

REFRACTORY METAL ANNEALING BANDS

BACKGROUND OF THE INVENTION

5 Participants of the wire-making industry have had a long-felt need for better annealing bands, better methods for making annealing bands, and better methods for annealing a metal wire. In wire drawing arts, it is common practice to anneal copper wire in-line through resistance heating between drawing steps, or as a final heat treatment. For that purpose the wire is passed over two wheels (shives) with a voltage applied to them. That way, a current is passed through the wire, which heats the wire to its annealing temperature. A so-called 'annealing band', which is part of the wheels (shive) assembly), provides the contact area for the wire when it passes over the wheel. An annealing wheel assembly (shive) can be a water cool hub and plate on one side, and a second plate that bolts to the assembly with the annealing band covering the hub. It looks similar to a pulley and fan belt, with the wire being the belt.

Nickel or nickel alloys are ordinarily used to make annealing bands. Unfortunately, wire manufacturers report that the lifetime of currently used annealing bands is very short and that frequent replacements of annealing bands are necessary. Wear mechanisms include friction between the wheel (shive) and the wire and arcing due to the voltage drop between the band and the wire. When replacing a worn annealing band, the equipment needs to be shut down, which constitutes two problems: loss of manufacturing time and interruption of a continuous process. Some efforts have been directed to producing annealing bands consisting of copper and niobium. However, such efforts have failed to produce an annealing band with suitable properties.

For the foregoing reasons, there is a need to develop improved annealing bands.

For the foregoing reasons, there is a need to develop improved methods for making such bands.

For the foregoing reasons, there is a need to develop improved methods for annealing a metal wire.

SUMMARY OF THE INVENTION

The invention relates to a process for making an annealing band that involves the steps of (a) producing a refractory metal powder; (b) optionally blending the powder with an oxide component or a nitride component or a carbide component; (c) consolidating the powder or powder blend and forming a consolidated powder component; (d) subjecting the consolidated powder component to thermo-mechanical treatment and forming a sheet, or tube; (e) cutting the sheet, or tube into a strip, or ring; and (f) forming an annealing band from the strip, in which the annealing band excludes an annealing band consisting of copper and niobium.

The invention also relates to a member comprising a refractory metal annealing band, in which the annealing band excludes an annealing band consisting of copper and niobium. The invention also relates to a process for annealing a metal wire that involves the steps of (a) providing two annealing wheel assemblies (an annealing shive), in which each comprising a first annealing wheel (shive body), a second annealing wheel (shive plate) and an annealing band such that the first annealing wheel and the second annealing wheel that are attached to each other each have a refractory metal annealing band, located between the first annealing wheel and the second annealing wheel, for providing a contact area for a wire; (b) passing a wire over the annealing bands of both annealing wheel assemblies; (c) applying a voltage between the first annealing band (a current from the shive body, through the annealing band) and the second annealing band, and thereby passing a current to the wire under conditions that heat the wire to at least the annealing temperature of the wire, and thereby annealing the wire, in which the annealing band excludes an annealing band consisting of copper and niobium.

The invention also relates to a two-step process for making an annealing band that involves the steps of (a) cutting a sheet into a strip; and (b) forming an annealing band from the strip; in which the metal sheet has been formed by subjecting a consolidated powder component to thermomechanical treatment; the consolidated powder component has been formed by consolidating a refractory metal powder into the consolidated powder component; and the powder has been optionally blended with an oxide component or a nitride component or a carbide component before it has been consolidated, in which the annealing band excludes

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an annealing band consisting of copper and niobium. The invention also relates to a one-step process for making an annealing band comprising forming an annealing band from the strip, in which the strip has been cut from a sheet that has been formed by subjecting the consolidated powder component to thermomechanical treatment; the consolidated powder component has been formed by consolidating a refractory metal powder into the consolidated powder component, in which the powder has been optionally blended with an oxide component or a nitride component or a carbide component before it is consolidated, in which the annealing band excludes an annealing band consisting of copper and niobium.

The invention also relates to a member comprising a refractory metal annealing band, in which the refractory metal is selected from the group consisting of (a) niobium, (b) tantalum, (c) molybdenum, (d) tungsten, (e) niobium alloys, (f) tantalum alloys, (g) molybdenum alloys, (h) tungsten alloys, (i) alloys of (1) a refractory metal and (2) a non-refractory metal selected from the group consisting of copper, nickel, titanium, iron, cobalt, and (j) combinations thereof, such that the annealing band has a thickness ranging from about 0.01" to about 0.5", a width ranging from about 0.25" to about 10", a diameter ranging from about 1.5" to about 6 ft, in which the annealing band excludes an annealing band consisting of copper and niobium.

