Jan. 24, 1956 R. S. OHL 2,732,464

ELECTRICAL CONTACTING DEVICES

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FIG. 1

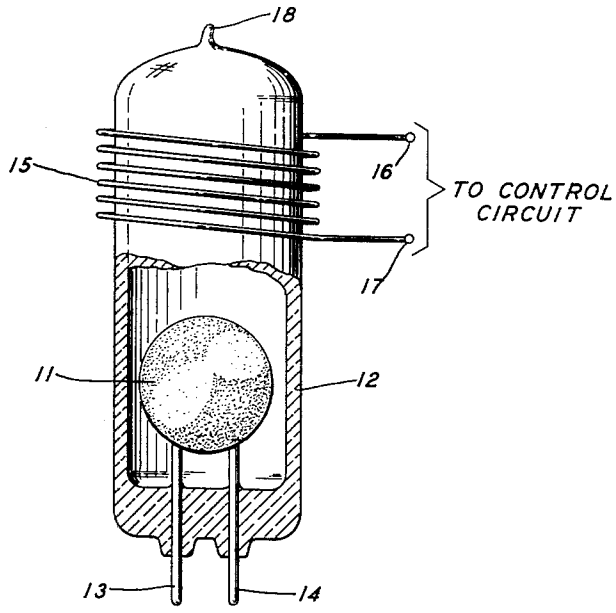
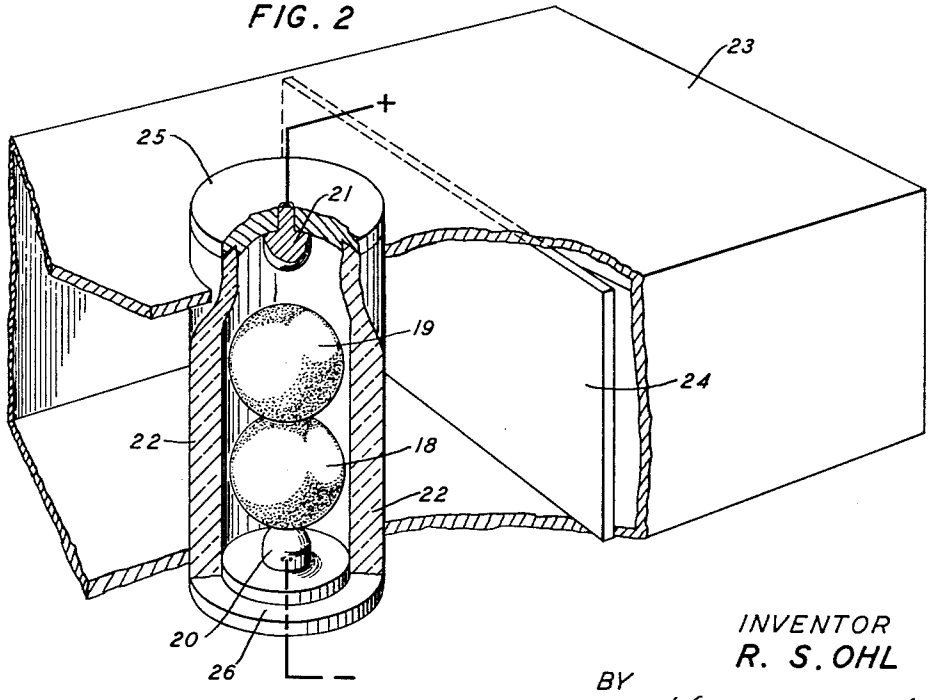


FIG. 2



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ELECTRICAL CONTACTING DEVICES

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This invention relates to electrical contacting devices and more particularly, to those in which a liquid surface is used as the contacting medium.

An object of the invention is to produce extremely fast operating make and break contact closures in electrical contacting devices.

A further object of the invention is to provide an electrical switch contact which has, and which maintains, low contact resistance, and which is self-healing to the effects of contact sparking.

It is well recognized that liquid contacting surfaces have distinct advantages over solid elements as the contact making media for electrical circuits. For instance, such liquid contacting media present a fresh surface for each successive contact closure and are not subject to the pitting and corroding effects that gradually reduce the usefulness of solid contact elements. With these advantages in view, several forms of mercury switches have been devised in the past. Substantially all of these switches necessitate a pool or reservoir for containing the liquid mercury. The requirement of this pool necessitates specialized contacting apparatus of complicated nature for, if the specialized apparatus is not employed, the use of the switch is undesirably limited to operation in a single stable position.

