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Anderson et al.

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[54] **TUNGSTEN ELECTRICAL SWITCHING CONTACTS**

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Related U.S. Application Data

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[52] **U.S. Cl.** ..... **200/166 C,** 29/630 C

[51] **Int. Cl.** **H01h 1/02**

[58] **Field of Search** ..... 200/166 C, 166 CM; 29/630 C, 630 R; 117/217, 227

[56] **References Cited**

UNITED STATES PATENTS

2,723,444	11/1955	Harvey	29/630 C
3,379,846	4/1968	Wood et al.	200/166 C
3,610,859	10/1971	Schreiner	200/166 C
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[57] **ABSTRACT**

A tungsten contact disc is treated by burnishing so as to smooth and compact the contact surface and remove the surface-crazed metals and oxides, while simultaneously filling the surface pores with a contaminant such as iron. The contaminants present in the pores are subsequently removed by immersing the contact disc in a dissolving agent, and the remaining natural oxides of the tungsten are removed from the walls of the pores by cathodic reduction, so as to create large pore sites which are free of oxides and contaminants. Next, there is applied a coating of a diffusion-absorbing metal, such as nickel, to the contact disc to provide a diffusion-absorbing layer for an outer film of gold. The gold lining the pore sites is applied with a thickness sufficient to maintain an amount of non-alloyed gold on the contact surface after some of the gold has been diffusion absorbed by the underlying nickel layer. During electrical switching operations, the gold alloys with the nickel, and the gold and gold alloy lining the pore surfaces are effective to prevent oxide formation on the pore surfaces and to substantially reduce surface destruction by the arc heat, thereby affording a longer contact operating life.

14 Claims, 4 Drawing Figures

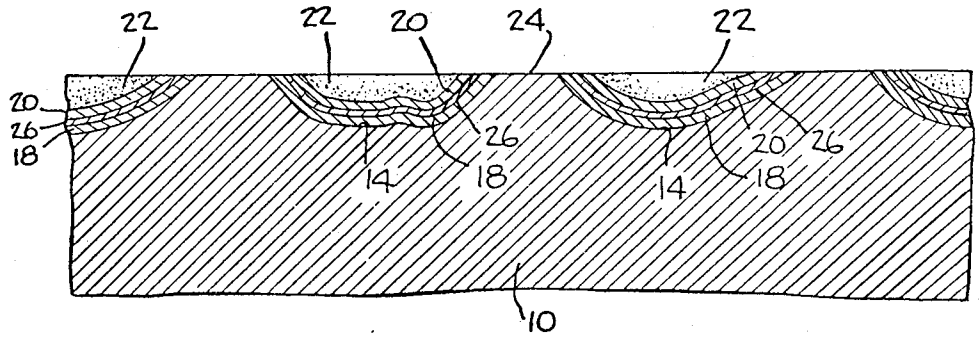


Fig. 1.

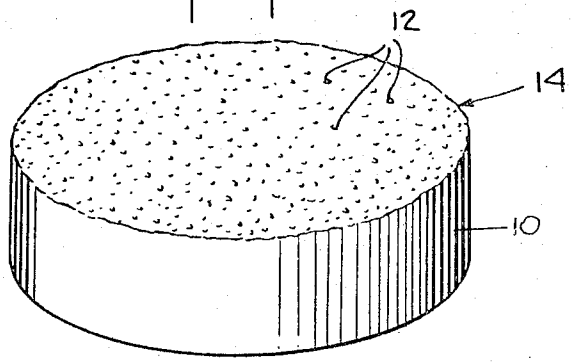


Fig. 2.

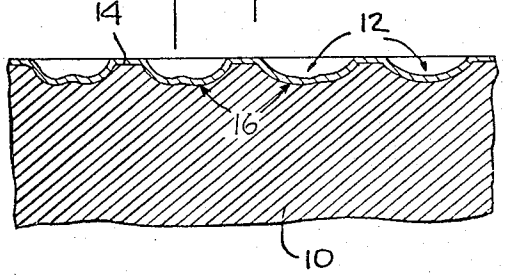


Fig. 3.