DESCRIPTION OF THE FIGURES

These and other features, aspects, and advantages of the present invention will become better understood with reference to the following description and appended claims, where

Fig. 1 shows a side view of an annealing band;

Fig. 2 shows a cross-sectional view of the annealing band shown in Fig. 1;

Fig. 3 shows a side view of an annealing wheel assembly containing the annealing band;

Fig. 4 shows a cross-sectional view of the annealing wheel assembly shown in Fig. 3.

Fig. 5 shows a side view of a continuous gap-free annealing band of this invention.

Fig. 6 shows an annealing band with a gap in a non-destructive position.

Fig. 7 shows an annealing band with a gap in a destructive position.

DESCRIPTION

The invention relates to a process for making an annealing band. The
5 process involves the steps of (a) producing a refractory metal powder; (b) optionally
blending the powder with an oxide component or a nitride component or a carbide
component; (c) consolidating the powder or powder blend and forming a
consolidated powder component; (d) subjecting the consolidated powder component
to thermomechanical treatment and forming a sheet or tube; (e) cutting the sheet, or
10 tube into a strip, or ring; and (f) forming an annealing band from the strip, in which
the annealing band excludes an annealing band consisting of copper and
niobium. The refractory metal powder used in the invention can be any refractory
metal powder, which when subjected to the treatment steps of the invention,
produces an annealing band of the invention. Examples of suitable refractory metal
15 powders include those made from (a) niobium, (b) tantalum, (c) molybdenum, (d)
tungsten, (e) niobium alloys, (f) tantalum alloys, (g) molybdenum alloys, (h) tungsten
alloys, (i) alloys of (1) a refractory metal and (2) a non-refractory metal selected from
the group consisting of copper, nickel, titanium, iron, cobalt, and (j) combinations
thereof. As used herein, the term "refractory metal" can apply to refractory metals,
20 refractory metal alloys, or combinations of refractory metals and refractory metal
alloys.

The powder has a sufficiently low oxygen content to enable the powder to be
consolidated and subjected to thermomechanical treatments. In one embodiment,
the refractory metal powder includes powders of tantalum, niobium or alloys of
25 tantalum or niobium having an oxygen content of less than about 300 ppm,
preferably below 200 ppm and more preferably below 100 ppm. Such a powder can
be made by a process that involves the steps of (i) providing a minus 100 mesh (or
minus 60 mesh) hydride powder of a first metal selected from the group consisting of
tantalum, niobium, and alloys of such metals with each other or one or both of them
30 with other metals, (ii) heating the hydride of the first metal in the presence of a metal
having a higher affinity for oxygen than the first metal's affinity to remove hydrogen
and oxygen in a single heating cycle, (iii) then removing the metal having a higher
affinity for oxygen from the metal, and (iv) thereby forming a powder of the first metal

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with an oxygen content of less than 300 ppm. Such powders are further described in U.S. Pat. No. 6,261,337, incorporated herein by reference in its entirety.

Optionally, the refractory metal powder is blended with an oxide component or a nitride component or a carbide component before it is consolidated. Suitable
5 oxides include stable oxides in the selected metal system. Examples of stable oxides include but are not limited to magnesium oxide, silicon oxide, yttrium oxide, zirconium oxide, lanthanum oxide, calcium oxide, and combinations of such oxides.

The amount at which such oxides can be used is at least about 5 ppm and can range from about 5 ppm to about 1000 ppm or from about 10 to about 500 ppm. Suitable

10 nitrides include stable oxides in the selected metal system. Examples of suitable nitrides include but are not limited to niobium nitride, tantalum nitride, zirconium nitride, hafnium nitride, and combinations thereof. The amount at which such nitrides can be used is at least about 5 ppm and can range from about 5 ppm to about 1000 ppm or from about

15 10 ppm to about 500 ppm. Suitable carbides include those carbides that are stable in the selected metal system. Examples of stable carbides include, but are not limited to: TaC, NbC, WC, HfC, ZrC, TiC, and combinations of such carbides. The amount at which such carbides can be used is at least about 10 ppm, and can range from about 5 ppm to about 1000 ppm or from about 10 ppm to about 500 ppm.

20 The powder can be consolidated by any process that enables the refractory metal powder to be subjected to the treatment steps of the invention so that an annealing band of the invention can be made. Examples of suitable processes include extrusion processes, hot isostatic pressing processes, pressing and sintering processes, and combinations of the foregoing.

