United States Patent

Blue

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[54] **METHOD OF MAKING ELECTRICAL CONTACT MATERIALS**

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[*] Notice: The portion of the term of this patent subsequent to April 28, 1987, has been disclaimed.

[22] Filed: **May 15, 1970**

[21] Appl. No.: **48,650**

Related U.S. Application Data

[60] Division of Ser. No. 741,606, July 1, 1968, abandoned, which is a continuation-in-part of Ser. No. 627,962, April 3, 1967, abandoned.

[52] **U.S. Cl.**.....**29/420.5,** 29/182.2, 29/630 C, 29/DIG. 31, 75/204, 75/214, 75/221

[51] **Int. Cl.**.....**B22f 3/24**

[58] **Field of Search**.....29/182, 182.1, 182.2, 420.5, 29/630 C, DIG. 31; 75/204, 208 R, 214, 221

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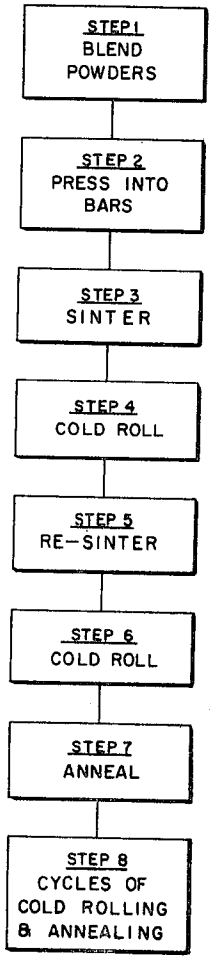
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[57] **ABSTRACT**

An electrical contact material consisting of a thin cold rolled material constructed of a high electrically and thermally conductive material and a refractory wherein particles of the refractory are dispersed within a matrix of the high electrically and thermally conductive material and also are layered in a predetermined direction.