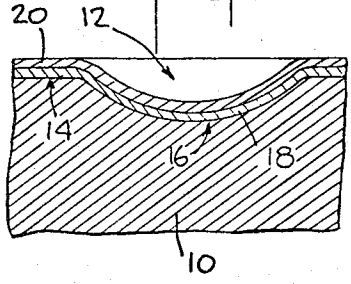
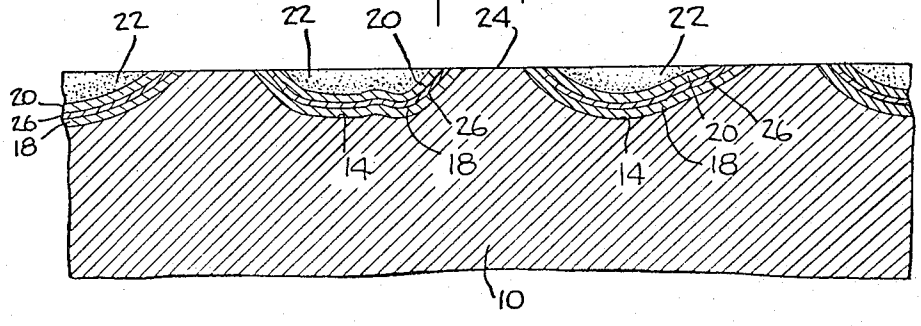


Fig. 4.



TUNGSTEN ELECTRICAL SWITCHING CONTACTS

This is a division of application Ser. No. 6,784 filed Jan. 29, 1970, now U.S. Pat. No. 3,671,314.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to electrical current switching contacts, and more particularly to the treatment of tungsten contact discs for use as a vibrator, relay, or the like, such as the vibratory make and break contacts in an automobile ignition set.

2. Description of the Prior Art

In general, the ideal contact material should have high electrical and thermal conductivity, high melting and vaporization temperatures and high resistance to mechanical wear. In addition, the ideal contact material should have either no tendency to form an oxide of tarnish film, or at least such film should be of low resistance. High thermal conductivity aids in carrying heat away from the point of contact, while a high melting point improves the ability of the contact to withstand high arc temperatures without melting or welding the contacts. Also, a high vaporization temperature results in less tendency for the formation of metallic vapors that help to maintain an arc. Furthermore, high electrical conductivity usually means lower contact resistance and less contact heating, which is especially important where high current densities are employed on the contacts.

Tungsten has long been recognized as one of the leading metals for use as an electrical switching contact, particularly in high current switching applications. Tungsten, which melts at about 3,370° C and boils at about 5,900° C, has a higher melting point than any other metal, thereby making it desirable for use in those applications where a high temperature arc is created. Also, the high degree of stiffness and tensile strength of tungsten render it highly resistant to mechanical wear. Because of its high melting point, casting and melting are impracticable. Tungsten is therefore produced by hydrogen reduction of its oxide to yield a powder which is compacted and sintered into bars which are then mechanically worked into rods.

It is a well-known fact that tungsten, when heated to redness in the presence of air, becomes covered with a layer of oxide. The presence of this oxide tends to increase the electrical contact resistance of the contact, thereby reducing the current carrying capacity of the electrical switch. Also, the readiness with which the thin oxide film forms on the surface of tungsten accounts for the fact that certain metals, such as gold will not adhere permanently to tungsten. One prior art method of treating this problem is to remove the loosely adherent oxide surface layer and then apply a coating of a high conductive metal directly on the contact surface. One disadvantage of this method is that under the high temperature arc conditions to which tungsten contacts are ordinarily associated, the lower melting point gold readily melts and forms balls which spall away from the tungsten body surface.