25 When extrusion is selected, the powder is consolidated at a temperature ranging from about room temperature (25°C) to about 3300°F (about 1815°C). The reduction in area of the process before extrusion and after extrusion can range from about 5:1 to about 20:1. In one preferred embodiment, the reduction in area of the process before extrusion and after
30 extrusion is about 9:1.

When isostatic pressing is selected, the powder is optionally subjected to a pressing step. Preferably, the hot isostatic pressing step is carried out by placing the powder in a hot isostatic pressing can, optionally coated with a barrier layer such as

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molybdenum, evacuating the can, placing the can in a hot isostatic press vessel, and subjecting the vessel to hot isostatic pressing conditions at a pressure ranging from about 10 ksi to about 45 ksi, for a period ranging from about 1 hour to about 10 hours, at a temperature ranging from about 1500°F (about 815°C) to about 2600°F (about 1427°C), preferably at least about 30 ksi for about 6 hours at 2300°F (about 1260°C).

When the powder is consolidated by pressing and sintering steps, it is possible to use uniaxial pressing processes, cold isostatic pressing processes, and combinations of such processes. In one embodiment, instead of subjecting the pressed powder to a sintering step, the pressed powder is subjected to resistance sintering conditions, in which an electrical current passes through the powder to create sufficient heat to sinter the metal powder.

The dimensions of the consolidated powder component can vary depending on the application. Generally, the length of the consolidated powder component is at least about 4" (about 10 cm), the width of the consolidated powder component is at least about 2" (about 5 cm), and the height of the consolidated powder component is at least about 2" (about 5 cm). In another embodiment, the length of the consolidated powder component ranges from about 4" (about 10 cm) to about 40" (about 101 cm) preferably from about 4" (about 10 cm) to about 30 ft (914 cm). In another embodiment, the width of the consolidated powder component ranges from about 0.5" (about 1.3 cm) to about 3" (about 7.6 cm), preferably from about 0.5" (about 1.3 cm) to about 40" (1219 cm). In another embodiment, the height of the consolidated powder component ranges from about 0.5" (about 1.3 cm) to about 3" (7.6 cm), preferably from about 0.5" (about 1.3") to about 40" (about 1219 cm).

The thermomechanical treatment step involves a combination of forging, rolling, and annealing steps.

The forging step can be carried out under any conditions that enables the annealing band of the invention to be formed. In one embodiment, the forging step is carried out at a temperature ranging from about room temperature to about 1800°F, preferably at room temperature, into a sheet bar having a thickness ranging from about 0.5" to about 15" (about 1.3 cm to about 38 cm), a width ranging from about 2" to about 60" (about 5 cm to about 152 cm) and a length ranging from about 2" to about 30 ft. (about 5 cm to about 914 cm). In another embodiment, the sheet

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bar has a thickness of about 1.5 inches, a width of about 4.5 inches, and a length of about 40 inches (102 cm).

The rolling step can be carried out under any conditions that enables the annealing band of the invention to be formed. The rolling step generally involves rolling a sheet bar into a sheet having a thickness ranging from about 0.010" to about 0.5" (about 0.03 cm to about 1.3 cm), a width ranging from about 0.25" to about 60" (about 0.64 cm to about 152 cm), and a length ranging from about 5" to about 100 ft. (about 12.7 cm to about 3048 cm). In another embodiment, the sheet has a thickness of about 4 millimeters, a width of about 30 inches, and a length of about 5 feet (about 152.4 cm).

The annealing step can be carried out under any conditions that enables the annealing band of the invention to be formed. Generally, the annealing step is carried out at a temperature ranging from about 850°C to about 2000 °C, preferably from about 1000 to about 1400°C.

In one embodiment, the process further includes at least one intermediate annealing step. Preferably, the annealing step is carried out after about a 70% to 90% total deformation. For example, when the consolidated powder component is rolled and its thickness is reduced to about 80% of its original thickness, an intermediate annealing step can be carried out before performing the forging step.

The sheet is cut into a strip having a thickness ranging from about 0.01" (about 0.03 cm) to about 0.5" (about 1.3 cm), a width ranging from about 0.25" (about 0.64 cm) to about 10" (about 305 cm), and a length ranging from about 5" (about 12.7 cm) to about 20 ft (about 610 cm). In one embodiment, the strip is a niobium strip having a hardness ranging from about 60 Vickers to about 200 Vickers.

In another embodiment, the strip is a molybdenum strip having a hardness ranging from about 190 Vickers to about 400 Vickers. In another embodiment, the strip is a tungsten strip having a hardness ranging from about 300 Vickers to about 600 Vickers.

The annealing band is formed by placing the strip on a three point bender or any other method from which annealing band can be formed from the strip.