11 Claims, 4 Drawing Figures



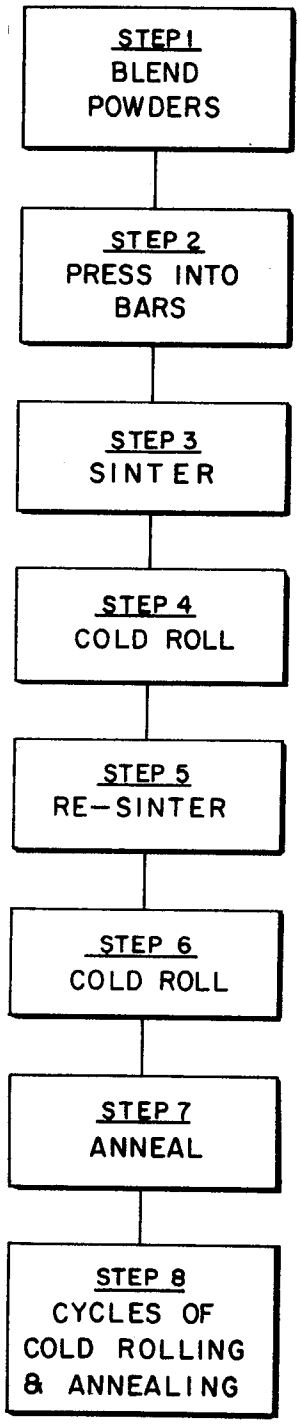


FIG. 1

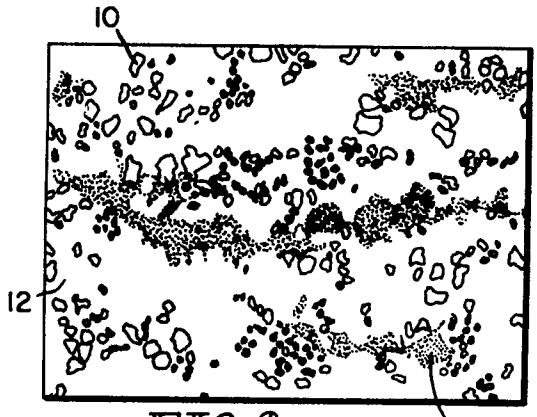


FIG. 2

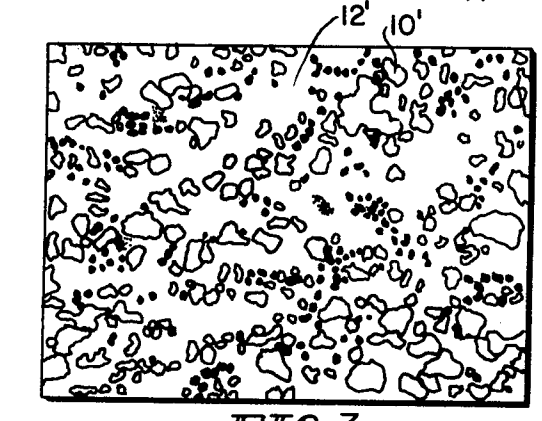


FIG. 3

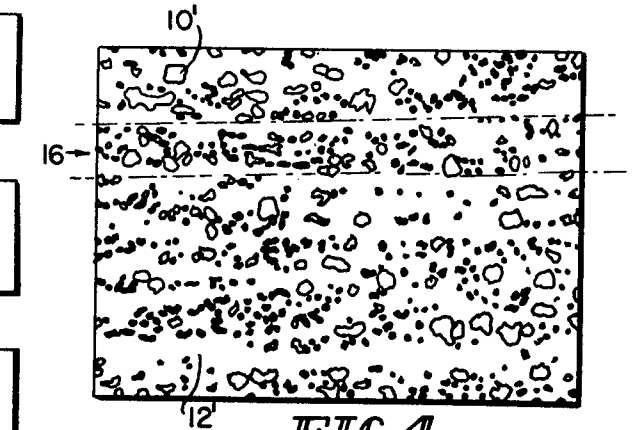


FIG. 4

METHOD OF MAKING ELECTRICAL CONTACT MATERIALS

This is a division of application Ser. No. 741,606, filed July 1, 1968, now abandoned, which in turn is a continuation-in-part of application Ser. No. 627,962, filed April 3, 1967, now abandoned.

Silver, copper, gold, bronze and brass are ideal electrical contact materials because of their high electrical conductivity and excellent heat dissipating or high thermal conductivity properties. However, when subjected to large short-circuit currents, on the order of 5,000 amps, for example, the materials are subject to severe arc erosion. Consequently, it has been the practice to fabricate such heavy duty contacts from mixtures of a high electrically and thermally conductive material and a high melting point refractory material such as tungsten. With this combination the tungsten, while it carries a substantial amount of current, acts as a skeleton for holding the high electrically and thermally conductive material. The tungsten phase also provides greater resistance to arc erosion.

Prior to this invention, silver-tungsten contacts, for example, were for the most part deficient in many respects, the deficiencies arising mainly from the methods by which the contacts were produced. Such deficiencies include but are not limited to relatively poor electrical conductivity due to the oxide barrier between the tungsten particles and the silver matrix, discontinuity of the silver matrix, inability to make thin strips or sheets of the material, and non-uniformity in physical properties such as hardness and density.

Among the objects of the present invention is the provision of an electrical contact material composed of a high electrically and thermally conductive material and a refractory material, such as for example, tungsten, titanium, molybdenum, carbide mixtures thereof and the like wherein the refractory particles are in substantial intimate contact with a matrix of the high electrically and thermally conductive material.

Another object of the invention is the provision of an electrical contact material wherein the refractory particles that are dispersed within a substantially continuous matrix of a high electrically and thermally conductive material are layered in a predetermined direction.

Another object of the invention is to provide such a contact material which is fabricated as a thin body with sufficient ductility so that it can be readily formed into desired shapes.

Still another object of the invention is to provide such a contact material which has more uniform physical properties such as those of hardness, density and lack of porosity.

Another object of the such contact is to provide a bar rolling technique for forming contact material.

Still another object of the invention is to provide a bar rolling technique wherein powders of the refractory material are blended with powders of the high electrically and thermally conductive material, pressed into bars, sintered, cold rolled, resintered and cold rolled with or without intermittent annealing treatments.

