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R. K. BEGGS ETAL

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METAL BODIES HAVING CONTINUOUSLY VARYING PHYSICAL
CHARACTERISTICS AND METHOD OF MAKING THE SAME

Filed June 26, 1959

2 Sheets-Sheet 1

FIG. 1

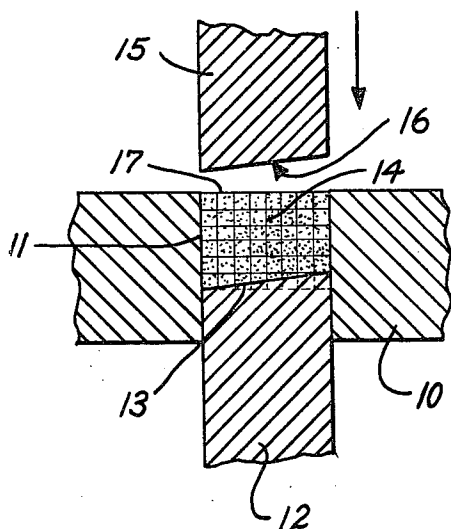


FIG. 2

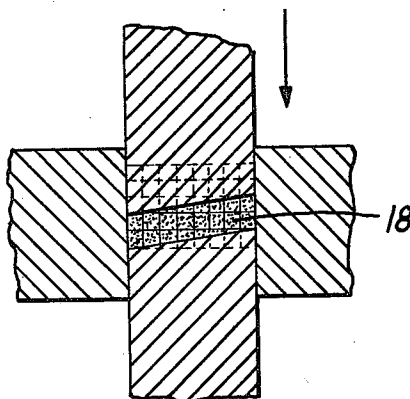
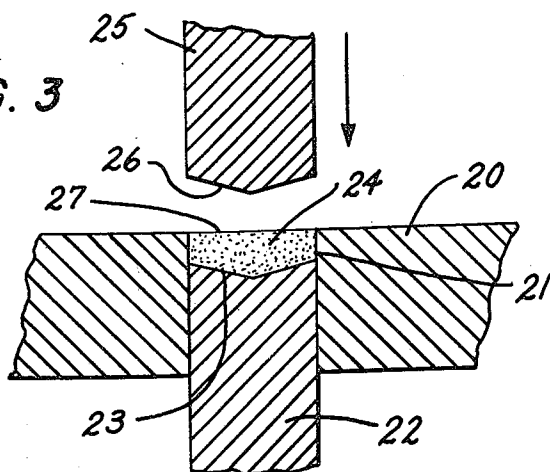


FIG. 3



INVENTORS
ROBERT K. BEGGS
BY GEORGE G. FERLING
George G. Ferling
ATTORNEY

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R. K. BEGGS ETAL

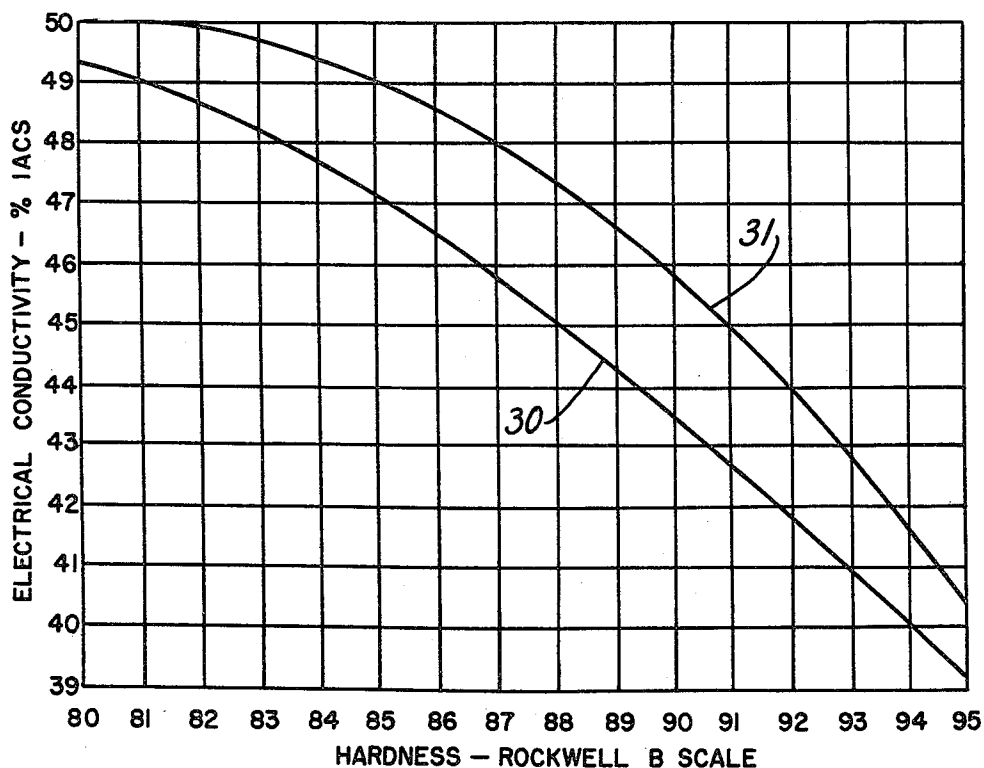
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2 Sheets-Sheet 2

