

United States Patent

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[54] ELECTRICALLY CONDUCTIVE MATERIAL AND ELECTRICAL CONTACT

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[51] Int. Cl.H01b 1/00

[58] Field of Search29/191.2, 195; 136/120;
75/201; 219/145, 146, 74, 75, 69 E, 119; 200/166 C

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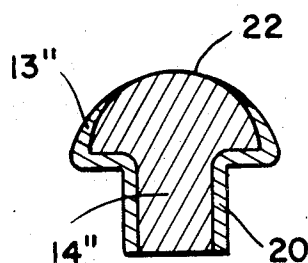
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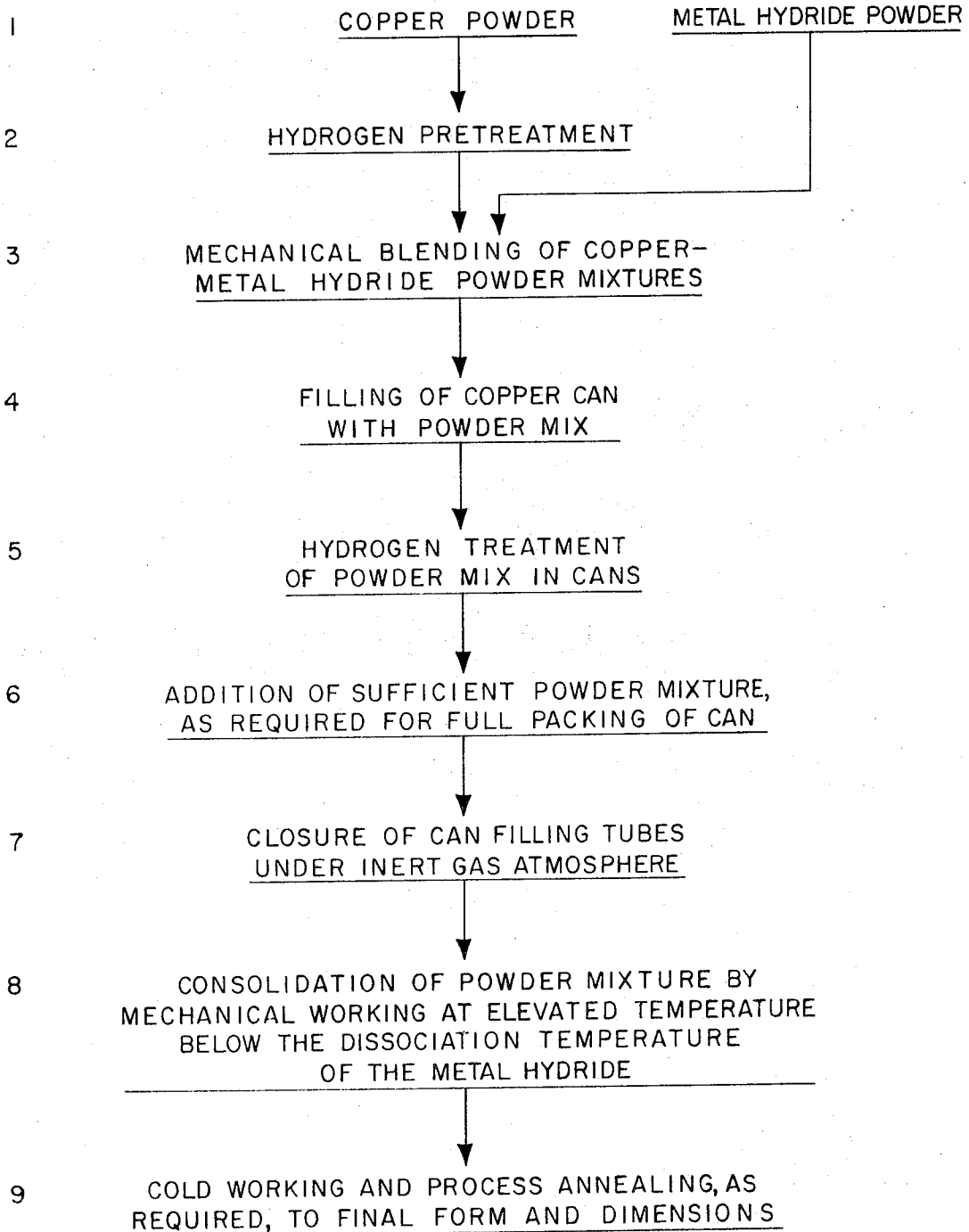
[57] ABSTRACT

An electrically conductive material consisting of a metal that forms a nonprotective surface film in an air atmosphere, and a metal compound capable of providing a reducing atmosphere at the working face of the material when operating in the atmosphere.