In one embodiment, an annealing band of this invention can be made from Ingot Metallurgy (I/M) techniques.

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The annealing band of the invention is made from (a) niobium, (b) tantalum, (c) molybdenum, (d) tungsten, (e) niobium alloys, (f) tantalum alloys, (g) molybdenum alloys, (h) tungsten alloys, (i) alloys of (1) a refractory metal and (2) a non-refractory metal selected from the group consisting of copper, nickel, titanium, iron, cobalt, and (j) combinations thereof. The annealing band can be attached to an annealing wheel assembly of an in-line annealer. When used in an in-line annealer, the annealing band remains useful for a period of more than 36 hours of continuous operation of the annealer, or for a period of more than 160 hours, or more, of continuous operation of the annealer. In one embodiment, the annealing band remains useful for a period ranging from more than 36 to about 160 hours of continuous operation of the annealer.

When it is said that the annealing bands are "useful," it means that the annealing bands can anneal wire in an in-line annealer continuously without requiring replacement of the annealing band and without shutting down the in-line annealer (Or the processing line).

The annealing bands of the invention preferably have a high arc resistance, which is related to high melting point and is believed to be an advantageous property in annealing bands.

Further, the annealing bands preferably are not soluble with the wire that touches the annealing band at high temperature, e.g., copper wire.

The dimensions of the annealing band are such that that the annealing band can be used in a wire-making machine that uses an annealing band. Preferably, the annealing band has a thickness ranging from about 0.01" to about 0.5", a width ranging from about 0.25" to about 10", and a diameter ranging from about 1.5" to about 6 ft. In one embodiment, the annealing band has a thickness of about 4 mm thick, a width ranging from about 20 to about 25 mm, and a diameter ranging from about 350 to about 500 mm. The annealing band can be (i) open-ended, (ii) welded together, or (iii) open-ended with overlapping beveled ends.

Advantageously, an annealing band of the invention preferably has a uniform microstructure. For instance, when the annealing band is made of (1) a refractory metal and (2) a non-refractory metal such as copper or nickel or titanium or iron or cobalt, uniformly distributed throughout the annealing band. Alternatively, when the annealing band of the invention is made of a combination of refractory metals, the

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chemical composition of the alloy is uniform throughout the annealing band. And when the annealing band is made of a single refractory metal, the microstructure of the annealing band is uniform throughout the annealing band. Uniformity of phase distribution, chemical composition and microstructure corresponds to uniform

5 physical properties, features that are valued by wire manufacturers.

In use, the process of the invention produces a suitable refractory metal powder. The powder is optionally blended with an oxide component or a nitride component or a carbide component and the powder or powder blend is consolidated such that a consolidated powder component forms. The consolidated powder
10 component is subjected to thermo-mechanical treatment, and a sheet forms. The sheet is cut into a strip and an annealing band forms from the strip.

When the powder formation steps, the powder consolidation steps and the sheet formation steps have been pre-performed, e.g., when these steps have been performed by a service provider, the invention includes a two-step process for
15 making an annealing band involving the steps of (a) cutting a sheet into a strip; and (b) forming an annealing band from the strip, in which the metal sheet has been formed by subjecting the consolidated powder component to thermomechanical treatment, and in which the consolidated powder component has been formed by consolidating a refractory metal powder into the consolidated powder component,
20 such that the powder is optionally blended with an oxide component or a nitride component, or a carbide component before it is consolidated.

When the powder formation steps, the powder consolidation steps, the sheet formation step, and the sheet cutting steps have been pre-performed, the invention includes a single-step process for making an annealing band comprising forming an
25 annealing band from the strip, in which the strip has been cut from a sheet that has been formed by subjecting the consolidated powder component to thermomechanical treatment, and in which the consolidated powder component has been formed by consolidating a refractory metal powder into the consolidated powder component, such that the powder is optionally blended with an oxide
30 component or a nitride component, or a carbide component before it is consolidated, in which the annealing band excludes an annealing band consisting of copper and niobium.

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For wire-making processes, the invention includes a process for annealing a metal wire in which two an annealing wheel assemblies are provided. Each annealing wheel (shive) assembly includes a first annealing wheel (shive body), a second annealing wheel (plate) and an annealing band, in which the first annealing
5 wheel (body) and the second annealing wheel(plate) that are attached to each other each have a refractory metal annealing band, located between the first annealing wheel (body) and the second annealing wheel (plate), for providing a contact area for
10 a wire. The annealing band can be attached to an annealing wheel (shive)assembly by any suitable technique, e.g., by clamping the annealing band into the annealing wheel(shive) assembly. A wire passes over the annealing bands of both annealing wheel assemblies and a voltage is applied between the first annealing band and the second annealing band, so that a current passes through the wire under conditions that heat the wire to at least the annealing temperature of the wire. The voltage that passes from the annealer can vary depending on application.

