

[54] **INHIBITING D-C NOTCHING EFFECT IN INCANDESCENT LAMP FILAMENTS**
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[57] **ABSTRACT**
Process and product produced thereby wherein the problem of “d-c notching” and resulting premature failure of tungsten, tantalum or molybdenum metal filaments for miniature lamps operating below 2400°C is avoided by steps which include: removal of reactive gases including residual chemically available oxygen and nitrogen by high vacuum, heating the filament to help drive off the reactive gases, flushing out at least once and back-filling the bulb envelope with a heavy inert gas from Group VIIIA of the periodic table.

2 Claims, 2 Drawing Figures

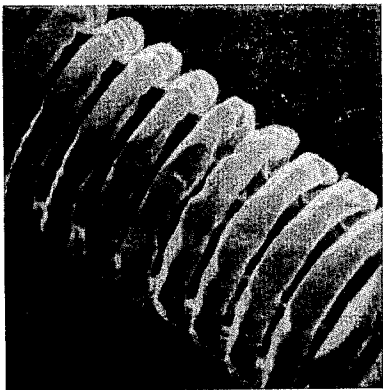


Fig. 1.

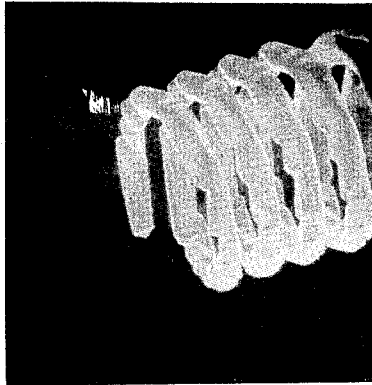
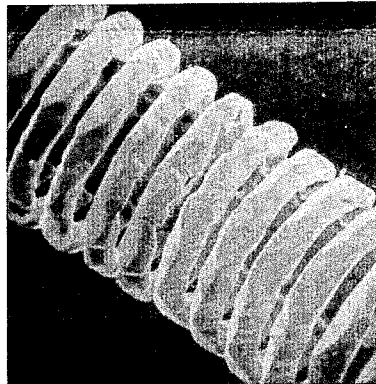


Fig. 2.



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INHIBITING D-C NOTCHING EFFECT IN INCANDESCENT LAMP FILAMENTS

This invention relates to d-c lamp filaments, and more particularly to the elimination therein of the life-shortening phenomenon known as "d-c notching."

BACKGROUND OF THE INVENTION

Tungsten incandescent lamp filaments of the type used in miniature and sub-miniature lamp sizes are normally operated on direct current at temperatures below 2,400°C for purposes of illuminating indicator dials and low intensity lamps. In contrast to the tungsten filaments used in the larger incandescent lamps for lighting purposes, which operate at temperatures above 2,400°C, usually on alternating current, the lamp filaments operating on direct current are subject to a phenomenon known as "d-c notching", which results in a drastic unexpected reduction of filament life. The lower temperature of operation would normally lead one to expect an extended life, because of less evaporation of tungsten metal from the wire. However, failure of the d-c lamp occurs due to the formation of saw-tooth facets or notching of the filament wires which reduces the wire cross-section at the notch, eventually breaking the continuity of the electric current or mechanical weakening of the filament. Similar effects to those occurring in tungsten have also been observed in filaments made of tantalum or molybdenum.

The causes of failure in the lower temperature d-c lamp filaments are not at all analogous to those which limit the life of larger type tungsten illuminating lamps operated on alternating current. Incandescent lighting lamps, e.g., of the household variety, operate at higher temperatures, i.e., above 2,400°C, principally on alternating current, and the life of such filaments is determined by evaporation of the tungsten metal from the surface of the wire. Thus, efforts to lengthen the life of illuminating lamps concentrate on suppressing or slowing down the rate of escape of tungsten by evaporation from the wire filament. When such illuminating lamps are filled with an inert gas it is for the purpose of carrying heat away from the filament, thus slowing the rate of vaporization of the tungsten.

In contrast thereto, the filaments in miniature and sub-miniature lamps usually are sealed after simply evacuating to a poor vacuum, in an atmosphere of ambient air, e.g. to a pressure not less than 10^{-3} mm Hg. When operated on direct current, the filaments exhibit a serrated faceting and notching effect wherein some of the tungsten material of the wire is transported to another location along the wire, leaving a notch where it has been removed and a build-up of the tungsten at another location along the wire. Failure occurs when the notch causes separation of the filament, and vaporization is not the critical cause of the filament failure. The reason for this faceting, notching and transporting of the material along the wire has been attributed to the presence of oxygen remaining from ambient air in the poor vacuum which they are normally sealed.

The phenomenon of d-c notching seems to involve two phases; namely, (1) formation of small facets; and (2) growth of these facets by electro-migration. These two effects eventually breaking the continuity of the current.

This faceting and notching has in the past been attributed to the presence of oxygen, use of known oxygen

getters, such as phosphorus or potassium, has not solved the problem of d-c notching.

It is therefore an object of the present invention to provide a method, and product produced thereby, wherein the problem of d-c notching and metal transport in filament wires under the effect of direct current can be inhibited or completely eliminated.

According to one feature of the invention, it involves the recognition that the faceting effect is caused by exposure of crystallographic planes of the metal of lowest surface energy to certain reactive gases, particularly oxygen and nitrogen, which are selectively chemisorbed upon certain planes, thus lowering their free surface energy. Elimination of chemically available oxygen and nitrogen and other reactive gases by vacuum and flash-heating of the filament helps to overcome this faceting effect.