16 Claims, 7 Drawing Figures



SHEET 1 OF 2

STEP NO.*FIG. 1*

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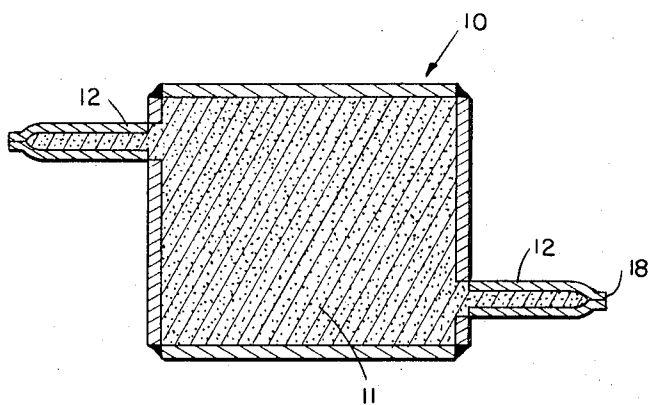


FIG 2

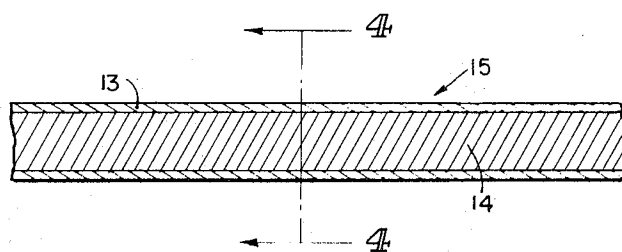


FIG 3

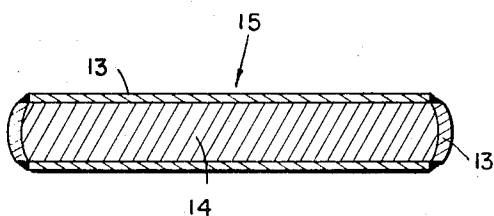


FIG 4

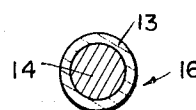


FIG 5

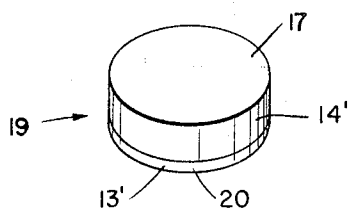


FIG 6

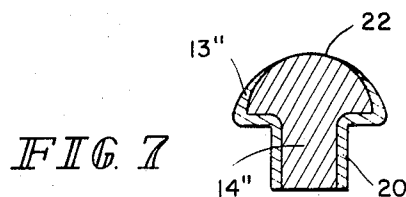


FIG 7

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ELECTRICALLY CONDUCTIVE MATERIAL AND ELECTRICAL CONTACT

Electrically conductive materials such as copper, silver, iron, and nickel have long been used in many electrical applications such as electrical contacts, soldering tips, resistance welding electrodes and spark gaps. These metals, however, have a basic problem—they form a nonprotective surface film at their working face when operating in the atmosphere. Copper, for example, when being used as an electrical contact material readily oxidizes at its active or working face when operating in the atmosphere. Such oxidation causes rapid deterioration of the material at its active face and erratic operation of the material in its use.

The present invention is concerned with a novel electrically conductive material and has as one of its objects the provision of such a material which has good electrical conductivity.

Another object of the invention is the provision of such material which consists basically of a material which forms a nonprotective surface at its active or working surface when operating in the atmosphere.

Still another object of the invention is the provision of such a material which provides a reducing atmosphere at its active or working face.

Yet another object of the invention is to provide an electrically conductive material comprising a composite of a metal that forms a nonprotective surface on its active or working face and a metal compound capable of providing a reducing atmosphere at the materials active face when such material operates in the atmosphere.

Yet still another object of the invention is to provide such a composite wherein the composite is metallurgically bonded between layers of the metal.