In the U.S. Pat. No. 2,504,906 issued to Tremblay there is disclosed a composite metal electrical contact in which the contact body is constituted by an intimate mixture of a good conducting metal, such as copper, silver or gold, with a more refractory substance, such as tungsten, molybdenum or tungsten carbide. The

contact surface is treated in a molten or fused alkali metal nitrate which causes removal of the oxides of the refractory substance or metal at the surface of the contact, thereby leaving a surface composed essentially of the good conducting metal. The contact body disclosed by Tremblay is disadvantageous for the following reasons. First, the Tremblay contact stresses the presence of a continuous layer of the high conductive metal covering the contact surface to provide a low contact drop. Therefore, under high temperature arc conditions, such as those existent in the contacts of an automobile ignition set, the high conductive metal surface would simply burn and spall away from the contact. Secondly, inasmuch as the main contact body is constituted by a significant per cent of softer and lower melting point materials combined with the refractory metal, then the overall effect of the composite metal is a much softer contact having lower resistance to mechanical wear.

In other conventional methods, such as that disclosed in the U.S. Pat. No. 3,379,846 issued to Wood et al, an electrode contact tip consists of sintered tungsten particles which are infiltrated throughout the body with a melted alloy of a reactive metal and a high purity metal. In order to infiltrate the alloy metal into the tungsten, the tungsten particles must be wetted, with an agent such as nickel, in a pure dry hydrogen atmosphere. This procedure results in a tungsten body having large amounts of an alloy of the reactive metal and the high-purity metal filling the tungsten pore. The Wood contact would not be suitable in electrical contact switch operations such as in an automobile ignition set, involving high mechanical stresses as well as high arcing temperatures, since a very large percentage of relatively dense tungsten approaching pure tungsten is required in the contact body to provide the high degree of stiffness and tensile strength needed. The Wood contact is a generally softer mass than the pure tungsten contact, and therefore, will not have the high mechanical integrity of pure tungsten. In addition, the large amount of the softer material filling the pores at the contact surface, as well as throughout the tungsten body, causes the opposing surfaces of two mating contacts to stick and weld together under high current switching operations.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a tungsten electrical contact disc which is relatively free of oxides and contaminant materials.

It is another object to provide a tungsten contact having high melting and vaporization temperatures and high resistance to mechanical wear.

It is another object to provide a tungsten contact having a surface treated with a low contact resistance metal which protects the contact against erosion and corrosion, even under high temperature arc conditions.

It is still another object to provide a method of treating a tungsten contact which is not too complex and requires minimum amounts of high-cost, high conductivity materials.

It is a further object to provide a tungsten contact having long operating life in an automobile ignition set.

These and other objects, which become apparent from the detailed disclosure and claims to follow, are achieved by the present invention which provides a treated contact disc for switching electrical current,

such treated contact disc being prepared by burnishing a porous contact disc, made of a refractory metal, such as tungsten, so as to smooth and compact the surface and remove the surface-crazed metals and oxides from the surface while filling the surface pores with a contaminant, such as iron. After burnishing, the contaminants present on the surface and in the surface pores are removed by immersing the contact disc in a dissolving agent to create large pore sites within the tungsten contact surface. The remaining natural oxides of the tungsten are removed from the pore sites by cathodic reduction, and a thin coating of a diffusion-absorbing metal, such as nickel, is applied on the contact surface and the walls of the pore sites to provide a diffusion-absorbing layer for an outer film of a good conductor metal, such as gold. During electrical switching, the operating temperature of the arc causes the nickel to bond to the tungsten while the gold alloys and adheres to the nickel. The nickel-gold alloy and the gold lining the pore sites are effective to prevent oxide formation on the pore surfaces and to substantially reduce surface destruction by the arc heat, thereby extending the normal operating life of the tungsten contacts.

Thus, the present invention provides a tungsten contact disc for switching electrical current, which comprises a porous tungsten body having a burnished contact surface, said tungsten body having pore sites at the contact surface which are substantially free from contaminants and oxides, a thin film of gold applied to the contact surface and lining the pore sites, and a coating of a diffusion-absorbing metal between such tungsten contact surface and such gold film which adheres to the tungsten and provides a diffusion-absorbing layer for the gold.