15 The wire that can be subjected to such annealing conditions include copper wires, copper alloy wires, aluminum wires, aluminum alloy wires, steel wires, steel alloy wires, and combinations thereof. The dimensions of the wire that can be used can range from about 0.002" (about 0.006 cm) to about 0.1" (about .23 cm). Of course, wires having other dimensions can be used as well.

20 Referring to the figures, Fig. 1 shows a side view of an open-ended annealing band 5. Sectional lines 1 and 3 of Fig. 1 refer to the cross-sectional view of the annealing band shown in Fig 2; Fig. 3 shows an annealing wheel assembly 11 containing the annealing band 13; and sectional lines 7 and 9 refer to the cross-sectional view of Fig. 4, in which the annealing band 15 is attached to the annealing
25 wheels 17 and 19.

In one embodiment, an annealing band of the invention has a gap. In another embodiment, however, the annealing band of this invention is continuous and does not include a gap. Fig. 5 shows a continuous, gap free annealing band made in accordance to the invention. Fig. 6 shows an annealing band with a gap in a non-destructive position (the gap does not coincide with the wire leaving the band). Fig. 7
30 shows an annealing band with a gap in a destructive position (the gap coincides with the wire leaving the band). Without being bound by theory, it is believed that when an annealing band has a gap, it breaks the circuit (in which the current is transferred

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from the annealing band to the wire), and increases arcing or the likelihood of arcing (an undesired erosion of the band). The use of a continuous band reduces arcing.

Advantageously, the use of a continuous annealing band allows the wear to be evenly distributed through the entire length of the band. The use of a continuous
5 annealing band imparts a continuous electrical field throughout the band, and thereby evenly distributes the arcing throughout the band, and removes the potential for excessive arcing caused by the gap in the band. Currently, in ordinary annealing bands (which contain gaps), the arcing is concentrated on 14% of the band, just beyond the gap.

10 The life of a continuous annealing band made in accordance to the invention is generally longer than the life of an annealing band made in accordance with the invention (with gaps) and substantially longer. Generally, a continuous annealing band of this invention has a life that is at least about 50% to about 80% more, or more than about 80%, as compared to an annealing band made in accordance with
15 the invention (with a gap). As compared to ordinary annealing bands (not made with the materials of this invention) a continuous annealing band of this invention has lasts at least about 100%, or more than about 200%, or more than about 300% in ordinary use. In one embodiment, the continuous annealing band of this invention lasts from about 100% to about 1000%, or more, as compared to ordinary annealing
20 bands, e.g., nickel bands.

A continuous annealing band of this invention is made by any suitable method. Generally, a continuous annealing band is made by determining the length and roundness of the band, and the joining of the two ends of the band after
25 fabrication as described above. The shaping of the band can be done using standard metal working practices, and joining of the ends can be accomplished using standard metal working practices as well, such as 3 point bending and welding. Other possible methods of manufacture are to produce a tube of sufficient diameter and thickness, and section widths to produce a continuous band.

Advantageously, the invention provides improved annealing bands, improved
30 methods for making such bands, and improved methods for annealing wires. The annealing band of the invention can replace conventional annealing bands and allow wire manufacturers to run annealers for extended periods of time. The invention is especially useful for in-line annealers in wire manufacturing because the use of the

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annealing band can decrease maintenance and equipment down time. When niobium annealing bands of the invention are used, the niobium bands can be more than 10 times more durable than conventional nickel bands.

The invention is further described in the following illustrative
 5 examples in which all parts and percentages are by weight unless otherwise indicated.

EXAMPLES

EXAMPLE 1

10 PROCEDURE

The cutting rates of various materials (see table below) were measured when cut by Electro Discharge Machining (EDM). In this case a wire was used as the cutting tool (Wire-EDM). For EDM the workpiece is immersed in petroleum or water. A voltage was applied between the workpiece and the wire, and the wire was
 15 brought so close to the workpiece that electric arcs were initiated from the wire to the workpiece. Each arc evaporated a very small volume of material at the surface of the workpiece. The wire cut the workpiece, as the piece eroded through arcing. The cutting rate that can be achieved with this method was an indicator for the arc-resistance of the material. Slow cutting rate indicated a high arc resistance. The
 20 table lists the cutting rate quantified as "cut area per hour" (square inch per hour). It can be seen that niobium had a much slower cutting rate than any of the other materials tested.

EDM experiments show slow cutting rates for Nb (See Table 1 below).