With the above and other objects in view, which will appear as he description proceeds, this invention resides in a novel article of manufacture and a process for making the same such as substantially described herein and more particularly defined by the appended claims, it being understood that such changes in the

precise embodiment of the invention here disclosed may be made as come with the scope of the claims.

In the drawings:

FIG. 1 is a flow sheet showing the various steps in forming the novel electrical contact material;

FIG. 2 is an enlarged cross section of a silver-tungsten electrical contact material showing the structure resulting from a commonly used sintering method;

FIG. 3 is an enlarged transverse cross section of a high electrically and thermally conductive refractory contact material showing the structure formed by using the method of invention; and

FIG. 4 is an enlarged longitudinal section of a high electrically and thermally conductive refractory contact material showing the structure formed by using the method of the invention.

The invention in its broadest aspect contemplates providing as an article of manufacture a body of an electrical contact material having an active contact face fabricated of a high electrically and thermally conductive material and a refractory material taken from the group consisting of tungsten, titanium, molybdenum, carbides thereof and the like, the powder particle size of the refractory material being from 4—20 microns with the refractory particles being in intimate contact with a continuous matrix of the high electrically and thermally conductive material to yield a contact having a high electrical conductivity. The electrical contact material is further characterized by the refractory particles being layered in a predetermined direction. Also the invention contemplates providing a process for forming such contact which comprises blending a mixture of powders of a refractory material taken from the group consisting of tungsten, titanium, molybdenum, carbides thereof and the like, and powders of a high electrically and thermally conductive material, said refractory powders having a particle size of from 4–20 microns as measured by F.A.P.S. analysis, pressing said mixtures into bars, sintering said bars in a non-oxidizing atmosphere, cold rolling said bars in a single pass to yield about a one-third reduction in the bar's thickness, resintering and cold rolling said bars, annealing said bars to remove all rolled grain structure, and thereafter alternately cold rolling and annealing said bars in cycles to yield reductions in thickness of from 10–30 percent in each cycle until the desired physical properties are obtained.

Referring now to FIG. 1, the first step in making the novel electrical contact material is that of blending the powders together. To this end, powders of the high electrically and thermally conductive material which preferably have a particle size of from 4–10 microns by F.A.P.S. analysis are blended with the refractory powder having a particle size of from 4–20 microns by F.A.P.S. analysis. The high electrically and thermally conductive materials includes silver, copper, gold, brass and bronze. The particle size of the refractory is particularly critical. In general, if the particle size becomes excessively large, a good intimate electrical contact is difficult to achieve between the refractory and the high electrically and thermally conductive material and the electrical load carrying capability of the contact is reduced; while on the other hand, if the refractory particle size becomes too small, the material becomes brittle and cracks develop during the rolling

operation. Preferably the particle size of the tungsten should be from about 6–20 microns, while for the tungsten carbide and molybdenum, it should be about 4–12 microns.

In general, the composition, that is, the weight percent of the refractory and the electrically and thermally conductive material is dependent upon the electrical properties desired and, in the case of the present invention, the rolling ability of the mixture. With too little electrically and thermally conductive material, the rolling operation becomes very difficult due to the high refractory material content. On the other hand, with too much electrically and thermally conductive material, the fine particles of the material reduce the material's current carrying capacity. In general, a high electrically and thermally conductive material in an amount of from about 20 to 90 percent by weight with the balance being the refractory material has been found to be suitable. Table I shows the ranges and the preferred percentages of silver and the ranges of copper for some of the named refractory materials of the invention.

TABLE I

	%-Ag-by weight		% cu - by weight
Refractory Material	Range	Preferred	Range
Tungsten	20–90	27,35,50,90	20–50
Tungsten Carbide	50–80	50	25–50
Molybdenum	65–80	65	20–50

The mixture is then, as shown in FIG. **1**, pressed into bars of a suitable shape by placing the mixture into a mold and applying pressure to it.

The bars are then, in step three, sintered in a a non-oxidizing atmosphere in a furnace of either the muffle or open element type. The atmosphere may be a neutral atmosphere such as pure nitrogen, but a reducing atmosphere such as dissociated ammonia or pure hydrogen is preferred from the standpoint of reducing the tendency for the formation of oxide layers on the refractory.

