening deposit thereon which absorbs the light rays radiated by the lamp filament. These molybdenum and iron surface impurities are introduced into filament coils which have been wound on molybdenum or steel mandrel wire by the vaporization of the molybdenum or iron off the molybdenum or steel mandrels during the high temperature sintering of the coiled filament wire while positioned on the mandrel wire, the vaporized molybdenum or iron then being diffused or driven into the surface layer of the coiled filament wire. Because of the comparatively low vapor pressure of tantalum, however, as compared to molybdenum or iron, the amount of tantalum that is evaporated off a tantalum wire mandrel and diffused or driven into the surface layer of the coiled filament wire 8 thereon during the sintering treatment of the coiled filament wire is many times less, i.e., around 900 or more times less, than the amount of molybdenum or iron which is evaporated off a molybdenum or steel mandrel and driven into the surface layer of the coiled filament wire under the same sintering conditions, i.e., the same sintering temperature and time. As a result, the tantalum surface layer embedded impurities present in the filament coils 7 according to the invention are so insignificant that their presence will produce little, if any, blackening deposit on the inside wall of the lamp bulb. Moreover, because of its characteristic of having an affinity for and readily combining with oxygen and hydrogen, the comparatively small amount of tantalum that is actually driven into the surface layer of the filament coil 7 of the invention during the sintering thereof on the tantalum mandrel wire 9 beneficially acts as a getter within the lamp, when evaporated from the tungsten filament occupying a surface site on the cooler filament portions near the connections of the filament to the lead-in wires 2 and 3, to combine with any oxygen or hydrogen that may be driven out of the filament wire or out of the bulb wall during lamp operation and which would normally have a deleterious effect on the filament.

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

1. An electric incandescent lamp comprising a sealed envelope, a pair of lead-in wires sealed into said envelope, and a tungsten filament coil in said envelope connected to said lead-in wires, said filament coil being substantially free of carbon, iron and molybdenum surface layer embedded impurities and containing tantalum diffused into and embedded in its surface layer in a small but effective amount serving as a getter but materially less than 300 parts per million of its surface layer composition.

2. A lamp filament comprising a tungsten wire coil substantially free of carbon, iron and molybdenum surface layer embedded impurities and containing tantalum diffused into and embedded in its surface layer in a small but effective amount serving as a getter but materially less than 300 parts per million of its surface layer composition.

3. A lamp filament of the type coiled and set on a wire mandrel and consisting of a tungsten wire coil substantially free of carbon, iron and molybdenum surface layer embedded impurities and containing tantalum diffused into and embedded in its surface layer in a small but effective amount serving as a getter but materially less than 300 parts per million of its surface layer composition.

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