

[54] **MANDREL FOR MANUFACTURING
FILAMENT COILS AND METHOD FOR
MANUFACTURING FILAMENT COILS**

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[51] Int. Cl. **B21f 45/00**

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[56] **References Cited**

UNITED STATES PATENTS

1,599,241	9/1926	Mery	140/71.5
3,045,713	7/1962	Cleven	140/71.5
3,461,921	8/1969	Ackerman	140/71.5

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[57] **ABSTRACT**

A mandrel and a method for manufacturing filament coils for electric lamps. The mandrel is coated with a material, such as copper, which does not alloy with the filament coil during annealing. The coil is wound on the coated mandrel and the mandrel is dissolved after the filament is annealed.

13 Claims, 2 Drawing Figures

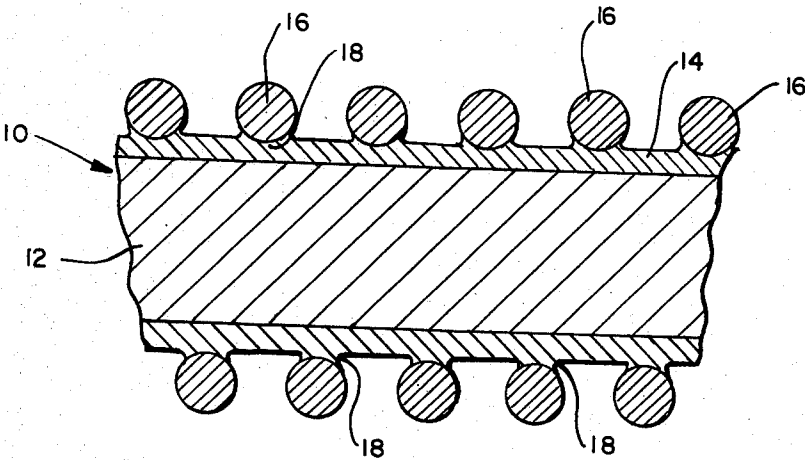


FIG. 1

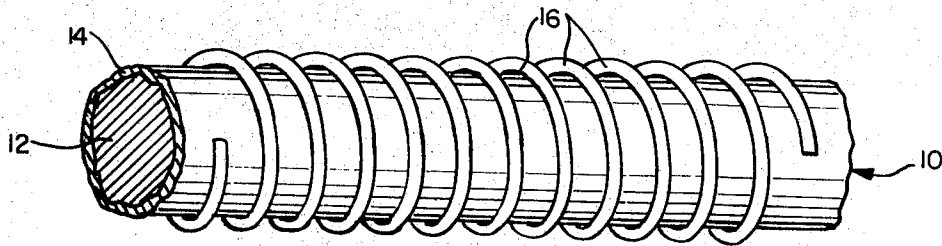
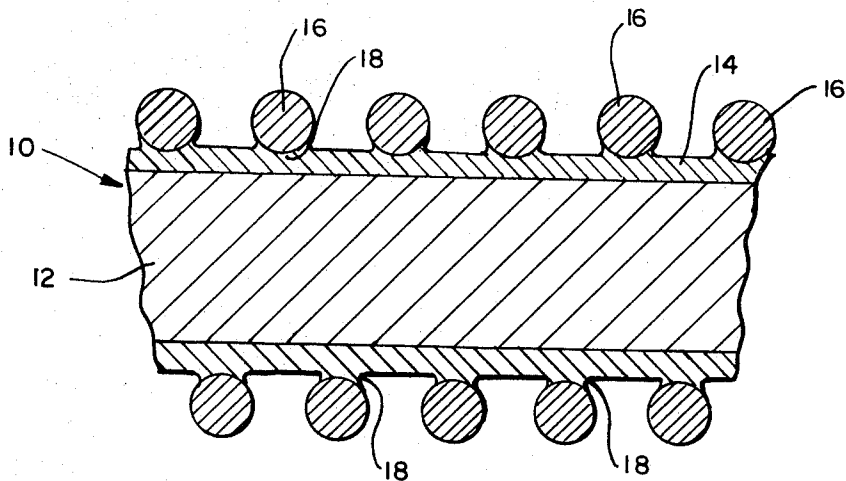


