# United States Patent [19]

**Davies**

[11] **3,920,452**

[45] **Nov. 18, 1975**


[54] **LIGHT-DUTY ELECTRICAL CONTACTS**


[75] Inventor: **Terrence Ardern Davies,** Northampton, England

[73] Assignee: **Square D Company,** Park Ridge, Ill.



[22] Filed: **June 25, 1973**

[21] Appl. No.: **373,054**

**Related U.S. Application Data**

[62] Division of Ser. No. 191,564, Oct. 21, 1971, Pat. No. 3,778,257.

[30] **Foreign Application Priority Data**

Oct. 21, 1970 United Kingdom ..... 49960/70

[52] **U.S. Cl.** ..... **75/200;** 75/206; 75/224; 252/514; 252/518

[51] **Int. Cl.²** ..... **B22F 1/00;** B22F 5/00

[58] **Field of Search** ..... 75/206, 224, 200; 252/514, 252/518



[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 2,486,341 | 10/1949 | Stumbock | 75/206 |
| 2,894,839 | 7/1959 | Matsukawa | 75/206 |
| 3,214,271 | 10/1965 | Halberg et al. | 75/206 |
| 3,687,657 | 8/1972 | Storchheim | 75/224 |

FOREIGN PATENTS OR APPLICATIONS

| | | | |
|---|---|---|---|
| 686,241 | 5/1964 | Canada | 75/206 |

OTHER PUBLICATIONS

Jones, Fundamental Principles of Powder Metallurgy, E. Arnold Ltd., 1960, p. 571.



*Primary Examiner*—Benjamin R. Padgett
*Assistant Examiner*—B. H. Hunt
*Attorney, Agent, or Firm*—James S. Pristelski; Harold J. Rathbun



[57] **ABSTRACT**

A light-duty electrical contact material which consists of a mixture of silver and ruthenium dioxide, the ruthenium dioxide content being in the range 0.1 to 13.0 weight per cent. For reasons of economy, the preferred ruthenium dioxide content is 1.3 per cent. The material is produced by powder metallurgical techniques from fine, irregular silver powder and preferably ultra fine ruthenium metal powder. Fine ruthenium dioxide powder can be utilized in place of the ruthenium metal powder.


**9 Claims, No Drawings**

# LIGHT-DUTY ELECTRICAL CONTACTS

This is a division of application Ser. No. 191,564, filed Oct. 21, 1971, now U.S. Pat. No. 3,778,257 on Dec. 12, 1973.

The invention relates to light-duty electrical contact materials and to methods of producing light-duty electrical contacts.

The invention provides a light-duty electrical contact material which consists of a mixture of silver and ruthenium dioxide, the ruthenium dioxide content being in the range 0.1 to 13.0 weight per cent. For reasons of economy, the preferred ruthenium dioxide content is 1.3 per cent.

The invention also provides a method of producing a light-duty electrical contact including the steps of mixing fine, irregular silver powder with ultra fine ruthenium metal powder to provide a mixture having a fine, evenly dispersed ruthenium content in the range 0.1 to 10.0 weight per cent; compacting the mixture into a desired shape; heating the compacted shape in a suitable atmosphere for a period of time to effect sintering of same; and internally oxidizing the sintered compacts to convert the ruthenium metal into ruthenium dioxide.

The invention further provides a light-duty electrical contact which is produced by the method outlined in the preceding paragraph.

The foregoing and other features according to the invention will be better understood from the following description of specific embodiments of the invention.

The electrical contact material according to the invention which, as previously stated, is suitable for light-duty applications, consists of a mixture of silver and ruthenium dioxide, and the concentration of ruthenium dioxide can vary from 0.1 to 13.0 weight per cent. The contact material is best fabricated by powder metallurgical techniques and the preferred and most economical material is a material having a ruthenium dioxide content of 1.3 per cent. Vacuum and gas melting techniques are unsuitable because it is not possible to disperse the ruthenium phase finely and evenly throughout the silver.

Thus in a method according to the invention fine. irregular silver powder, and ultra fine ruthenium powder are initimately mixed together such that the ruthenium content of the mixture is in the range 0.1 to 10.0 weight per cent. The intimate mixing can be effected by dry tumble milling for a period of time of the order of 2 to 24 hours. Alternatively, the intimate mixing of the powder particles can be effected by dry tumbling in the presence of glass spheres, or by milling under acetone.