Sintering temperatures depend upon the particle size of the refractory material and composition of mix, the temperature, in general, being inversely proportional to both. The larger particle sizes, within the aforementioned range, tend to cause bleed-out of the high electrically and thermally conductive material or to cause the bars to deform. In such case, solid phase sintering at a temperature near the melting point of the high electrically and thermally conductive material (about 980° C for silver) is adequate. Bars which may be sintered above the melting point (liquid-phase) of the electrically and thermally conductive material may be sintered in the range of from about 1,000°–1,130°C. Optimum temperature conditions are dependent upon the electrically and thermally conductive refractory composition of the mixture. And, in addition, enough refractory structure must be present to hold the matrix of electrically and thermally conductive material. For example, with a mixture of **50** percent silver, 50 percent tungsten liquid phase sintering at temperatures up to 1,130°C may be used. With a 90% Ag/10% W mixture solid phase sintering with temperatures of from 900° to 950°C would be used regardless of particle size. With a 35%/65% mixture, liquid phase sintering with temperatures up to 1,130°C may be used. In any event the maximum temperature is thought to be about 1,130°C to prevent excessive vaporization of the electrically and thermally conductive material.

A sintering temperature for 50 percent silver, balance molybdenum would be 1,100°C, as would the sintering temperature for a 65 percent silver, balance tungsten carbide composite. Greater silver contents within the ranges shown in Table I should be sintered at about 940°C. Sintering temperatures for a mixture of from about 20–50 percent copper by weight, the balance being tungsten would be from about 1,140°–1,150°C.

Again referring to the drawing, after the bars have been sintered, they are cold rolled through a suitable rolling mill, the roll gap being set to about two-thirds of the bar's thickness to yield a one-third reduction in thickness in a single pass. With a one-third reduction, optimum economic rolling conditions are achieved without having a tendency for the bars to crack, especially along the edges.

As shown in step **5**, following the cold rolling, the material is resintered. This step completely relieves the stresses of rolling and promotes rapid grain growth in the matrix of electrically and thermally conductive material to exclude voids. This void exclusion is a result of grain growth in the solid sinter and refractory particle wetting in liquid phase sintering. More important, the resinter step at this point provides for a continuous matrix of electrically and thermally conductive material, uninterrupted by a refractory skeleton as exists in prior art infiltrated materials. This continuous matrix provides better electrical properties with no expense of hardness. Electrical conductivity tests consistently indicate superior conductivity for these rolled materials over materials of the same composition produced by so-called standard techniques.

It is believed that the cold rolling substantially eliminates the oxide barrier normally formed on the refractory particles, thus leaving, as shown in FIG. **3**, a direct or intimate contact between the refractory particles **10'** and the matrix **12'** so as to achieve a good intimate electrical contact between the refractory and the electrically and thermally conductive material. While not desiring to be so limited, it is thought that the cold rolling step sets up an abrasive action between the refractory particles so as to cause the substantial elimination of the oxide barrier. Although there may be an abrasive action with hot rolling, there may still be the tendency to create an oxide layer due to the heat involved. The substantial elimination of the oxide barrier yields a better electrical contact between the refractory particles and the matrix of electrically and thermally conductive material thus yielding increased electrical conductivity. As previously noted, the resintering step promotes grain growth so as to eliminate voids in the material.

Thus these two steps have eliminated two of the major defects of prior art electrical contact materials which, as shown in FIG. **2**, includes voids **14**, and substantially no intimate contact between the refractory particles **10** and matrix **12** thus making it difficult to achieve a good intimate electrical contact between the refractory particles and the matrix of electrically and thermally conductive material.

As shown in FIG. **1**, in the next two steps the body is rolled and annealed and then as shown in the last step

resintered in an atmosphere of dissociated ammonia for about 10 minutes at a temperature of about 1,140°C. After resintering the bars are alternately cold rolled and annealed until a strip having a thickness of about 0.020 inch is produced. The annealing is done at a temperature of about 900°C for about 10 minutes in an atmosphere of dissociated ammonia. The cold rolling is done in passes with a 10–15 percent reduction per pass.