FIG. 2



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MANDREL FOR MANUFACTURING FILAMENT COILS AND METHOD FOR MANUFACTURING FILAMENT COILS

BACKGROUND OF THE INVENTION

Tungsten filaments for incandescent lamps are commonly manufactured in the form of coils or coiled coils, the latter comprising a coil which is itself coiled. The most commonly used method for making such filament coils comprises the following steps: (1) winding tungsten wire as a coil on an elongated mandrel; (2) annealing the coil while still on the mandrel by passing it through a hydrogen furnace maintained at an elevated temperature, usually about 1,200° C.; (3) cutting the mandrel and coil to the desired length of the individual filaments; (4) dissolving away the individual mandrels in a suitable acid such as hydrochloric acid; and (5) re-annealing the tungsten wire in wet hydrogen at an elevated temperature, usually round 1,300° C., for cleaning.

The two materials for mandrels in common use throughout the lamp industry are steel and molybdenum. Aside from economics, the choice of mandrel material is severely limited by a large number of technical requirements. The most significant of these requirements for the mandrel are: (1) high tensile strength is required for filament winding and annealing under tension without plastic deformation of the mandrel; (2) the melting point of the mandrel must be above the annealing temperature required to set the filament coil prior to cutting; (3) the temperature coefficient of expansion of the mandrel should be close to that of the filament coil at the annealing temperature; (4) an adequate amount of bonding is needed between the filament coil and the mandrel during annealing to assure the retention of coil geometry upon subsequent cutting of the mandrel into individual filaments; and (5) the mandrel must be capable of being dissolved chemically without affecting the tungsten coil. For the foregoing reasons steel mandrels have been and are currently being used almost universally for most coiled filaments, while molybdenum mandrels are used for coiled-coil filaments which require annealing temperatures above the melting point of steel.

The use of steel for the mandrel material, although economical, is undesirable from the standpoint of quality of the filaments produced, since steel has an adverse effect on the metallurgical properties of the tungsten filament during the manufacturing process. The main reason is that in forming the bond between the coil and the mandrel during the annealing step, a small amount of iron inevitably diffuses into and embrittles the tungsten. To understand this it should be considered that in the heavily drawn tungsten wire used as lamp filaments, a fibrous substructure exists prior to recrystallization, the average subgrain size of this structure being less than one micron. It is well recognized that substitutional diffusion of elements such as iron in tungsten occurs much more rapidly along sub-boundaries and grain boundaries of the tungsten than within the grains through the normal lattice sites. Since the activation energy for volume diffusion (within the grains)—being around 120 Kcal/mole for iron in tungsten—is several times higher than that for interfacial diffusion (along boundaries), the ratio of the relative amounts of interfacial to volume diffusion increases with decreasing annealing temperature. Therefore for tungsten material, which has a high concentration of sub-boundaries and grain boundaries per unit volume in the heavily drawn wire commonly used for lamp filaments, a substantial amount of iron can diffuse, by interfacial diffusion into the tungsten preferentially along the boundaries during annealing at a relatively low temperature (less than one-half the temperature of its melting point). Furthermore, a concentration gradient of iron in the tungsten coil also exists, which decreases from the inner coil surface, in contact with the steel mandrel, to the outer coil surface, which is never in contact with the mandrel.