Table 1

Material	Cut Rate (in ² /hr)
CuCrNb	4.512
CuCrNb	3.600
Glidcop™	3.510
Copper	3.066
Cu 18Nb	2.832
Ni 201	2.646
Glidcop™	2.160
Glidcop™ & Nb	1.962

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Niobium	0.936
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"Glidcop™" is an oxide dispersion strengthened (ODS) copper alloy by OMG.

From these results it was concluded that niobium had a higher resistance to spark erosion than the other materials. Since spark erosion is one of the main wear mechanisms for annealing bands it was further concluded that annealing bands made from Nb will wear slower than bands made from the other materials and that they will have a higher life time than other bands.

10 EXAMPLE 2

PROCEDURE

Vickers hardness measurements were determined according to ASTM E92-82, a well-known standard that describes in great detail how to perform Vickers hardness measurements. Table 2 shows the Vickers hardness obtained for different material grades.

Table 2

Material Grade	Vickers Hardness Number
I/M Nb	70
P/M Nb	110

(I/M): Ingot Metallurgy

(P/M): Powder Metallurgy

The results showed that the P/M grade of Nb is considerably harder than I/M grade Nb. From these results it was concluded P/M Nb had a higher resistance to mechanical erosion than I/M Nb. Since mechanical erosion is one of the main wear mechanisms for annealing bands it was further concluded that annealing bands made from P/M Nb will wear slower than bands made from I/M Nb and that they will have a higher life time than I/M Nb bands.

Although the present invention has been described in detail with reference to certain preferred versions thereof, other variations are possible. Therefore, the spirit

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and scope of the appended claims should not be limited to the description of the versions contained therein.

WHAT IS CLAIMED IS:

1. A process for making an annealing band, the process comprising:
 - (a) producing a refractory metal powder;
 - 5 (b) optionally blending the powder with an oxide component or a nitride component or a carbide component;
 - (c) consolidating the powder or powder blend and forming a consolidated powder component;
 - (d) subjecting the consolidated powder component to thermo-
 - 10 mechanical treatment and forming a sheet;
 - (e) cutting the sheet into a strip; and
 - (f) forming an annealing band from the strip, wherein the annealing band excludes an annealing band consisting of copper and niobium.
2. The process of Claim 1, wherein the refractory metal is a component
15 selected from the group consisting of (a) niobium, (b) tantalum, (c) molybdenum, (d) tungsten, (e) niobium alloys, (f) tantalum alloys, (g) molybdenum alloys, (h) tungsten alloys, (i) alloys of (1) a refractory metal and (2) a non-refractory metal selected from the group consisting of copper, nickel, titanium, iron, cobalt, and (j) combinations thereof.
- 20 3. The process of Claim 1, wherein the annealing band has a uniform microstructure.
4. The process of Claim 1, wherein the powder has sufficiently low oxygen content to enable the powder to be consolidated and subjected to thermomechanical treatments.
- 25 5. The process of Claim 1, wherein the refractory metal powder has an oxygen content that is less than about 300 ppm.
6. The process of Claim 1, wherein the oxides are selected from the group consisting of magnesium oxide, silicon oxide, yttrium oxide, zirconia oxide, lanthanum oxide, hafnium oxide, calcium oxide and combinations thereof.
- 30 7. The process of Claim 1, wherein the carbide component comprises carbides selected from the group consisting of TaC, WC, HfC, TiC, NbC, ZrC, stable carbides other than the foregoing, and combinations thereof.

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8. The process of Claim 1, wherein the powder is consolidated by a process selected from the group consisting of extrusion processes, hot isostatic pressing processes, pressing and sintering processes, and combinations of the foregoing.

5 9. The process of Claim 1, wherein the powder is consolidated at a temperature ranging from about room temperature to about 3300°F by extrusion and the process has a reduction in area before extrusion and after extrusion of about 9:1.

10. The process of Claim 1, wherein the powder, optionally subjected to a pressing step, is consolidated by hot isostatic pressing.

10 11. The process of Claim 10, wherein the hot isostatic pressing step is carried out by placing the powder in a hot isostatic pressing can, optionally coated with a barrier layer, evacuating the can, placing the can in a hot isostatic press vessel, and subjecting the vessel to hot isostatic pressing conditions at a pressure ranging from about 10 ksi to about 45 ksi, for a period ranging from about 1 hour to
15 about 10 hours, at a temperature ranging from about 1500°F to about 2600°F.

12. The process of Claim 1, wherein the powder is consolidated by pressing and sintering steps and the pressing step is selected from the group consisting of uniaxial pressing processes, cold isostatic pressing processes, and combinations thereof.