EXAMPLE 5

A powder mixture of 25 percent copper-75 percent tungsten by weight is pressed and sintered to a bar size of 0.125 inch in thickness. The particle size of the tungsten is about 5–6 microns, and the copper about 12–13 microns. The powders are pressed with a pressure of from about 20–25 ton/in.^{2}. They are sintered in an atmosphere of dissociated ammonia for about 15 minutes at a temperature of about 1,150°C. The pressed bars are then cold rolled in air at a 30 percent thickness reduction for two passes. The bars are then resintered in an atmosphere of dissociated ammonia for about 15 minutes at a temperature of about 1,150°C. After resintering the bars are alternately cold rolled and annealed until a strip having a thickness of about 0.020 inch is produced. The annealing is done at a temperature of about 1,000°C for about one half hour in dissociated ammonia. The cold-rolling is done in passes with a 10–15 percent reduction per pass.

EXAMPLE 6

A powder mixture of 20 percent copper-80 percent tungsten by weight is pressed and sintered to a bar size of 0.125 inch in thickness. The particle size of the tungsten is about 5–6 microns, and the copper about 12–13 microns. The powders are pressed with a pressure of from about 20–25 ton/in.^{2}. They are sintered in an atmosphere of dissociated ammonia for about 15 minutes at a temperature of about 1,150°C. The pressed bars are then cold rolled in air at a 30 percent thickness reduction for two passes. The bars are then resintered in an atmosphere of dissociated ammonia for about 15 minutes at a temperature of about 1,150° C. After resintering the bars are alternately cold rolled and annealed until a strip having a thickness of about 0.020 inch is produced. The annealing is done at a temperature of about 1,000°C for about one half hour in dissociated ammonia. The cold rolling is done in passes with a 10–15 percent reduction per pass.

Electrical contact materials of the type noted in the examples are then formed into suitable electrical contacts for testing, the contacts being "blanked out" of the strips. The contacts are tested along with contacts formed by standard prior art infiltrating techniques to give a basis of comparison. The contacts, having silver as the matrix, are compared for weight loss and voltage drop while contacts using silver and copper are tested for electrical conductivity.

For the weight loss measurements of a silver matrix, sample weld buttons are mounted and tested in an RBM appliance relay. Four pairs of contacts from each lot are tested. The test parameters are:

Contact Closed Force	30 grams
Contact Opening Force	75 grams
Contact Gap	020" minimum
Relay Overtravel	.030" minimum
Operations	150,000 at 45/minute
Circuit Voltage	120 volts AC
Load Current	Ag-Mo, 5 amps Ag-WC, 5 amps Ag-W, 9 amps

The contacts are weighed before and after testing. Contact resistance measurements are made at intervals during the test.

Table II shows the results of the tests performed on the materials produced as indicated by the examples as compared to similar materials produced by standard infiltrating techniques. The compositions of the materials made by the infiltration techniques are the same as those indicated in the example.

TABLE II

Composition	Avg. Wt. loss per cycle - X10 $^{-7}$	Avg. voltage drop
Ag-W (Std.)	3.69	421
Ag-W (Exp. 1)	3.35	405
Ag-WC(Std.)	3.13	323
Ag-WC (Exp. 2)	3.97	260
Ag-Mo (Std.)	2.05	523
Ag-Mo (Exp. 3)	1.36	417

Electrical conductivity comparisons were made of materials of the present invention and materials made by standard infiltrating techniques using eddy current methods. The materials were compared as a percentage of the International Annealed Copper Standard (I.A.C.S.) The results are shown in Tables III and IV.

TABLE III

Composition	Conductivity - % I.A.C.S. Materials of Invention	Infiltrated
50% Ag - 50% W	71–73	64–65
35% Ag - 65% W	60–62	54–56
27% Ag - 73% W	50–52	46–48
65% AG - 35% WC	71–72	61–65
50% Ag - 50% Mo	64–66½	53–55
40% Ag - 60% Mo	58½ – 60	47–19

TABLE IV

Composition	Conductivity - % I.A.C.S. Materials of Invention	Infiltrated
50% Cu - 50% W	55–65	51–65
25% Cu - 75% W	45–53	42–49
20% Cu - 80- W	40–50	38–45

It is readily seen from Table II that the materials of the present invention show appreciably less voltage drop compared to that of the standard infiltrated material. Such decrease in voltage drop indicates a lower resistance at the contact interface. Such lower resistance means that less heat is being generated, thus prolonging contact life. Except for the tungsten carbide-silver combination, the materials of the invention showed less weight loss than that of the standard materials.