Another object of the invention is to provide such a composite wherein the metal compound consists of a metal hydride.

Still another object of the invention is to provide such composite which consists of copper and a metal hydride taken from the class consisting of titanium hydride, calcium hydride, yttrium hydride, lithium hydride and barium hydride.

Another object of the invention is to provide an electrical contact material.

Another object of the invention is to provide a process for forming the novel electrically conductive material.

With the above and other objects in view, which will appear as the description proceeds, this invention resides in a novel electrically conductive material 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 within the scope of the claims.

In the drawings:

FIG. 1 is a flow chart showing the steps used in forming the novel material;

FIG. 2 is a cross section of a compacted powder mixture held in a can suitable for use in carrying out the process of the invention;

FIG. 3 is a partial section of the novel material;

FIG. 4 is a section taken along line 4—4 of FIG. 3;

FIG. 5 is a cross section of the novel material in rod form;

FIG. 6 is a perspective view of an electrical contact made from the novel material; and

FIG. 7 is a cross section of another form of an electrical contact made by the material of the invention.

Generally speaking, the objects of the invention are accomplished by providing a novel electrical material which when in use provides a reducing atmosphere at the material's active or working face. More particularly, an electrical material includes a mixture consisting essentially of a metal such as copper, silver, iron and nickel, which forms a nonprotective film on its active face and a metal compound capable of providing the reducing atmosphere at the active face of the material when it is in use. The novel material also includes a clad composite having a compacted mixture of the metal and the metal compound metallurgically bonded between layers of the metal.

The process of the invention which, in general, includes blending powders of the mixture, consolidating the mixture, and cold working the consolidated mixture along with the can holding the mixture, yields a highly densified material to yield a good electrically conductive material.

While the invention will be described with particular reference to the metal copper, it should be understood that the invention is applicable to the aforementioned silver, iron and nickel.

Step 1

Referring now to the drawings the first step in carrying out the invention is to select the proper powders for the novel material. The copper powder is a commercial grade with 99.5–99.7 percent purity. The metal hydrides in fine powder form that can be used include, but are not restricted to, zirconium hydride (ZrH_2), titanium hydride (TiH_2), lithium hydride (LiH), calcium hydride (CaH_2), yttrium hydride (YH_3), and barium hydride (BaH_2). The principal requirement for the metal hydride are:

1. It must dissociate upon heating to liberate hydrogen.
2. The dissociation temperature must be reasonably high, i.e., above 300° C., to permit ready consolidation with copper powder in Step 8 below. The dissociation temperatures of the hydrides cited as examples vary as follows:

Metal hydride	Dissociation temp., ° C. (at atmospheric pressure unless otherwise indicated)
ZrH_2	550
TiH_2	≈350
LiH	≈600
CaH_2	≈600
BaH_2	675
YH_3	<700

Step 2

The commercial copper powder is heated in dry hydrogen to reduce surface oxides, volatilize any organic or inorganic surface films that are applied by the powder manufacturer to inhibit oxidation, and/or to drive off adsorbed moisture.

The temperature of such treatment is not critical. A range of 300°–500° C. is most effective. A treatment time of 1–2 hours is sufficient.

Step 3

The copper and metal hydride powders are dry blended to produce an intimate, uniform intermixture. Conventional metal powder blending methods and techniques are applicable.

The content of metal hydride in the mixture can vary upwards to around 20 volume percent. The maximum limit of metal hydride depends on the following factors:

- a. Blending characteristics
- b. Electrical conductivity requirements of the ultimate consolidated composite material
- c. Plasticity and formability requirements of same.

Step 4

The blended mixture of copper and metal hydride powders is poured into an all-copper can 10 which is provided with filling tubes 12. The can is vibrated during the filling operation so as to promote a high free-packing density mixture 11. When the level of the powder column in the filling tube remains stationary under the influence of the vibration, filling is complete. Can 10 may be of any suitable configuration, such as cylindrical, rectangular, square, etc., depending on the end product desired, as will be hereinafter discussed.

