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TUNGSTEN ALLOY

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FIG. 1.

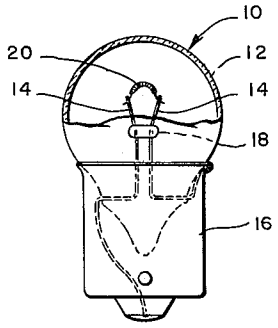
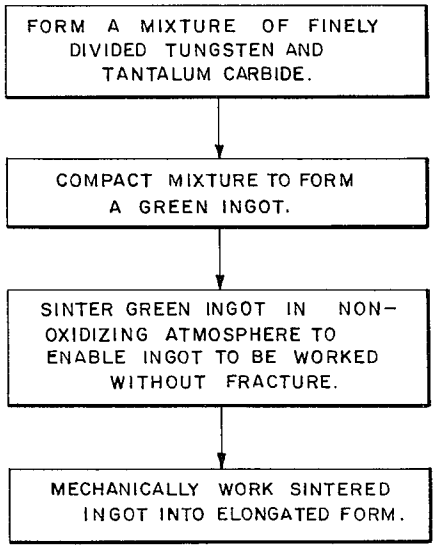


FIG. 2.



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TUNGSTEN ALLOY

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This invention relates to tungsten alloys and, more particularly, to a tungsten-tantalum alloy and an incandescible filament made from this alloy as well as a method for preparing such an alloy and filament.

Tungsten is well known as a refractory material and conventional lamp filaments are fabricated of so-called "doped" tungsten. The high-temperature strength characteristics of tungsten are not as good as desired and this is readily observed by subjecting the usual incandescent lamp to shock or vibration. It is also desired to improve the high-temperature-strength characteristics of tungsten members for applications other than incandescent filaments.

It is the general object of this invention to avoid and overcome the foregoing and other difficulties of and objections to prior-art practices by the provision of a tungsten alloy having high-strength characteristics at high temperatures.

It is another object to provide a tungsten base filament for incandescent lamps, which filament has high-strength characteristics when operated.

It is an additional object to provide preferred and optimum proportions for the constituents comprising the present tungsten alloy.

The aforesaid objects of the invention, and other objects which will become apparent as the description proceeds, are achieved by providing a tungsten-tantalum alloy which includes carbon. The alloy contains tungsten in amount of from about 99.9% to 98% by weight, with remaining elements in the alloy consisting essentially of tantalum and carbon, and with the atom ratio of carbon to tantalum being from 0.2 to 0.6. There is also provided a method for making such a tungsten member, which member can be fabricated as an incandescent lamp filament.

For a better understanding of the invention, reference should be had to the accompanying drawings wherein:

FIG. 1 is an elevational view, partly in section, illustrating a miniature-type incandescent lamp incorporating the tungsten alloy filament of the present invention;

FIG. 2 is a flow diagram setting forth the method for increasing the high-temperature strength of an elongated tungsten member.

The lamp as shown in FIG. 1 is a miniature type since the present filament has particular utility with such lamps. It should be understood, however, that the present filamentary material can be used with any size or type of incandescent lamp and, in addition, tungsten members which are fabricated from the present alloy can be used in structural applications where high-strength characteristics at high temperatures are required.

With specific reference to the form of the invention illustrated in the drawings, the numeral 10 in FIG. 1 indicates generally a miniature-type incandescent lamp comprising an envelope 12 having lead conductors 14 butt sealed through the neck portion thereof. The lead conductors 14 are connected to a bayonet-type base 16. A mounting bead 18 facilitates support for the lead conductors 14, and the filament 20 of the present invention is

carried between the inwardly extending extremities of the lead conductors 14.

In preparing the tungsten alloy of the present invention, and as generally set forth in FIG. 2, finely divided tungsten powder and finely divided tantalum carbide (TaC) are thoroughly dry mixed in a ball mill. The tungsten comprises from 99.9% to 98% by weight of the mix and the tantalum carbide comprises from 0.1% to 2% by weight of the mix. The optimum mix proportions are 99.5% by weight tungsten and 0.5% by weight tantalum carbide. The state of division of the tungsten and the tantalum carbide are not critical, but as an example, the average particle diameter of the tungsten is approximately 4 microns and the tantalum carbide is of such size that it will pass a No. 325 mesh.