It is clearly shown by Tables III and IV that the materials of the invention have a much higher conductive value than that of commonly used electrical contact materials.

In addition to the advantages shown by the above noted tests, it should be understood that the material of the present invention is much easier to fabricate into useful electrical contacts because of the ease in "blanking out" the contacts from the strip or sheets into which the present material is formed.

The electrical contact material of the present invention, as hereinbefore described, is merely illustrative

the rolling and annealing is continued in cycles with a 10–30 percent reduction in thickness in each cycle until the desired properties of hardness, density, thickness, etc., are obtained. The optimum amount of reduction in thickness is a balance of reducing the thickness as quickly as possible without causing cracks in the rolled body and is dependent upon the composition of the original mixture.

For a 90 percent by weight of silver, 10 percent tungsten mixture a 30 percent reduction is thought to be optimum; for a 30%/50% mixture, 15 percent would be optimum; for a 35%/65% mixture, 10 percent is thought to be optimum; and for a 27%/73% mixture, a 10 percent reduction per cycle is thought to be optimum. For a 50 percent by weight silver-50 percent molybdenum composite a 15 percent reduction is thought to be optimum. For a 65 percent by weight silver-35 percent tungsten carbide composite, a 10 percent reduction is thought to be optimum. For a mixture of from about 20–50% by weight copper, the balance being tungsten, a 15–20% reduction per cycle would be used.

Annealing for all compositions consists of heating the rolled body in a reducing atmosphere such as dissociated ammonia at a temperature of about 900°C for about one half hour. This procedure completely removes the rolled grain structure, permitting further reductions in thickness without cracking or splitting the bar.

With reference to FIG. **4** there is shown a longitudinal cross section of a finished strip of contact material similar to that of FIG. **3** showing its structure. That is, the section is taken along the length of a strip, which is the direction of rolling. It is seen that the refractory particles **10'** are dispersed or suspended within the matrix **12'** of electrically and thermally conductive material and are layered, shown generally at **16**, in a predetermined direction, that is, the rolling direction. The layering effect **16**, which is shown between the dotted lines, extends along the length of the material and across its width. This layering of the refractory particles in a predetermined direction gives a better ductility of the contact material such that is can be more readily formed.

Using the method herein described, electrical contacts of a high electrically and thermally conductive refractory composition have been formed in very thin continuous strips. These strips, which can be "blanked out" to form electrical contacts of various sizes and shapes, not only have better electrical conductivity due to the intimate contact of the refractory particles with the matrix of high electrically and thermally conductive material, but also have a more uniform density and hardness than those of the prior art. This can be more clearly shown by the following examples and accompanying test data.

EXAMPLE 1

A powder mixture of 50 percent silver-50 percent tungsten by weight is pressed and sintered to a bar size of 0.125 inches in thickness. The particle size of the tungsten is about 6 microns, and the silver about 10 microns. The powders are pressed with a pressure of from about 20–25 ton/in.^{2}. They are sintered in an atmosphere of dissociated ammonia for about 20 minutes at a temperature of about 1,130°C. The pressed bars are then cold rolled in air at a 30 percent thickness reduction for one pass. The bars are then resintered in an atmosphere of dissociated ammonia for about 5–10 minutes at a temperature of about 1,000°C. After resintering the bars are then alternately cold rolled and annealed until a strip having a thickness of about 0.031 inches is produced. The annealing is done at a temperature of about 900°C for about one half hour in an atmosphere of dissociated ammonia. The cold rolling is done in passes with a 10–15 percent reduction in each pass.