FIG. 4



INVENTOR.
ROBERT K. BEGGS
BY GEORGE G. FERLING
George G. Ferling
ATTORNEY

1

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METAL BODIES HAVING CONTINUOUSLY VARY-
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Robert K. Beggs, Indianapolis, and George G. Ferling,
Greenwood, Ind., assignors to P. R. Mallory & Co.,
Inc., Indianapolis, Ind., a corporation of Delaware

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This invention relates to the art of making materials having physical characteristics which are graduated or are continuously varying in one direction, and, more particularly, to electrical contacts having a face in which the contact properties are graduated in accordance with a predetermined pattern.

As those skilled in the art know, a satisfactory electrical contact, requires a number of characteristics which are difficult or impossible to provide by a single material. Thus, contacts made of certain refractory metals, such as, for example, tungsten, molybdenum, or of their carbides, had the desirable characteristics of high hardness, good wear and are erosion resistance but had relatively low electrical conductivity. On the other hand, contacts made of typical low melting contact metals, such as copper or silver, had the desirable characteristics of high heat and electrical conductivity but were relatively soft and thus subject to wear and arc erosion. From an effort to combine the desirable characteristics of refractory contact metals and low melting point contact metals in a single metal body resulted the well-known group of contact materials sold under the registered trademark Elkonite. In contact materials of this type, a pressed and sintered porous compact or skeleton of refractory contact metal was infiltrated with molten contact metal of high electrical conductivity, combining high hardness, good wear and arc erosion resistance and high heat and electrical conductivity in a single contact body. Of course, the degree of porosity or density of the refractory metal skeleton and thus the proportion of low melting metal in the contact face was adjusted in accordance with the particular application for which the contact was intended.

While contact materials of the described character were highly successful commercially and were used on a large scale for many years, certain operating difficulties were experienced particularly in heavy duty applications due to the fact that an electrical contact had to satisfy widely different requirements when opening or closing the circuit and when merely carrying the load current. For example, most of the wear and arc erosion would occur during opening and closing and a high percentage of refractory metal in the contact face was desirable for these operations. On the other hand, once the contact was closed, a high percentage of the high conductivity material was desirable to minimize ohmic losses and heating up of the contact. Obviously, these requirements were mutually contradictory and could not be satisfied except by a compromise. Although this problem existed in the contact art for a long time and various suggestions and proposals were made to solve the same, none, as far as is known, of these suggestions and proposals was completely satisfactory and successful.

It has been discovered that the outstanding problem can be solved in a remarkably simpler manner.

It is an object of the present invention to improve electrical contacts.

It is another object of the present invention to provide electrical contacts having different characteristics in different portions of the operating face thereof.

A further object of the invention is to provide electrical contacts, the hardness and arc erosion characteristics of which are graduated in one direction on the face

2

thereof and the conductivity characteristics of which are graduated in the opposite direction on the face thereof.

It is also within the contemplation of the invention to generally provide pressed and sintered compacts certain physical characteristics of which are continuously varying in one direction.

The invention also contemplates a method of producing the metal bodies or contacts of the invention.

Other and further objects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawing, in which

FIG. 1 is a vertical sectional view, somewhat diagrammatic and fragmentary in character, of a die body and associated top and bottom punches suitable for carrying the principles of the invention into practice;

FIG. 2 is a similar view of the die body and punches illustrated in FIG. 1, showing the top punch at the end of its thrust;

FIG. 3 is a vertical sectional view of a modified die body and associated punches adapted to produce compacts having a high density area in the center thereof; and

FIG. 4 is a graph showing the relationship of the hardness and conductivity of bars of porous tungsten impregnated with silver and copper, respectively, embodying the principles of the invention.