It is to be understood that, as used herein, the term "tungsten" is intended to mean tungsten or any other refractory metal suitable for use as an electrical switching contact material, such as molybdenum, rhenium and niobium, and alloys or mixtures thereof. It is also to be understood that as used herein, the term "gold" is intended to mean gold or any other semi-precious to precious metals which are characterized by their low contact resistance and low rates of oxide formation, such as silver, platinum, palladium or rhodium, or alloys or mixtures thereof.

It is also to be understood that, as used herein, the term "diffusion-absorbing metal" is intended to mean a metal which will bond to tungsten directly, and yet will alloy with "gold," such as nickel or cobalt, or alloys or mixtures thereof. It is to be further understood that, as used herein, the term "contaminant" is intended to mean any material that is not metallic tungsten or one of the metals applied on the tungsten body, such as nickel and gold.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of the electrical contact disc, shown magnified several times, illustrative of the invention;

FIG. 2 is a longitudinal cross-sectional view of a portion of the contact area of the contact disc shown in FIG. 1, showing a close-up of several pore sites at the contact surface;

FIG. 3 is a further magnified cross-sectional view of one of the pore sites, showing the nickel and gold lining the surfaces of the pore sites and the tungsten contact surface, prior to operation of the contact in an electrical circuit; and

FIG. 4 is a longitudinal cross-sectional view of a portion of the contact area, showing some of the many tungsten projections, and the nickel and gold lining the surfaces of the pore sites, after operation of the contact in an electrical circuit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, there is shown the tungsten contact disc **10** of the invention. Tungsten disc **10** is prepared from a substantially pure tungsten material by a conventional sintering process to produce a porous tungsten body having the high degree of hardness required for the mechanical stresses to which a switching contact, such as an automobile ignition contact, is ordinarily subjected. While conventional tungsten discs, as noted previously, have a natural tendency to form oxides of tungsten on the contact surface as well as having surface-crazed contaminant particles due to the various conventional surface-smoothing techniques, it has been found that the tungsten contact surface can be treated by a technique in accordance with the present invention which produces pore suites on the contact surface which are free of oxide and contaminant materials, while such pore sites are lined with a high conductive metal which functions to improve the useful life of the tungsten contact.

More specifically, the tungsten discs **10** are barrel burnished to clear the surface of surface-crazed particles and oxides, and work harden the tungsten material. In addition, in accordance with the present invention, the tungsten discs **10** are burnished in a contaminant media, such as iron, by burnishing for the specific purpose of filling the pores with the iron. In the burnishing process, most of the tungsten oxides on the disc surface and in the surface pores are replaced by the iron contaminant. It is to be understood that metals other than iron, such as copper and aluminum oxide, can be employed as the contaminant in the burnishing step.

By burnishing the contact surface and filling the surface pores with a contaminant, the size of the pores are held open to its original size and prevented from being substantially reduced in size or closed as would be the case according to conventional surface-smoothing techniques. In this fashion, the disc surface is prepared for subsequent surface-coating steps which require deep pore sites accessible to the contact surface.

The contact areas where the pore sites are located are indicated by the numeral **12** in FIG. **1.** Pore sites **12** extend over the contact surface **14.** Essentially, two types of materials are now present in the pore sites **12.** One material present in the pore sites **12** are those contaminants, such as iron, which were intentionally filled into the pore sites **12** during the burnishing procedure. These contaminants are soluble in suitable mineral acids. The second material present in the pore sites **12** are those remaining natural oxides of tungsten which were not cleared from the surface during the burnishing procedure. These pore sites **12** now being substantially filled with the iron contaminant are now cleared of the contaminant by immersing the contact disc **10** in a dissolving agent, such as hydrochloric acid, thereby removing the contaminant. After removing the iron contaminant, there will be some oxides remaining on the surfaces of the pore sites **12** consisting mainly of

tungsten oxides and perhaps some small traces of iron. Now, because of the fairly large size and depth of the pore sites **12** made possible by filling and then removing the iron contaminant from the pore sites **12** in the manner described above, a large number of pore sites **12** are exposed. The tungsten oxide surface layer is very thin and since the pore site **12** is now accessible, then the tungsten oxide is relatively easy to remove by the conventional oxide removal methods.