Step 5

During blending, the hydrogen pretreated copper powder may reoxidize and readsorb moisture. Also, the inner surfaces of the copper can can be contaminated with an oxide layer and adsorbed moisture film. After consolidation of the powders, surface oxide that is internally incorporated can make the material subject to hydrogen embrittlement. Internally en-

trapped moisture can result in blistering upon subsequent thermal treatment. Consequently, it is preferred procedure to heat the can with contents in dry hydrogen in order to minimize the amount of oxide and moisture present immediately before sealing the can. The temperature of such treatment should be as high as possible without exceeding the dissociation temperature of the metal hydride (see Step 1). Provision of the can with two filling tubes permits the free through-flow of hydrogen.

Step 6

After hydrogen treatment, the powder mixture inside the can may tend to pack more closely because of interparticle surface attraction and adhesion. When this occurs, an additional quantity of the pretreated copper-metal hydride mixture is added (under vibration as in Step 4) sufficient to fully pack the can.

An optional procedure is to clean the interior surfaces of the can shortly before filling. Hydrogen reduction, chemical, or electrochemical treatment may be used. If treated in aqueous solutions, care must be taken to thoroughly dry the inside of the can. When the can has been processed in this manner, then steps 5 and 6 can be bypassed. If this method is employed, the can need be equipped with only a single inlet filling tube.

Step 7

The filled can is transferred to an environmental chamber equipped with a vacuum and atmospheric control system. The chamber is evacuated and then backfilled with a partial pressure of a dry inert gas, such as argon or helium. The filling tubes of the can are crimped and then seam-welded at their ends 18 by the TIG method, making a leaktight closure. The hermetically sealed can can then be handled in an air atmosphere.

An alternative method is to connect the filled can directly to a vacuum system through the inlet tube. If the can is equipped with two inlet tubes, then, of course, one is to be welded closed before vacuum hookup. After a vacuum is drawn, the can is backfilled with a partial pressure of argon or helium. The inlet tube is crimped and welded off, all the while maintaining a positive pressure of inert gas inside the tube.

Step 8

The powder mixture inside the hermetically sealed can is then heated to an elevated temperature and consolidated by mechanical deformation at that temperature. The mechanical working temperature must be kept below the dissociation temperature of the metal hydride. At the same time, it must be high enough to promote consolidation of the powder particles by pressure welding. A mechanical working temperature as low as 500° C. was demonstrated to be highly effective. The minimum amount of mechanical deformation required for good densification is in the order of 75 percent, in terms of reduction of area. Theoretical density is essentially attainable by the method.

The process is adaptable to a wide variety of mechanical working methods, as for example, extrusion, forging, pressing, rolling or combinations thereof.

As is more clearly shown in FIG. 3, during the elevated temperature deformation processing, the original walls of the can form an integral cladding 13 which is metallurgically bonded to the solid copper-metal hydride composite 14. In the case of processing by forging or rolling, the cladding 13 will be parallel to the flat planar surfaces of the resulting plate 15 shown in FIG. 4. If a cylindrical can was employed and processing was by axial extrusion, then the cladding 13 would be concentric with the composite core 14 as shown in FIG. 5 to form a rod 16. The final cladding thickness will be governed by the original can wall thickness and the reduction during deformation processing.

Step 9

A variety of end products may be produced from the consolidated composite material starting with plate 15 or rod 16 by cold working and process annealing. The plate 15 can be cold rolled to strips or sheets. As shown in FIG. 6, the sheet

can then be blanked out to form disc-shaped electrical contacts 19. Such a contact will have a base 20 consisting of copper cladding 13' for the copper-metal hydride composite 14', with one of the clad layers 13 of the plate 15 being removed by suitable stripping means to form a working surface or active face 17. The removal of the clad layer would preferably be done during formation of the sheet or strip.

Rod 16 can be cold drawn to wire. Such wire can then be cut into suitable lengths. Each length can then be forged or otherwise formed into an electrical contact such as shown in FIG. 7. Depending upon the size of contact desired, the contact could also be formed from rod 16. As shown, the contact is the form of a button having an active face 22 formed from the copper-metal hydride composite 14'' disposed within a wall 20 consisting of the copper cladding 13''.

During the material's use the faces 17 and 22 will release hydrogen from the metal hydride due to the heat generated so as to create a reducing atmosphere of hydrogen at the active face. The copper cladding on the final product is a unique side advantage of the process used to form the material. When the material is used in an electrical application, notably electrical contacts, the copper cladding contributes to a higher bulk electrical conductivity in proportion to its relative volume.