20 13. The process of Claim 10, wherein instead of subjecting the pressed powder to a sintering step, the pressed powder is subjected to resistance sintering conditions, wherein an electrical current passes through the powder to create sufficient heat to sinter the metal powder.

25 14. The process of Claim 1, wherein the thermomechanical treatment step comprises a combination of forging, rolling, and annealing steps.

15. The process of Claim 14, wherein the forging step is carried out at a temperature ranging from about room temperature to about 1800°C into a sheet bar having a thickness ranging from about 0.5" to about 15", a width ranging from about 2" to about 60", and a length ranging from about 2" to about 30 ft.

30 16. The process of Claim 15, wherein the sheet bar has a thickness of about 1.5 inches, a width of about 4.5 inches, and a length of about 40 inches.

17. The process of Claim 14, wherein the rolling step comprises rolling a sheet bar into a sheet having a thickness ranging from about 0.010" to about 0.5", a

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width ranging from about 0.25" to about 60", and a length ranging from about 5" to about 100 ft.

18. The process of Claim 17, wherein the sheet has a thickness of about 4 millimeters, a width of about 30 inches, and a length of about 5 feet.

5 19. The process of Claim 14, wherein the annealing step is carried out at a temperature ranging from about 850°C to about 2000°C.

20. The process of Claim 14, wherein the process further includes at least one intermediate annealing step.

10 21. The process of Claim 14, wherein the sheet is cut into a strip having a thickness ranging from about 0.01" to about 0.5", a width ranging from about 0.25" to about 10", and a length ranging from about 5" to about 20 ft.

22. The process of Claim 21, wherein the strip is a niobium strip having a hardness ranging from about 60 Vickers to about 200 Vickers.

15 23. The process of Claim 21, wherein the strip is a molybdenum strip having a hardness ranging from about 190 Vickers to about 400 Vickers.

24. The process of Claim 21, wherein the strip is a tungsten strip having a hardness ranging from about 300 Vickers to about 600 Vickers.

20 25. The process of Claim 1, wherein the annealing band is formed by placing the strip on a three point bender or any other forming method and shaping the strip into an annealing band.

26. The process of Claim 1, wherein the annealing band has a thickness ranging from about 0.01" to about 0.5".

27. The process of Claim 1, wherein the annealing band has a width ranging from about 0.25" to about 10".

25 28. The process of Claim 1, wherein the annealing band has a diameter ranging from about 1.5" to about 6 ft.

29. The process of Claim 1, wherein the annealing band has a thickness of about 4 mm thick, a width ranging from about 20 to about 25 mm, and a diameter ranging from about 350 to about 500 mm.

30 30. The process of Claim 1, wherein the process further comprises attaching the annealing band to an annealing wheel assembly of an in-line annealer.

31. The process of Claim 1, wherein the annealing band is

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(i) open-ended, (ii) welded together, or (iii) open ended with overlapping beveled ends.

32. The annealing band made from the process of Claim 1.

5 33. A member comprising a refractory metal annealing band, wherein the annealing band excludes an annealing band consisting of copper and niobium.

34. The annealing band of Claim 32, wherein the refractory metal is selected from the group consisting of (a) niobium, (b) tantalum, (c) molybdenum, (d) tungsten, (e) niobium alloys, (f) tantalum alloys, (g) molybdenum alloys, (h) tungsten alloys, (i) alloys of (1) a refractory metal and (2) a non-refractory metal selected from
10 the group consisting of copper, nickel, titanium, iron, cobalt, and (j) combinations thereof.

35. The annealing band of Claim 34, wherein the annealing band has a uniform microstructure.

36. The annealing band of Claim 34, wherein the annealing band has a
15 thickness ranging from about 0.01" to about 0.5", a width ranging from about 0.25" to about 10", and a diameter ranging from about 1.5" to about 6 ft.

37. The annealing band of Claim 34, wherein when the annealing band is used in an in-line wire annealer, wherein the annealing band remains useful for a period of more than 36 hours of continuous operation of the annealer.

20 38. The annealing band of Claim 34, wherein when the annealing band is used in an in-line wire annealer, the annealing band remains useful for a period of more than 160 hours of continuous operation of the annealer.

39. A process for annealing a metal wire comprising:

25 (a) providing two annealing wheel assemblies, each assembly comprising a first annealing wheel, a second annealing wheel and an annealing band;

wherein the first annealing wheel and the second annealing wheel that are attached to each other each have a refractory metal annealing band, located between the first annealing wheel and the second annealing , for providing a contact area for a wire;

30 (b) passing a wire over the annealing bands of both annealing wheel assemblies;

(c) applying a voltage between the first annealing band and the second annealing band, and thereby passing a current to the wire under conditions that heat

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the wire to at least the annealing temperature of the wire, thereby annealing the wire, wherein at least one annealing band excludes an annealing band consisting of copper and niobium.