An appreciable amount of iron diffuses into the filament coil. This has been substantiated by impurity analyses on annealed coils, after dissolving away the steel mandrel. The

amount of iron present after annealing varies from one coil segment to another, and depends upon the prior history of the tungsten wire. For tungsten wire approximately 2.5 mils in diameter, annealing in the manner described above typically results in an increase in iron concentration up to 50–100 ppm (by weight), as compared with 10 ppm or less of iron in the wire prior to annealing. Analyses of the surface material etched off from the annealed coil shows concentrations of iron substantially above 100 ppm.

The presence of localized segregations of iron diffused into a tungsten wire filament coil has been found to be responsible for the formation of numerous slivers of iron on annealed filament coils after the mandrel has been dissolved away. When the coil is stretched out, the slivers are evident on the inner surface of the coil at the areas where it was originally in contact with the steel mandrel. The amount of slivering increases with increasing concentration of iron, and is absent wherever the diffusion of iron into the tungsten wire coil is prevented. On tungsten wire coils made using standard production techniques, the slivers frequently bridge adjacent coil turns and thus promote arcing in lamps during operation.

Tungsten wire filament coils having excessive segregation of iron are also brittle and contribute to shrinkage (rejects) in the manufacture of incandescent lamps. Fracture of the filaments frequently occurs at the inner side of the coil being clamped by the nickel leads during mounting of the coil in a lamp. This is indicative of the strong embrittlement effect of localized iron, since the compressive stresses at the inner side of the coil should favor plastic flow instead of crack initiation.

Another detrimental effect of iron is to reduce the advantages achieved by doping in non-sag filaments. Incandescent lamp filaments are normally doped with small quantities of aluminum, silicon, and potassium compounds to raise the recrystallization temperature and to develop an interlocking grain structure characteristic of sag resistant tungsten at elevated temperatures. It is well known that iron diffused into doped tungsten reduces the recrystallization temperature and develops a non-interlocking equi-axed grain structure, partially nullifying the effect of dopants in producing a non-sag material.

In accordance with the present invention a new type mandrel is utilized for forming filament coils as well as a new method for manufacturing the coils. A material which has a lower melting point than the filament material and does not alloy therewith is coated over an inner core of the mandrel. The coil is then wound over the coated mandrel and is annealed. Upon annealing the coating material forms a strong bond with the coil, serves as a barrier to the diffusion of the inner core material into the core, and thus eliminates the formation of slivers on and the embrittlement of the annealed coil. The annealed coil is cut into desired lengths and the mandrel is dissolved from the coil. The coating material also aids in speeding the dissolving process.

In a preferred embodiment of the invention, copper or a copper alloy is used as the coating material over an inner mandrel core of steel. The copper or copper alloy melts during the annealing of the filament coil and forms a bond therewith to provide a better geometrical set. The mandrels also can be dissolved very rapidly from the coils using a suitable acid, such as nitric acid.

It is therefore an object of the present invention to provide a novel mandrel to be used in the production of filament coils.

A further object is to provide a process for making filament coils which includes winding the coil over a coated mandrel, annealing the coil and dissolving the mandrel.

Other objects and advantages of the present invention will become more apparent upon reference to the following specification and annexed drawings, in which:

FIG. 1 is a perspective view of the mandrel of the subject invention showing the filament coil wound thereon; and

FIG. 2 is a cross-section of an annealed coil shown on a mandrel.

Referring to FIG. 1, a mandrel 10 has an inner core 12 on which is coated a thin layer of a suitable material 14. In the preferred embodiment of the invention being described, the core 12 is steel and the material of the coating 14 is copper. Alloys of copper also can be used as is described below. Where steel is used as the inner core and copper or a copper alloy as the coating material, the latter can be plated or clad on to the inner core.

A coil 16 of filament wire is wound on the outer layer 14 out of direct contact with the mandrel inner core 12. The wire is, for example, of tungsten material and any suitable number of turns per inch of the coil can be wound.