The size and shape of the metal powder particles is of prime importance in the manufacture of optimum silver-ruthenium dioxide materials and both powders should preferably be as fine as is economically possible. This in practice involves the use of precipitated silver of less than 300 or 350 mesh (preferably less than 20 microns average intercept), and ruthenium powder in the sub-sieve size range (preferably less than 2 microns average intercepts) with preferably no ruthenium powder particles of a size greater than 5 microns diameter. The use of fine powders ensures that a fine, even dispersion of the ruthenium is obtained in the finished contact material and facilitates the rapid oxidation of silver-ruthenium alloys which are to be internally oxidized to obtain a fine, even dispersion of ruthenium dioxide in the silver.



The powder mixture is then compacted, using molds, into the desired shape for the electrical contacts. The compacting can for example be effected at a pressure of the order of 10 to 20 tons per square inch to give green densities of the order of 70% of the theoretical maximum density.

The contact compacts are then sintered by being heated in a neutral or reducing atmosphere, for example 90% $N_2$/10% $H_2$, for a period of time of not less than one hour. The upper temperature limit for the sintering operation is 960.5°C i.e. the melting point of silver. In order to maximize the sintering rate a temperature just below the melting point temperature should be utilized, for example a temperature of the order of 930°C. The sintering process increases the density of the contact material to between 80 and 90 per cent of the theoretical maximum density, the actual density attained being dependent upon the sintering time and temperature.

With silver-ruthenium alloys which have been sintered in a reducing atmosphere it should be noted that an increase in the dimensions of the contact compact occurs during the subsequent internal oxidation step due to an increase in the volume of the material when the ruthenium is converted to ruthenium dioxide, and to the generation of pockets of steam due to the reaction of oxygen with any dissolved/residual hydrogen. The latter effect can be avoided by sintering the initial alloy in a neutral atmosphere.

Cold welding of the soft silver powder particles readily occurs when compacting is effected at high pressures, for example 40 tons per square inch, and this welding results in pockets of trapped air in the green contact compact. The pockets of air are expanded during the sintering step and can, therefore, cause distortion and even expansion of the compact. Thus it is important to ensure that high forming pressures of this order are avoided during the method according to the invention.

The sintered contact compacts are then internally oxidized by being heated in air at a temperature of the order of 930°C for a period of time of not less than one hour. This oxidation process completely converts the sub-surface particles of ruthenium metal in the silver (Ag) to ruthenium dioxide ($RuO_2$). Metal particles at greater depths will only be partially oxidized on their surfaces.

Ruthenium dioxide is a conducting oxide which exhibits very low electrical resistivity and is contained in the contact material as a fine, even dispersion.

The density of the contact material may then, if desired, be increased to at least 95 per cent of the theoretical maximum density by a stamping operation at a pressure of the order of 40 to 45 tons per square inch.

The material of the electrical contacts produced by this method exhibits low, stable contact resistance at low contact forces over a period of years under atmospheric conditions which would normally tarnish and corrode known silver base contact materials such as silver-cadmium oxide or silver alone.

In an alternative method according to the invention, the green silver-ruthenium compacts can be compacted at a pressure of the order of 10 tons per square inch, and then sintered in air for a period of the order of 1 hour at a temperature of the order of 930°C. This sintering process simultaneously sinters the contact material and oxidizes the ruthenium to $RuO_2$. The ruthenium powder particles situated well below the surface of the compacts are oxidized and the density of the

contact material is increased from 70 to 80 per cent of the theoretical maximum density.

As with the previous method, the density of the contact material may then, if desired, be increased to at least 95 per cent of the theoretical maximum density by a stamping operation at a pressure of the order of 40 to 45 tons per square inch.

The contact material produced by this alternative method also exhibits low, stable contact resistance at low contact forces for long periods in tarnishing atmospheres.

It should be noted that the simultaneous sintering and oxidation of green silver-ruthenium contacts results in a net shrinkage when the material is initially compacted at 10 tons per square inch. At 20 tons per square inch a net expansion occurs.

When, during the sintering step of the methods according to the invention, the silver recrystallizes and grain growth begins, the grains grow until they meet a ruthenium dioxide particle. The ruthenium dioxide particles impede further grain growth and remain in the grain boundaries to effectively anchor them in position. Thus the ruthenium dioxide content of the contact materials produced by the methods according to the invention is mostly located in the grain boundaries in the silver.