After thorough mixing, the tungsten-tantalum carbide powder is pressed into a green ingot. As a specific example, 2050 grams of the mixture are pressed into an ingot having dimensions of 0.725 inch by 0.655 inch by 24 inches and the pressure used in forming the green ingot is 17 tons per square inch. While the resulting pressed green ingot has sufficient strength to facilitate its being handled, where an electrical sintering technique is utilized it is highly desirable to presinter the ingot in order to render it more self-sustaining in nature so that it can readily be clamped between electrodes. As a specific example, the pressed green ingot is pre-sintered in a dry-hydrogen atmosphere at a temperature of about 1000° C. for about 20 minutes, for example, using an electric furnace. This presintering schedule can be varied considerably.

The self-sustaining green ingot is then placed into a vertical position in an electrical sintering bottle, wherein the top end portion of the ingot is clamped between heavy molybdenum electrodes and a tungsten contact clamp connects to the bottom of the ingot and is suspended in a mercury pool to facilitate electric contact. Electric sintering is normally effected in a dry-hydrogen atmosphere in a double-walled copper bottle which is preferably water cooled and such sintering bottles are well known. With an ingot of the aforementioned dimensions, a flow of hydrogen through the sintering bottle of approximately 100 cubic feet per hour has been found to be satisfactory.

The electrical sintering for the foregoing ingot is subject to considerable variation and any suitable sintering schedule can be used, provided the ingot is sintered at a sufficient temperature and for a sufficient time to enable it to be mechanically elongated in configuration without fracturing. As a specific example for sintering the ingot as specified hereinbefore, following is a suitable sintering schedule.

Sintering current R.M.S., amperes (60 c.p.s.):	Time current is held, minutes
500	1
800	3
1000	2
1400	5
1800	4
2200	3
2600	3
3000	2
3400	2
3800	2
4200	2
4400	10
4800	0.5
5200	0.5
5400	15

The maximum sintering current is normally held for a somewhat extended period. The gradual increase in sintering current is desirable in order to permit any residual impurities to volatilize before the maximum sintering current is applied.

The relative proportions of tungsten to tantalum in the present alloy are the same before and after sintering. Some carbon is volatilized from the alloy during the sintering, however, and after sintering, the atom ratio of carbon to tantalum in the finished alloy can vary from 0.2 to 0.6.

After the ingot has been sintered, it is cooled within the sintering bottle, while maintaining the stream of dry hydrogen thereover. Approximately 5% of the length dimension is removed from each end of the cooled and sintered ingot, since the sintering of these portions is uneven due to the contact electrodes, such a procedure being standard sintering practice. The resulting sintered ingot is then heated to approximately 1600° C.–1650° C. in a non-oxidizing atmosphere such as hydrogen and swaged through three swaging dies, using conventional swaging equipment and conventional swaging practices. This will produce a partially swaged ingot having a generally circular cross-section and a diameter of approximately 0.467 inch. The partially swaged ingot is then annealed to relieve strains and annealing is accomplished by passing a current of 2600 amperes therethrough for a period of two minutes, while maintaining the partially swaged ingot in a dry-hydrogen atmosphere. Thereafter the ingot is heated to approximately 1350–1400° C. and is swaged through two swaging dies to a diameter of about 0.337 inch. The partially swaged ingot is then reheated to about 1900° C. in a non-oxidizing atmosphere such as hydrogen for about three minutes, in order to relieve strains, and it is thereafter heated to about 1300° C. and swaged to a cross-sectional diameter of 0.186 inch. The elongated material is then annealed at a temperature of 1950° C. in a non-oxidizing atmosphere such as hydrogen for about one and one-half minutes, reheated to about 1300° C., and reswaged to a cross-sectional diameter of about 0.083 inch.

After a diameter of 0.083 inch is achieved, further reduction in diameter is achieved through hot-drawing, using conventional drawing equipment. As an example, the elongated material is heated to approximately 800 to 900° C. and is reduced approximately 12% in diameter on each pass through a drawing die. After approximately every fifth pass through the drawing dies, the drawn material is annealed at a temperature of about 1700° C. in a non-oxidizing atmosphere such as hydrogen for about ten minutes, in order to relieve strains. The drawing procedures are continued until the desired wire diameter is achieved, which as a specific example is 1.23 mils.