Broadly stated, in accordance with the principles of the invention, there is provided a die cavity, the depth of which is different at different transverse regions thereof. This cavity is filled with metal powder to a horizontal level. A top punch is then displaced into the cavity, the pressure face of said punch being so constructed and arranged as to compress the powder at a higher ratio in regions where the body of powder is of greater depth than in regions where the said body of powder is of lesser depth. The result will be a pressed compact the porosity of which is graduated or is continuously varying in a direction which is transverse to that of the compression. Upon sintering, the pressed and sintered metal skeleton is impregnated or infiltrated with molten metal of lower melting point. As the portions of greater porosity or lower density will take up more low melting metal than the portions of lesser porosity, the finished product will have graduated physical characteristics in a transverse direction. For example, when using a refractory contact metal, such as tungsten, for the skeleton and a low melting high conductivity metal, such as copper or silver, for the impregnating metal, the resulting contact will be characterized by high hardness and arc erosion resistance continuously varying in one direction and by high electrical conductivity continuously varying in the opposite direction.

Referring now more particularly to FIG. 1 of the drawing, reference numeral 10 denotes a die body having an opening 11 therein. A bottom punch 12 having an inclined face 13 is located in the opening of the die body and defines therewith a die cavity 14. A top punch 15 having an inclined face 16, which is substantially parallel with face 13 of the bottom punch, is mounted for cooperation with the die body, a conventional press or operating mechanism (not shown) being provided for the said top punch.

In operating the compacting mechanism just described, die cavity 14 is filled to a horizontal level 17 with refractory metal powder, such as with powder composed of one or more of the metals tungsten, molybdenum, zirconium, titanium, tantalum, columbium and/or of the carbides of such metals. The top punch is then displaced downwardly, applying compacting pressure to the powder fill.

FIG. 2 shows the completed downward stroke of the top

punch by means of which the powder fill in die cavity 14 has been converted into a pressed compact 18. It will be noted that in the extreme left side of the compact there are six unit weights of loose powder compacted into two unit volumes, while at the extreme right there are only five unit weights compacted into two unit volumes. This, obviously, produces a higher density, or lower porosity, in the left end of the compact. The density will uniformly decrease until the lowest density is found at the extreme right.

After pressing, the compact is sintered in a reducing or protective atmosphere, or in vacuum, at a time and temperature sufficient to produce a sinter structure without excessive shrinkage.

The sintered compact is impregnated with a relatively low melting point metal possessing high electrical conductivity, such as copper, silver, gold, alloys or compounds composed of these metals, or such noble metals as the members of the platinum group. Other alloying additives or secondary materials may be incorporated in the impregnating metal, such as silicon, cadmium, zinc, tin, lead, indium, calcium, arsenic, phosphorus, or antimony to change the surface tension or melting point of the infiltrating material, to lower the energy of the arc produced during the circuit breaking operation, or to spread the arc.

In general, the impregnation step is carried out by placing a piece of the impregnating metal on top of the porous sintered compact and heating them to a temperature above the melting point of the impregnating metal whereby the said metal will melt and infiltrate the compact, substantially completely filling out the pores thereof. After impregnation, such excess impregnating material as may remain frozen to the compact is removed by conventional machining methods. If desired, the sintering and the impregnation can be carried out in a single furnacing operation.

The finished product is characterized by high electrical conductivity in one area and high refractory concentration and thus high hardness in another area, there being a gradation or continuous transition from one to the other in the direction of the contact face. The materials of the invention find many applications, but their principal use is as circuit breaker contact members. In that case, the contacts will open and close on the high refractory area, thus inhibiting excessive erosion and welding due to the attendant arc. Upon completing the closure of the circuit, the current will pass through the low refractory, or high conductivity area, thereby reducing ohmic losses and the generation of heat in the contacts.

FIG. 3 illustrates one of the many possible variations of the principles of the invention. Reference numeral 20 denotes the die body having an opening 21 therein which there is arranged a bottom punch 22. The pressure face 23 of the said punch 22 is defined by a broken line of which the lowest point is at the center of the punch, thus defining with die body 20 a cavity 24 having its maximum depth in the center thereof. Top punch 25 is arranged for cooperation with the die cavity 24 and has a pressure face 26 which is in substantial parallelism with that of the bottom punch.

In view of the similarity of construction, the operation of this modified embodiment of the invention will be readily understood by those skilled in the art without any detailed explanation. It will be sufficient to state that upon filling the die cavity with refractory metal powder up to horizontal level 27 and at the end of the downward thrust of punch 25, a higher compression ratio will be applied to the center of the powder fill and gradually decreasing compression ratios will be applied to the peripheral portions of the powder fill. Thus, upon sintering the pressed compact and infiltrating it with a lower melting point contact metal, a contact is obtained which has a high density area in the center thereof. It will be readily understood that by using top and bottom punches of suitable configuration, the high density area, or, conversely,

ly, the high conductivity area, can be located wherever desired within the limits of the geometry of the proposed compact.