EXAMPLE 2

A powder mixture of 65 percent silver-35 percent tungsten carbide by weight is pressed and sintered to a bar size of 0.100 inch in thickness. The particle size of the tungsten carbide is about 4 microns, and the silver about 10 microns. The powders are pressed with a pressure of from about 20–25 ton/in.^{2}. They are sintered in an atmosphere of dissociated ammonia for about 15 minutes at a temperature of about 1,300°C. The pressed bars are then cold rolled in air at a 30 percent thickness reduction for one pass. The bars are then resintered in an atmosphere of dissociated ammonia for about 5–10 minutes at a temperature of about 1,200°C. After resintering the bars are then alternately cold rolled and annealed until a strip having a thickness of about 0.031 inch is produced. The annealing is done at a temperature of 900°C for about one half hour in an atmosphere of dissociated ammonia. The cold rolling is done in passes having a 10 percent reduction in each pass.

EXAMPLE 3

A powder mixture of 60 percent silver-40 percent molybdenum by weight is pressed and sintered to a bar size of 0.125 inch in thickness. The particle size of the molybdenum is about 4 microns, and the silver about 10–12 microns. The powders are pressed with a pressure of from about 20–25 ton/in.^{2}. They are sintered in an atmosphere of dissociated ammonia for about 20 minutes at a temperature of about 1,200°C. The pressed bars are then cold rolled in air at about a 30 percent thickness reduction for one pass. The bars are then resintered in an atmosphere of dissociated ammonia for about **5** minutes at a temperature of about 1,100°C. After resintering the bars are then alternately cold rolled and annealed until a strip having a thickness of about 0.031 inch is produced. The annealing is done at a temperature of about 900°C for about one half hour in an atmosphere of dissociated ammonia. The cold rolling is done in passes having a reduction of about 10 percent in each pass.

EXAMPLE 4

A powder mixture of 50 percent copper-50 percent tungsten by weight is pressed to a bar size of 0.125 inch in thickness. The particle size of the tungsten is about 5–6 microns and the copper about 12–13 microns. The powders are pressed with a pressure of from about 15–20 ton/in.^{2}. They are sintered in an atmosphere of dissociated ammonia for about 15 minutes at a temperature of about 1,140°C. The pressed bars are then

and not exhaustive in scope. It is intended that all matter contained in the above description and shown in the accompanying drawings shall be interposed as illustrative and not in a limiting sense.

What is claimed is:

1. A process for forming thin electrical contact material which comprises: blending a mixture of powder of a refractory material taken from the class consisting of tungsten, titanium, molybdenum, and carbides thereof; and a powdered conductive material selected from the group consisting of copper and copper alloys, said conductive material being present in an amount of 20 to 90 percent by weight of said mixture; said refractory powders having a particle size of from about 4 to 20 microns as measured by FAPS analysis; pressing said mixture into bars; sintering said bars in a non-oxidizing atmosphere; cold-rolling said bars in a single path to yield at least about one-third reduction in the bar's thickness; resintering said bars; and thereafter alternately rolling and annealing said bars in cycles to yield reduction of thickness of about 10 to 30 percent in each cycle.

2. A process according to claim 1, wherein said refractory material is tungsten.

3. A process according to claim 1, wherein said high electrically and thermally conductive material is in an amount of from about 50–80 percent by weight of said body, the balance being tungsten carbide.

4. A process according to claim 1, wherein said high electrically and thermally conductive material is in an amount of from about 50–80 percent of said body, the balance being molybdenum.

5. A process according to claim 1, wherein said material of high electrically and thermally conductive material is copper in an amount of from about 20–50 percent by weight of said body, the balance being said refractory material.

6. A process according to claim 5, wherein said refractory material is taken from the group consisting of tungsten and molybdenum.

7. A process according to claim 1, wherein said high electrically and thermally conductive material is copper in an amount of from about 25–50 percent by weight of said body, the balance being tungsten carbide.

8. A process according to claim 1, wherein said non-oxidizing atmosphere is dissociated ammonia.

9. A process according to claim 1, wherein said refractory material has a particle size of from 4–20 microns and said high electrically and thermally conductive material has a particle size of from 4–10 microns.

10. A process according to claim 1, wherein said sintering is carried out at a temperature which is inversely proportional to the refractory particle size such that there will be no bleed-out of the high electrically and thermally conductive material.

11. A process according to claim 1, wherein said rolling is cold rolling.

* * * * *