40. The process of Claim 39, wherein the wire is selected from the group
5 consisting of copper wires, copper alloy wires, aluminum wires, aluminum alloy wires, steel wires, steel alloy wires, and combinations thereof.

41. The process of Claim 39, wherein the refractory metal is selected from the group consisting of (a) niobium, (b) tantalum, (c) molybdenum, (d) tungsten, (e) niobium alloys, (f) tantalum alloys, (g) molybdenum alloys, (h) tungsten alloys, (i)
10 alloys of (1) a refractory metal and (2) a non-refractory metal selected from the group consisting of copper, nickel, titanium, iron, cobalt, and combinations thereof.

42. The process of Claim 39, wherein the annealing band has a uniform microstructure.

43. A process for making an annealing band comprising:

- 15 (a) cutting a sheet into a strip; and
(b) forming an annealing band from the strip;

wherein the metal sheet has been formed by subjecting a consolidated powder component to thermomechanical treatment;

wherein the consolidated powder component has been formed by
20 consolidating a refractory metal powder into the consolidated powder component;
and

wherein the powder has been optionally blended with an oxide component or a nitride component or a carbide component before it has been consolidated,
wherein the annealing band excludes an annealing band consisting of copper and
25 niobium.

44. The process of Claim 43, wherein the annealing band has a uniform microstructure.

45. A process for making an annealing band comprising forming an annealing band from the strip;

30 wherein the strip has been cut from a sheet that has been formed by subjecting the consolidated powder component to thermomechanical treatment;

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wherein the consolidated powder component has been formed by consolidating a refractory metal powder into the consolidated powder component, and

5 wherein the powder has been optionally blended with an oxide component or a nitride component, or a carbide component before it is consolidated, wherein the annealing band excludes an annealing band consisting of copper and niobium.

46. The process of Claim 45, wherein the annealing band has a uniform microstructure.

10 47. A member comprising a refractory metal annealing band having a uniform microstructure, wherein the refractory metal is selected from the group consisting of (a) niobium, (b) tantalum, (c) molybdenum, (d) tungsten, (e) niobium alloys, (f) tantalum alloys, (g) molybdenum alloys, (h) tungsten alloys, (i) alloys of (1) a refractory metal and (2) a non-refractory metal selected from the group consisting of copper, nickel, titanium, iron, cobalt, and (j) combinations thereof, and

15 wherein the annealing band has a thickness ranging from about 0.01" to about 0.5", a width ranging from about 0.25" to about 10", and a diameter ranging from about 1.5" to about 6 ft, wherein the annealing band excludes an annealing band consisting of copper and niobium.

20 48. The annealing band of Claim 47, wherein the annealing band is made by a process comprising:

- (a) producing a refractory metal powder;
- (b) optionally blending the powder with an oxide component, or a nitride component, or a carbide component;
- 25 (c) consolidating the powder or powder blend and forming a consolidated powder component;
- (d) subjecting the consolidated powder component to thermo-mechanical treatment and forming a sheet, or tube;
- (e) cutting the sheet, or tube into a strip, or ring; and
- (f) forming the annealing band from the strip, or ring, wherein the
- 30 annealing band excludes an annealing band consisting of copper and niobium.

49. The annealing band of Claim 47, wherein the annealing band is made by a process comprising:

- (a) cutting a sheet into a strip; and

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(b) forming an annealing band from the strip;

wherein the metal sheet has been formed by subjecting the consolidated powder component to thermomechanical treatment;

wherein the consolidated powder component has been formed by

5 consolidating a refractory metal powder; or refractory metal alloy powder into the consolidated powder component; and

wherein the powder has been optionally blended with an oxide component, or a nitride component or a carbide component before it has been consolidated.

10 50. The annealing band of Claim 47, wherein the annealing band is made by a process comprising forming an annealing band from a strip;

wherein the strip has been cut from a sheet that has been formed by subjecting the consolidated powder component to thermomechanical treatment; and

15 wherein the consolidated powder component has been formed by consolidating a refractory metal powder; or refractory metal alloy powder into the consolidated powder component,

wherein the powder is optionally blended with an oxide component or a nitride component, or a carbide component before it is consolidated, wherein the annealing band excludes an annealing band consisting of copper and niobium.

20 51. The annealing band of Claim 47, wherein the annealing band is a continuous gap-free annealing band.