Obviously, in both illustrated embodiments of the invention, the cross section of the die cavity and of the cooperating punches is determined by the desired shape of the compact and may be rectangular, circular or may have the configuration of any regular or irregular polygon.

The curves shown in FIG. 4 were drawn from the test result of two pressings of bars of tungsten powder, the pressed dimensions of each of which were 4" long by 1/4" wide by 1/2" high. These pressings were made in equipment of the type shown in FIGS. 1 and 2 with parallel top and bottom punches which were inclined 5° from the horizontal. The die cavity was filled with tungsten powder having an average particle size of 5-7 microns, which was compacted at a pressure of about 20,000-30,000 p.s.i. and the pressed compacts were sintered for about 30 minutes at a temperature of 1200° C. in an atmosphere of cracked ammonia. Thereupon, the sintered bars were impregnated with copper and silver, respectively.

In FIG. 4, curve 30 shows the interrelation between the hardness and the electrical conductivity for the copper-impregnated tungsten bar and curve 31 the same interrelation for the silver-impregnated tungsten bar. As noted in the foregoing, these bars were pressed with parallel top and bottom punches which were inclined 5° from the horizontal. The difference in properties from end to end is controlled by the degree of inclination from the horizontal as a function of the over-all length. However, the degree of inclination may be over 5° and as high as 30°, or more. Also, the faces of the top and bottom punches need not be parallel so long as the cooperation of the faces of said punches will result in different compression ratio of the powder fill in different transverse regions thereof.

Although the present invention has been disclosed in connection with a few preferred embodiments thereof, variations and modifications may be resorted to by those skilled in the art without departing from the principles of the invention. All of these variations and modifications are considered to be within the true spirit and scope of the present invention as disclosed in the foregoing description and defined by the appended claims.

We claim:

1. The method of making electrical contacts having characteristics which vary continuously along one face thereof, which comprises providing a die cavity having different depths in different transverse regions thereof, filling said cavity to a uniform horizontal level with refractory contact metal powder, displacing a punch into said cavity to compact said powder at different compression ratios in said respective regions without causing appreciable displacement of the powder in the transverse direction, removing the pressed compact from said cavity, sintering said compact to convert it into a refractory metal skeleton the porosity of which varies continuously in the transverse direction, and infiltrating said skeleton with a low melting contact metal to obtain an electrical contact having a face in which erosion resistance and electrical conductivity are continuously and inversely variable.

2. The method of making electrical contacts having continuously varying hardness and electrical conductivity characteristics in one face thereof, which comprises filling a die cavity with refractory contact metal powder to a predetermined horizontal level to provide different depths of powder in different transverse regions of the cavity, displacing the top level of the powder in said cavity by a uniform distance thereby compressing the powder to a greater extent in the regions of greater depth than in the regions of lesser depth without causing appreciable displacement of the powder in the transverse direction, withdrawing the pressed compact from said cavity, sintering said compact to convert it into a refractory metal skeleton having a porosity gradient in the transverse direction, and

5

infiltrating said skeleton with low melting point contact metal to obtain an electrical contact having a face characterized by a conductivity gradient in correspondence with said porosity gradient and by a hardness gradient inversely related to said porosity gradient.

3. An electrical contact comprising a pressed and sintered skeleton of refractory contact metal of relatively low conductivity, said skeleton being characterized by continuously varying porosity in a direction transversely of the pressing direction, and low melting contact metal of relatively high conductivity infiltrated in and substantially filling out the pores of said body, said contact having a face in which erosion resistance and electrical conductivity are continuously and inversely varying.

4. An electrical make-and-break contact comprising a pressed and sintered skeleton of refractory contact metal of relatively low conductivity having interconnected pores the distribution of which is continuously varying in accordance with a predetermined pattern, in a direction transversely of the pressing direction and relatively low melting contact metal of relatively high conductivity infiltrated in and substantially filling out the pores of said skeleton, said contact having a face in which the hardness

6

and resistance to arc erosion are continuously varying in one direction and in which the electrical conductivity is continuously varying in the opposite direction.

5. The electrical make-and-break contact as claimed in claim 4, in which the refractory contact metal comprises at least one metal selected from the group consisting of tungsten, molybdenum, zirconium, titanium, tantalum, columbium and their carbides.

6. The electrical make-and-break contact as claimed in claim 4, in which the relatively low melting contact metal comprises at least one metal selected from the group consisting of copper, silver, gold and platinum group metals.

7. The electrical make-and-break contact as claimed in claim 4, in which the infiltrating metal comprises small amounts of additives for adjusting its contact properties.

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