The tungsten discs **10** are subjected to cathodic reduction to reduce the oxides and to carry away any residual particles that are not adhered to the tungsten body **10**, thereby assuring removal of all oxides and iron contaminants from the contact surface **14** and the pore sites **12**. Since the tungsten is an inert element, any oxides can be readily removed by cathodic reduction

Referring to FIGS. **2** and **3**, as soon as the pore sites **12** are free of any oxides or contaminant, a thin coating of diffusion-absorbing metal, such as nickel, is applied to the contact surface **14** and the surfaces **16** of pore sites **12**. This is accomplished by immersing the contact disc in a nickel-plating electrolyte, such as Woods nickel solution, so as to deposit a thin film **18** of nickel which bonds to the tungsten surfaces **14** and **16** and provides the diffusion-absorbing layer for the outer surface of gold. In this connection, it is noted that coating methods other than the electrolytic method described may also be suitably employed, such as the conventional evaporation or sputtering vacuum process. The nickel film **18** must be of a sufficient thickness to absorb on its surface a saturation amount of gold while also being of a sufficient thickness to prevent gold from reaching the tungsten body **10**. This latter requirement arises from the well-known fact that gold cannot be plated directly on tungsten since the lower melting point gold when it melts will separate and spall away from the tungsten. According to our invention, the nickel is applied in a layer having a thickness sufficient to prevent the gold from coming into direct contact with the tungsten. Therefore, this diffusion-absorbing layer provides self-limiting diffusion in that it is applied in a thickness which will not permit the gold to penetrate completely therethrough into direct contact with the tungsten body **10**. The purpose in applying the nickel layer is, therefore, to provide a diffusion-absorbing surface for the retention of the gold. As an example of the thickness of the nickel film **18**, such film may be in the order of about 50×10^{-6} inches, this being sufficient to prevent the gold from reaching the tungsten at operating temperatures.

A thin film **20** of gold is now applied on top of the nickel coating **18**. The gold film **20** has a thickness which is sufficient so that free, non-alloyed gold will remain as a lining in the pore sites **12** after an amount of gold has been diffusion absorbed by the underlying nickel **18**. The gold layer should not be so thick as to cause contact sticking. As an example, the gold film **20** may be applied with a thickness of about 50×10^{-6} inches. In this case, after the heat of operation has alloyed some of the gold with the nickel, the overall coating on the surfaces **16** of the pore sites **12** may comprise an outer film of gold having a thickness in the order of 40 microinches on top of a gold-nickel alloy having a thickness of about 10 microinches which, in turn, covers a nickel underlayer having a thickness in the order of 40 microinches.

Use of the gold functions to protect the contact surface **14** from oxidation, particularly in the areas of the pore sites **12**. The overall treated tungsten body **10** is made of the hard material required to withstand the make and break switching operations, while the gold and gold alloy is sufficiently set within the pore sites **12** so that it does not merely burn off under high arc temperatures. Also, the presence of the gold and gold alloy in the pore sites **12** provides an overall contact surface **14** which is generally free of the oxides and contaminant materials otherwise found on the surface of tungsten contacts, which materials act to deteriorate the structural foundation below the contact surface **14**.

Referring to FIG. **4**, there is shown a magnified cross section view of a portion of the contact body **10** after extended electrical current switching operations. In FIG. **4**, the cross section of the gold layer is indicated once again by the numeral **20**, while the side walls of the pore sites **12** are shown as being covered at **22** by the gold layer **20**. During the use of the tungsten contacts **10** in, for example, an automobile ignition set, the surface **14** of the contact is subjected to a highly inductive electric arc. Consequently, a large amount of heat is generated at the contact surface projections **24**, as shown in FIG. **4**. Although the gold generally present on the contact surface **14** becomes molten, such gold is not completely dissipated in the vapor as is the usual occurrence in circuits of this type. Here, the presence of the nickel perform the function of a sponge to which the gold adheres. The oxidation which does work is limited to the actual points of contact which are the raised projections **24** at the surface **14**. In the area of the projections **24**, the nickel and gold have been found to boil off and evaporate due to theheat of arc produced across such projections **24**. Even during extended switching operations when some of the surface material of the projections **24** in the arcing area is being eroded, the pure gold and the nickel-gold alloy remain in the pore sites **12**.