Considering now the preferred embodiment of the manufacturing process of the mandrel shown in FIG. 1, the copper or a copper alloy is coated onto a steel wire core which is initially at a relatively large diameter wire size. For example, the wire is in the order of 0.1 inch in diameter and the thickness of the coating is 0.03 inch. The coated steel wire is then drawn to a fine wire size, for example, in the order of 0.01 inch in diameter with the coating layer having a thickness of about 0.002 inch. By doing this the copper or copper alloy becomes sufficiently work-hardened to the extent that it resists deformation during winding of the coil on the mandrel.

A coil of tungsten wire is wound on the mandrel with the desired number of turns per inch. The tungsten coil on the mandrel is then annealed around 1,100° C by passing it through a tube furnace containing a non-oxidizing atmosphere of hydrogen or nitrogen. The mandrel and coil are then cooled to room temperature.

After the annealing and cooling, the coil and the mandrel are cut to desired lengths. The individual cut mandrels are then dissolved from the coils. To do the latter, the individual coils and mandrels are placed in a container which is partially filled with water at room temperature. Concentrated nitric acid is then added to the water to attain an acid concentration of 25 to 35 percent. The entire mandrel is dissolved rapidly in this solution leaving the coil. The tungsten coils are ready to be used as filaments after they are removed from the acid bath and washed.

The present invention has numerous advantages with respect to the copper-coated mandrel itself. Copper has a melting point within the temperature range required to "set" the tungsten coil by annealing. Visual inspection of the annealed coils made in accordance with the invention showed that the copper was molten during the annealing process (the melting point of copper is 1,083° C.) and that a strong bond was formed between the coil and the mandrel copper layer upon cooling. This is shown in FIG. 2 where bonding points 18 of the coil to the previously molten coating material 14 are shown. The bond has been found to be stronger than that normally obtained from a coil wound on a steel mandrel without copper coating. The reason for this is that the flow of molten copper partially around the tungsten wire provides a larger area of bonding between the tungsten wire and the copper coated mandrel. The strong bond formed between the filament coil and the copper upon melting and resolidifying of the copper aids in retaining the coil geometry upon cutting the annealed continuous coil into the desired lengths of individual filaments.

As a further advantage, the surface tension of copper is sufficiently high that the molten copper does not drip off during annealing of the filament and remains as a layer over the steel core, the latter never being in contact with the tungsten coil. This is also illustrated in FIG. 2. The bond is formed by resolidification of the molten copper coating 14 partially around the tungsten coil 16 at points 18 with a layer of copper 14 remaining over the inner steel core 12. It has been found that a copper coating of 0.002 inch thick is sufficient to prevent the diffusion of iron from the steel core into the tungsten filament coil, so that formation of slivers on and embrittlement of the annealed filament coil is prevented.

Another advantage of using copper-covered steel mandrel is the increase in efficiency of coil processing through the use of

nitric acid in dissolving the mandrel. In the conventional prior art method, steel mandrels are dissolved in hydrochloric acid and require as long as over one hour for complete dissolution of mandrels of large diameter. In the present invention, the copper-covered mandrels are dissolved rapidly in nitric acid, preferably 25 percent nitric acid to which is added 10 percent sulfuric acid. For examples, complete dissolution of steel mandrels 0.011 inch diameter in hydrochloric acid requires about 25 minutes, whereas copper-covered steel mandrels of the same size are completely dissolved in a nitric acid - sulfuric acid bath within 1 minute.

That the entire copper-covered mandrel can be dissolved rapidly in a relatively concentrated solution of nitric acid is attributed to the depassivating effect of the copper coating on the inner steel core. Without the copper coating, steel becomes passivated in nitric acid at concentrations above approximately 20 percent and resists attack by the acid. The copper-covered steel mandrels, however, are readily dissolved in nitric acid at concentrations up to 50 percent.

It has been found that the use of the copper-covered steel mandrel and the process for dissolving the mandrels further improves the quality of the completed coiled filaments. Since the copper-covered steel mandrels can be dissolved within a few minutes without applying heat, the weight loss on coils which occurs during mandrel dissolving is substantially less than on coils processed with hydrochloric acid, typically the weight loss being reduced by 50 percent. The decrease in weight loss increases the uniformity of processed coils and the lumen output of the filament used in a lamp.