After the wire has been drawn to size, it is formed into filament coils by well-known techniques and then incorporated into a lamp such as shown in FIG. 1. While filament coils normally have a generally helical configuration, in some cases the helical coils are again coiled to form a coiled-coil, such practices being usual in the art. Also, for some special types of miniature lamps, a straight wire filament is utilized.

It should be understood that the foregoing swaging-annealing-swaging-drawing-annealing-drawing procedures are only given in detail by way of specific example and may be varied considerably to achieve substantially the same end result. For example, while hydrogen is the preferred atmosphere for sintering and swaging, other non-oxidizing atmospheres can be utilized, such as the rare gases.

Other additive materials can be incorporated into the green ingot, such as the standard so-called alkali silicate doping, which causes the tungsten to recrystallize with what is known in the art as an interlocking grain structure. As a specific example, potassium, alumina and silica are added as potassium chloride, potassium silicate and aluminum chloride and these materials are normally added either to the tungstic oxide or to tungstic acid, before reduction to metal. During the sintering, the majority of these doping constituents will volatilize from the tungsten. While these doping constituents in some cases improve the performance of incandescible filament wire, they do not materially affect the high-temperature strength of the present tungsten alloy.

During the initial mixing procedures, the tantalum carbide can be added to tungstic acid or to tungsten compound during a previous tungsten purification step, after which the resulting acid is converted to the metal by heating in a reducing atmosphere. Also, the tantalum carbide can be added in modified form such as Ta_2C.

In testing the present tungsten alloy, a prepared batch of pure tungsten was separated into two parts. One of these parts was modified by adding the preferred amount of tantalum carbide and the two tungsten partial batches were sintered into coherent form in the manner as specified hereinbefore. Following are the test results which were obtained.

Material Tested	Tested Temperature, ° F.	0.2% Yield Stress, p.s.i.	Tensile Strength, p.s.i.	Hardness, DPH
TaC alloy	2,500	56,000	67,000	----------
Pure W	2,500	11,000	22,000	----------
TaC alloy	1,800	----------	----------	172
Pure W	1,800	----------	----------	80

At a temperature of 2500° F., the yield strength of the present alloy is approximately five times higher than that of pure tungsten and the tensile strength is triple that of the pure tungsten. In addition, at a temperature of 1800° F., the hardness of the present alloy is over twice that of pure tungsten.

Because of the improved yield and tensile strength characteristics, the present alloy has application in shock-resistant incandescent lamp filaments, particularly of the miniature type. In addition, the present alloy has application for structural or similar members which are intended to be operated at extremely high temperatures, as well as tungsten sheet material.

It will be recognized that the objects of the present invention have been achieved by providing a tungsten alloy having high-strength characteristics at high temperatures. This alloy can be fabricated into an elongated structural member or an incandescible filament. There have also been provided preferred and optimum proportions for the constituents comprising the present tungsten alloy.

While a best example has been illustrated and described in detail, it is to be particularly understood that the invention is not limited thereto or thereby.

I claim:

1. A sintered tungsten-tantalum alloy including carbon and having high-strength characteristics at high temperatures, said alloy containing tungsten in amount of from about 99.9% to 98% by weight, remaining elements in said alloy consisting essentially of tantalum and carbon, and the atom ratio of carbon to tantalum in said alloy being from 0.2 to 0.6.

2. A sintered tungsten-tantalum alloy including carbon and having high-strength characteristics at high temperatures, said alloy containing tungsten in amount of about 99.5% by weight, remaining elements in said alloy consisting essentially of tantalum and carbon, and the atom ratio of carbon to tantalum in said alloy being from 0.2 to 0.6.

3. A sintered powder metallurgy tungsten-tantalum alloy including carbon and having high-strength characteristics at high temperatures and a greatly elongated configuration, said alloy containing tungsten in amount of from about 99.9% to 98% by weight, remaining ele-

ments in said alloy consisting essentially of tantalum and carbon, and the atom ratio of carbon to tantalum in said alloy being from 0.2 to 0.6.

4. A sintered powder-metallurgy tungsten-tantalum alloy including carbon and formed as a filament and also having high-strength characteristics at high temperatures, said alloy containing tungsten in amount of from about 99.9% to 98% by weight, remaining elements in said alloy consisting essentially of tantalum and carbon, and the atom ratio of carbon to tantalum in said alloy being from 0.2 to 0.6.

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