Also, where the gold and gold alloy layers on the contact surface **14** are boiled off after extended switching operations, the gold and gold alloy remain as a lining in the pore sites **12** and their presence has been found to provide a contact of greater endurance and operating life than heretofore available. More specifically, the presence of the gold and nickel, as shown by the FIG. **4**, prevents oxidation from occurring on the walls **16** of the pore sites, which oxidation would otherwise have the effect of forming exposed holes or valleys in the contact surface **14**, and thereby would deteriorate the structural foundation below such contact surface **14**. It is further believed that the film of gold in the pore sites **12** acts as a heat sink over a large surface area, and this high conductive material heat sink greatly reduces the amount of tungsten erosion at and beneath the contact surface **14**. The reason for this is that tungsten is not as high a conductor of electricity or heat as the gold, and consequently, the tungsten tends to retain the heat of arc in the arcing areas. By providing a large heat dissipating surface area comprising the large, gold-lined pore sites **12**, the gold acts as a stabilizer to reduce the contact material temperature around the joint of arcing, and thereby prevents the buildup of temperature at the arcing areas.

In addition, by virtue of the multiplicity of small arcing areas available as provided by the projections **24**, the arc is not localized to a confined portion of the sur-

face, but rather operates over the many top surfaces of the projections **24** extending throughout the contact surface of disc **10.** In this manner, the arc does not continuously and repeatedly occur in only one specific peak area on the contact surface.

Therefore, the presence of a multiplicity of projections or arcing areas, together with the provision of a film of gold on the surfaces **16** of the pore sites **12,** provide better heat dissipation by spreading the arc heat over a larger area.

Although the above description is directed to the preferred embodiment of the invention, it is noted that other variations and modifications will be apparent to those skilled in the art and, therefore, may be made without departing from the spirit and scope of the present disclosure.

What is claimed is:

1. A contact disc for switching electrical current comprising:

a. a porous body of a refractory metal, selected from the group consisting of tungsten, molybdenum, rhenium and niobium;

b. said porous body having pore sites open at the contact surface;

c. a thin film of a good conducting metal, selected from the group consisting of gold, silver, platinum, palladium and rhodium, covering said contact surface and the walls of said pore sites, said good conducting metal film having a thickness of about 50 $\times 10^{-6}$ inches; and

d. an intermediate layer of a diffusion-absorbing metal, selected from the group consisting of nickel and cobalt, positioned between said conducting metal film, and said contact surface and the walls of said pore sites, said intermediate layer adhering to the refractory metal and providing a diffusion-absorbing layer for said conducting metal film.

2. A contact disc as recited in claim **1,** wherein said refractory metal is tungsten, said good conducting metal is gold and said diffusion-absorbing metal is nickel.

3. A contact disc for switching electrical current comprising:

a. a porous body of a refractory metal, selected from the group consisting of tungsten, molybdenum, rhenium and niobium;

b. said porous body having pore sites open at the contact surface;

c. a thin film of a good conducting metal selected from the group consisting of gold, silver, platinum, palladium and rhodium, covering said contact surface and the walls of said pore sites; and

d. an intermediate layer of a diffusion-absorbing metal, selected from the group consisting of nickel and cobalt, positioned between said conducting metal film, and said contact surface and the walls of said pore sites, said intermediate layer adhering to the refractory metal and providing a diffusion-absorbing layer for said conducting metal film, and said intermediate layer of a diffusion-absorbing metal having a thickness of about 50 $\times 10^{-6}$ inches.

4. A contact disc as recited in claim **3,** wherein said good conducting metal film has a thickness of about 50 $\times 10^{-6}$ inches.