An additional advantage of dissolving the copper-covered steel mandrel in nitric acid is that the aquadag coating on the tungsten coil is simultaneously removed. In the conventional method of dissolving the uncoated steel mandrel in hydrochloric acid, the Aquadag remains on the tungsten coil and is removed by subsequent firing of the coils in wet hydrogen above 1,400° C. In the present invention, firing the coils for cleaning is often times no longer necessary. Coils from which the mandrels are dissolved away in nitric acid at temperatures above 80° C are generally free of Aquadag and can be used in lamps without further cleaning. This contributes to a reduction in manufacturing cost.

The present invention is not restricted to pure copper as the coating material and a specific type of steel as the inner core. Alloys of copper also can be used for the coating material. For example, copper-base alloys coated on the steel mandrel can achieve the same results as are described above. The addition of 1 percent - 5 percent of silver or indium into copper decreases the melting point of pure copper. Since alloys of these compositions exhibit a liquid-solid region extending through a wide temperature range, the alloys remain partially molten in a temperature range lower than the melting point of pure copper. This has two advantages over pure copper. First, control of the annealing temperature of the tungsten coil is less critical. Second, the ability to form a bond between the coil and the mandrel at lower temperatures further improves the ductility of the tungsten since the inherent ductility of heavily drawn tungsten wire decreases with increasing annealing temperature. The presence of these alloying elements, such as indium or silver, has no detrimental effect on the tungsten coil because of the lack of solubility of these elements in tungsten.

Filament coils processed in the manner previously described on copper-covered or copper-alloyed mandrels have been inspected and have been found to be substantially completely free of slivers. This indicates the absence of diffusion of iron into the coil. The absence of slivering is also accompanied by a marked increase in ductility. The increase in ductility is most pronounced on coils which are fully recrystallized; that is, annealed or flashed at temperatures above 2,000° C. Recrystallized coils processed on copper-covered steel mandrels can be stretched at room temperature for length several times greater than coils processed similarly on bare steel mandrels before fracture occurs. This not only im-

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proves the shrinkage, decreases waste in coil mounting during manufacturing, but also increase the cold-shock resistance of filaments when mounted in lamps.

What is claimed is:

1. In combination a mandrel for making filaments for electric lamps comprising an inner core of a first material and a coating of a material over said core, filament material wound over said mandrel, said coating material having a melting temperature which is lower than the melting temperature of the filament material.

2. The combination of claim 1 wherein the material of the inner core includes iron.

3. The combination of claim 1 wherein the coating material includes copper.

4. The combination of claim 2 wherein the coating material includes copper.

5. The combination of claim 4 wherein the filament material includes tungsten.

6. The combination of claim 2 wherein the coating material is copper alloyed with indium.

7. The combination of claim 2 wherein the coating material is copper alloyed with silver.

8. The combination of claim 1 wherein the material of the inner core is steel, the coating material is copper or a copper-alloy, and the filament material is tungsten.

9. The process of manufacturing lamp filaments comprising the steps of forming a mandrel having an inner core and an outer coating of a material different from that of the inner core, winding a coil of filament wire over the mandrel coating, annealing the filament wire by heating, and dissolving the mandrel from the filament in an acid bath.

10. The process of claim 9 wherein the annealing step is carried out at a temperature at which the mandrel coating material melts and a bond is formed between the filament wire and the coating material.

11. The process of claim 9 wherein said dissolving step is carried out in an acid bath containing nitric acid.

12. The process of claim 11 wherein said acid bath also contains sulfuric acid.

13. The process of claim 9 wherein the coating material includes copper and the annealing step is carried out at a temperature near the melting temperature of the copper coating material.

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