The contact resistance properties of the light-duty electrical contact materials according to the invention in comparison with silver (Ag) and silver-cadmium oxide (AgCdO) contact materials are indicated in the table given below:

| Contact Force (Grms. wt.) | CONTACT RESISTANCE (OHMS) | | | | |
|---|---|---|---|---|---|
| | Silver | Ag-10%CdO | Ag-1.3%$RuO_2$ | Ag-2.6%$RuO_2$ | Ag-3.9%$RuO_2$ |
| 7.0 | 3.32 | 0.36 | — | 0.165 | 0.150 |
| 10.3 | 2.90 | 0.13 | 0.034 | 0.011 | 0.030 |
| 13.6 | 2.50 | 0.032 | 0.008 | 0.005 | 0.009 |
| 17.0 | 2.15 | 0.014 | 0.009 | 0.009 | 0.003 |
| 20.3 | 0.28 | 0.011 | 0.006 | 0.006 | 0.003 |
| 23.6 | 0.20 | — | 0.003 | 0.006 | 0.003 |
| 27.0 | 0.12 | 0.007 | 0.004 | 0.010 | 0.005 |
| 30.3 | 0.13 | — | 0.003 | 0.012 | 0.003 |
| 33.6 | — | — | 0.003 | 0.012 | 0.003 |
| 37.0 | 0.04 | 0.006 | 0.002 | 0.008 | 0.004 |

The contact resistance is shown as a function of contact force after 21 hours exposure to a moist $H_2S$ atmosphere i.e. an atmosphere containing 700.0 mm $H_2S$ and 17.0 mm of $H_2O$.

It should be noted that when low tolerance contact dimensions are required it is important to avoid excessive shrinkage of the contact compact during the sintering step of the methods according to the invention. The shrinkage which occurs during the sintering step is directly influenced by the initial forming pressure used to press the green contact compacts and therefore the correct choice of the initial forming pressure is, under these circumstances, very important.

An advantage of the silver-ruthenium dioxide is that it is readily solderable with soft solder, it is readily capable of heading to form a rivet, and it is capable of being brazed.

In a further alternative method according to the invention the ruthenium metal powder utilized in the methods outlined in preceding paragraphs is replaced by ruthenium dioxide powder such that the ruthenium dioxide content of the silver-ruthenium dioxide mixture is in the range 0.1 to 13.0 weight per cent. The silver-ruthenium dioxide mixture is then compacted and sintered in an inert atmosphere in the manner outlined in preceding paragraphs. While this production method produces a silver-ruthenium dioxide material that may be suitable for certain applications it is not the preferred method because it results in a less favorable dioxide particle size distribution and an inferior dispersion of dioxide particles within the silver matrix.

It is to be understood that the foregoing description of specific examples of this invention is made by way of example only and is not to be considered as a limitation in its scope.

What is claimed is;

**1.** A method of producing a light-duty electrical contact including the steps of mixing fine, irregular silver powder with ultra fine ruthenium metal powder to provide a mixture having a fine, evenly dispersed ruthenium content in the range of 0.1 to 10.0 weight per cent; compacting the mixture into a desired shape; heating the compacted shape in an inert or reducing atmosphere for a period of time to effect sintering of same; and oxidizing the sintered compacts both on the surface and internally to convert the ruthenium metal into ruthenium dioxide.

**2.** A method as claimed in claim **1** wherein the sintering and the surface and internal oxidizing of the compacted shape is effected simultaneously by heating the compacted shape for a period of time in air.

**3.** A method as claimed in claim **2** wherein the compacted shape is compacted at a pressure of 10 tons per square inch, and wherein the simultaneous sintering and the surface and internal oxidizing is effected at a temperature of 930°C for a period of time of one hour.

**4.** A method as claimed in claim **1** wherein the compacting is effected at a pressure in the range 10 to 20 tons per square inch, wherein the sintering is effected at a temperature in the range 850°C to 940°C for a period of time of not less than one hour, and wherein the surface and internal oxidizing is effected in air at a temperature of 930°C for a period of time of not less than one hour.

**5.** A method as claimed in claim **4** wherein the sintering is effected in a reducing atmosphere.

**6.** A method as claimed in claim **5** wherein the reducing atmosphere consists of 90%$N_2$ and 10%$H_2$.

**7.** A method of producing a light-duty electrical contact including the steps of mixing fine, irregular silver powder with ultra fine ruthenium metal powder to provide a mixture having a fine, evenly dispersed ruthenium content in the range 0.1 to 10.0 atomic per cent; compacting the mixture into a desired shape; heating the compacted shape in an inert or reducing atmosphere for a period of time to effect sintering of same; surface and internally oxidizing the sintered compacts to convert the ruthenium metal into ruthenium dioxide; and pressure stamping the compacts to increase the density thereof.

**8.** A method as claimed in claim **7** wherein the pressure stamping is effected at a pressure in the range 40 to 45 tons per square inch.

**9.** A method as claimed in claim **4** wherein the sintering is effected at a temperature of approximately 930°C.

* * * * *