5. A contact disc for switching electrical current in an automobile ignition contact switching circuit, comprising:

a. a porous body of refractory metal, selected from the group consisting of tungsten, molybdenum, rhenium and niobium, said porous body having pore sites open at the contact surface;

b. a thin coating of a diffusion-absorbing metal, selected from the group consisting of nickel and cobalt, coating the contact surface and the walls of said pore sites;

c. an outer film of a good conducting metal, selected from the group consisting of gold, silver, platinum, palladium and rhodium, on top of said diffusion-absorbing metal, said good conducting metal film having a thickness of about 50 $\times 10^{-6}$ inches; and

d. said diffusion-absorbing metal being bonded to said refractory metal and said good conductor metal being alloyed and adhered to said diffusion-absorbing metal as a result of subjecting the contact disc to the electrical switching current across the contact surface.

6. A contact disc as recited in claim **5,** wherein said diffusion-absorbing metal and said good conductor metal are substantially not present on the contact surface in those areas where raised projections are located, while said metals remain as a lining on the walls of said pore sites, as a result of said metals being boiled off and evaporated from said raised projections on said contact surface by the arc heat of the electrical switching current.

7. A contact disc for switching electrical current, comprising:

a. a porous body of a refractory metal, selected from the group consisting of tungsten, molybdenum, rhenium and niobium, said porous body having pore sites which are open at a contact surface thereof;

b. a thin film of a good conducting metal, selected from the group consisting of gold, silver, platinum, palladium and rhodium, covering said contact surface and lining the pore sites, and said good conducting metal film having a thickness of about 50 $\times 10^{-6}$ inches; and

c. a coating of diffusion-absorbing metal between said contact surface and said film of good conducting metal, said diffusion-absorbing metal adhering to said refractory metal and providing a diffusion-absorbing layer for said good conducting metal, and said diffusion-absorbing metal having a thickness of about 50 $\times 10^{-6}$ inches.

8. A contact disc as recited in claim **7,** wherein the walls of said pore sites at the contact surface are substantially free from contaminants and oxides.

9. A contact disc as recited in claim **7,** wherein said good conductor metal film has a thickness sufficient to maintain an amount of non-alloyed good conductor metal on the contact surface after someofsaid good conductor metal has been diffusion-absorbed by the underlying layer of said diffusion-absorbing metal.

10. A contact disc as recited in claim **7,** wherein said porous body of refractory metal has a generally smooth and compacted contact surface.

11. A contact disc as recited in claim **10,** wherein said contact disc surface is provided with said smooth and compacted surface characteristics by burnishing said contact disc during manufacture.

12. A contact disc as recited in claim **7,** wherein said diffusion-absorbing metal and said film of good conducting metal line the walls of said pore sites, while said

metals substantially do not line the raised projections at the contact surface.

13. A contact disc as recited in claim **7**, wherein said diffusion-absorbing metal is bonded to said refractory metal and said good conductor metal is alloyed and adhered to said diffusion-absorbing metal at those locations where said pore sites are lined with said diffusion-absorbing metal and said good conducting metal, by means of subjecting said contact disc to an electrical switching current across the contact surface.

14. A contact disc for switching electrical current, comprising:

a. a porous body of refractory metal, selected from the group consisting of tungsten, molybdenum, rhenium and niobium, said porous body having a smooth and compacted contact surface which is provided by burnishing said porous body in the presence of a contaminant material while filling the pore sites located at the contact surface with said contaminant material, and thereafter dissolving said contaminants and remaining oxides to provide pore sites which are open at the contact surface and substantially free of oxides and contaminants;

b. a thin film of diffusion-absorbing metal, selected from the group consisting of nickel and cobalt, coating the walls of said pore sites, said diffusion-absorbing metal film having a thickness of about 50×10^{-6} inches; and

c. an outer film of a good conducting metal, selected from the group consisting of gold, silver, platinum, palladium and rhodium, on top of said diffusion-absorbing metal, said good conducting metal film having a thickness of about 50×10^{-6} inches.

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