As an example of fabrication of the novel material of the present invention, copper powder that was pretreated for 2 hours in hydrogen at 500° C. was blended with ZrH₂ powder, and the mixture was poured through a filling tube into a closed, precleaned copper can of the type shown in FIG. 3 under vibration until the can was fully packed. The powders in the can were then placed under vacuum and the filling tube sealed by welding. The sealed, canned powder mixture was hot worked by forging and finished by hot rolling. The hot-working temperature was maintained at 500° C., and the total reduction amounted to almost 90 percent. Samples were made by these procedures, using mixtures of copper powder with about 2.5 and 6.5 volume percent. Metallographic examination showed that excellent densification and good distribution of ZrH₂ dispersion were obtained. Coalescence of grains (grain boundary migration) and, therefore, grain boundary cohesion were promoted. As a result, good ductility and formability were achieved. Furthermore, the electrical conductivity was high: 94.8 percent IACS with 2.5 volume percent ZrH₂ and 89.2 percent IACS with 6.5 volume percent ZrH₂.

As an indication of the novel materials ability to provide the reducing atmosphere, the surface of a copper-10 volume percent ZrH₂ sample was first metallographically polished and then exposed to an indoor air environment for 2 weeks. A visible tarnish film formed on the polished surface during the atmospheric exposure. Optical microscopic examination showed that the tarnish was essentially uniform over the entire surface.

An area of the tarnished surface was then subjected to a relatively low energy electrical spark. A spark coil, which is commonly used for electrostatic detection of leaks in vacuum systems of glass construction, provided the electrical discharge source. After about a 30-second period of exposure to the spark, the affected area was examined under the optical microscope. The copper matrix surrounding each zirconium hydride particle was observed to be clear and tarnish-free. Evidently, the tarnish film in the neighborhood around the hydride particle was chemically reduced by hydrogen that was liberated by dissociation of the hydride under the thermal influence of the spark.

A duplicate tarnished specimen of copper-10 volume percent zirconium hydride was exposed to a high-energy electrical spark. The source of the spark was the high frequency arc starting circuit of a TIG welding machine. With the controls set for 10,000 volts and 1 milliamp, the current was switched on and the tungsten electrode without argon gas flow was brought into proximity with the tarnished specimen surface until electrical spark discharge occurred. The spark was maintained for about 5 seconds. Examination of the affected area

by optical microscopy showed that hydrogen generated by the dissociation of the zirconium hydride dispersion reduced the tarnish film of the copper matrix.

From the foregoing description it will be apparent to those skilled in the art that this invention provides a new and useful electrical material. Accordingly, it is contemplated that the scope of the invention is to be determined from the claims appended hereto.

What is claimed is:

1. An electrically conductive material comprising a composite of copper and a metal hydride taken from the class consisting of zirconium hydride, titanium hydride, lithium hydride, calcium hydride, yttrium hydride and barium hydride, said composite being metallurgically bonded between layers of copper cladding.
2. An electrically conductive material according to claim 1 wherein said metal hydride is in an amount up to about 20 percent by volume.
3. A contact comprising an electrically conductive material according to claim 1 which is disc shaped.
4. A contact comprising an electrically conductive material according to claim 1 which is button shaped.
5. An electrically conductive material according to claim 1 in the form of plate.
6. An electrically conductive material according to claim 1 in the form of sheet.
7. An electrically conductive material according to claim 1

in the form of strip.

8. An electrically conductive material according to claim 1 in the form of rod.

9. An electrically conductive material according to claim 1 in the form of wire.

10. An electrical contact comprising an electrically conductive material according to claim 1 which is shaped as shown in FIG. 7.

11. An electrical contact comprising an electrically conductive material according to claim 1 wherein said hydride is titanium hydride.

12. An electrical contact comprising an electrically conductive material according to claim 1 wherein said hydride is zirconium hydride.

13. An electrical contact comprising an electrically conductive material according to claim 1 wherein said hydride is calcium hydride.

14. An electrical contact comprising an electrically conductive material according to claim 1 wherein said hydride is yttrium hydride.

15. An electrical contact comprising an electrically conductive material according to claim 1 wherein said hydride is lithium hydride.

16. An electrical contact comprising an electrically conductive material according to claim 1 wherein said hydride is barium hydride.

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