Another feature of the invention involves the recognition that growth of the facets is caused by "electromigration." The electrons and electron holes in the tungsten filament move in the wire when a d-c voltage is applied. As they move, they interact with the tungsten atoms and cause the latter to migrate along the wire. If the wire has faceted into different planes with corresponding different diffusion coefficients, then the tungsten atoms will move more swiftly along one plane and accumulate in layers on the other plane where they move more slowly, with a resulting growth of the facets. A heavy inert gas, such as argon, krypton or xenon, in contact with the planes has the beneficial effect of interfering with the motion of the atoms and inhibits electromigration.

Briefly, the invention comprises a combination of steps for the prevention of faceting of the wire metal and also prevention of the growth of the facets if any do form.

The formation of facets is inhibited by elimination of the reactive gases from the envelope, and use of a heavy inert gas back-fill inhibits the transport of the tungsten metal along the filament. Elimination of reactive gases, particularly oxygen and nitrogen, may be accomplished by applying a high vacuum. Instantaneous flash heating of the filament also helps drive off the reactive gases, as does baking the bulb envelope, and flushing out the envelope with an inert flush gas. The envelope is then back-filled with a heavy inert gas selected from Group VIIIA of the periodic table, particularly argon, krypton or xenon, up to a pressure of $\frac{1}{2}$ to 3 atmospheres around the metal filament, and the bulb enclosure around the filament is sealed from the ambient atmosphere.

For a better understanding of the invention and the advantages thereof reference may be had to the accompanying drawings of which

FIG. 1 is a magnified view (500X) of a prior art tungsten filament which has been subjected to 400 hours of direct current flow at a temperature of 1,750°C (brightness temperature) and which exhibits a serious d-c notching condition; FIG. 2 is a magnified view (500X) of a tungsten wire specimen similar to that prepared according to the method of the present invention in a bulb evacuated, baked, flushed out and filled with argon, exposed to direct current at 1,750°C (brightness) after 1,400 hours, showing a substantially decreased d-c notching effect in spite of the longer exposure.

As shown in FIG. 1 after 400 hours use on direct current, the prior art problem of faceting and transporta-

tion of the metal to higher points along the wire is apparent, leading to eventual failure of the filament wire.

In FIG. 2, a similar tungsten wire is shown which has withstood 1,400 hours on direct current, in a bulb envelope evacuated to 10^{-6} mm Hg pressure, baked at 400°C for 16 hours while under vacuum, flushed while hot for 30 seconds with hydrogen gas, the filament was flash-heated to incandescence; and the bulb envelope was flushed with argon gas and backfilled with argon to a pressure of one half atmosphere, i.e., 380 mm Hg.

In general, the following steps have produced satisfactory results in the preparation of miniature and sub-miniature d-c incandescent bulbs with tungsten filaments:

a. Reducing the content of all gases, particularly oxygen and nitrogen by evacuating the surrounding bulb envelope to a pressure of less than 10^{-3} millimeter Hg.

b. During the evacuation, baking the envelope bulb to drive off adsorbed gases at a temperature up to about 400°C but below the softening point of the glass bulb.

c. Optionally, the bulbs may be flushed out at least once with a pure heavy inert gas consisting of at least one gas of Group VIIIA of the periodic chart, preferably argon, krypton or xenon.

d. Also optionally, during the baking operation, an additional step may include quick flushing out of the bulb with hydrogen gas during the bake-out, lasting for less than 30 seconds so as not to lose the vacuum seal. This added step may be helpful to remove and flush out residual active gases such as oxygen, nitrogen, carbon dioxide and halogens. The remaining reactive gases should preferably be less than 10^{-3} mm Hg total gases.

e. A further optional penultimate step to help eliminate residual gases is by heating the filament to incandescence, i.e., "flashing" the filament.

f. The envelope bulb is then back-filled to a pressure up to 3 atmospheres with the heavy inert gas; and

g. the envelope is sealed gas-tight to the ambient atmosphere.

The elimination of nitrogen as well as oxygen is important because the present inventors have found that nitrogen also acts to cause faceting and notching in a manner similar to the presence of oxygen.

The gas used to flush and back-fill the envelope is one of the heavier inert gases argon, krypton or xenon in order to inhibit electro-migration. Helium or neon are too light for this purpose. Radon, being radioactive, is not used for safety reasons.

It will be obvious to those skilled in the art upon reading the foregoing disclosure that many modifications and alterations in the specific method steps and products disclosed as non-limiting examples may be made within the general context of the invention, and that numerous modifications, alterations and additions may be made thereto within the true spirit and scope of the invention as set forth in the appended claims.

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

1. In the manufacture of miniature incandescent lamps having wire filaments of tungsten for operation on direct current at temperatures less than 2,400°C, the method of treating the wire filament to inhibit d-c notching and electromigration metal transport along the wire, which includes the steps of:

a. exhausting from the bulb enclosure reactive gases including oxygen and nitrogen by applying a vacuum to the lamp bulb to a pressure of less than about 10^{-3} millimeters Hg,

b. filling the bulb surrounding said filament with a heavy inert gas selected from Group VIIIA of the periodic table, and

c. sealing said bulb from the ambient atmosphere with less than 10^{-3} mm Hg of total reactive gases including chemically available oxygen and chemically available nitrogen within the bulb.

2. The method according to claim 1 wherein the inert gas is argon.

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