It is, therefore, a further object of the invention to simplify and improve electrical contacting devices employing liquid contacting surfaces.

It has been found by experiment that the metallic element gallium may be electroplated by the special process to be described hereinafter upon a base metal contacting member. At substantially room temperatures the plated coating of gallium becomes liquid and adheres firmly and evenly to the surface of the base metal. It has been further found that under these conditions the gallium has a very low vapor pressure and vapor which may be produced from sparking at the contacting surface is rapidly condensed and added to the molten surface layers upon the base metal member. Furthermore, it has been found that because of this low vapor pressure condition, the gallium does not evaporate readily to produce an ionized conductive gas and, therefore, as a contact material, produces a very fast break and make in an electrical circuit.

The nature of the present invention, its various objects, features and advantages, will appear more fully upon consideration of the embodiment illustrated in the accompanying drawings and in the following detailed description thereof.

Fig. 1 shows in pictorial form a simplified electrical contacting device in accordance with the invention; and

Fig. 2 shows a self-operating contacting device in accordance with the invention, suitable for generating high frequency pulses of electrical energy.

Referring to Fig. 1, the contacting device comprises a cylindrical glass envelope or capsule 12. Through one end of the capsule protrude the two conducting elements 13 and 14 to be electrically connected. Each of these

elements is of conducting material, for example nickel wire, and is sealed into the end face of the capsule 12 to extend a fraction of an inch therein. Located within capsule 12 is a sphere or ball 11 of a base metal coated with gallium in the manner to be described in detail hereinafter. The diameter of the sphere is slightly smaller than the cross-sectional diameter of capsule 12, so that when the capsule 12 is turned in the position as indicated in the drawing with electrodes 13 and 14 at the bottom, the sphere 11 will rest, due to the force of gravity, upon the electrodes 13 and 14. The end of capsule 12 opposite electrodes 13 and 14 is constricted and sealed off at 18 to render capsule 12 an air-tight container for the reasons to be pointed out below.

Around capsule 12 at a position slightly above sphere 11 are wound several turns of insulated conductor forming a solenoid 15 having end terminals 16 and 17 which are connected to the desired control circuit. Thus, when an electric current is passed through solenoid 15 by the control circuit, the magnetic field developed by solenoid 15 will raise sphere 11, since the sphere is of magnetic material as will be pointed out, away from electrodes 13 and 14, breaking the electrical connection therebetween. When the current from the control circuit ceases, sphere 11 will fall again to produce an electrical connection between electrodes 13 and 14. This electrical connection is made in accordance with the invention by the electrodes 13 and 14 contacting the liquid coating of gallium on sphere 11. In order to provide some indication of the relative size of the components thus described, it should be noted that sphere 11 may have a diameter in the order of $\frac{1}{32}$ inch and the other components proportioned accordingly.

Sphere 11 should be made of a magnetic base metal or alloy with which the element gallium will not easily amalgamate. For this purpose an alloy of iron, preferably passivated and magnetic stainless steel, has, for example, been found entirely suitable.

An important feature of the invention resides in the manner in which the small sphere 11 of a base metal, for example, steel, is coated with gallium so that the gallium when in liquid form remains in a smooth, evenly distributed layer over the entire surface of sphere 11 without forming droplets or globules which would eventually drop off or be knocked off by the physical contact of sphere 11 with electrodes 13 and 14. In accordance with the invention, a suitable surface of gallium may be deposited on a stainless steel surface by the process of electroplating.

The necessary electrolyte for the electroplating operation may be prepared by dissolving a small quantity of gallium metal in sulphuric acid to obtain gallium sulphate. A precipitate of gallium hydroxide is formed by adding a limited quantity of sodium hydroxide to the gallium sulphate, which precipitate is filtered and dissolved in an excess of sodium hydroxide to form a diluted alkaline aqueous solution of gallium hydroxide.

After one or more steel balls, of the type to be employed for sphere 11, are thoroughly cleaned, they are placed in a rotating, non-metallic plating basket of the type commonly used by electroplaters for plating small objects. In general, these plating baskets are such that the small objects, in this case the steel spheres, are continually agitated or moved from one position to another as the plating basket is rotated in the above prepared electrolyte solution, while at all times making electrical contact at successively different points with a cathode contact of gold alloy. The electrolyte should be at about 25 degrees centigrade. The anode comprises a small puddle of gallium metal in the electrolyte, which puddle is contacted by an electrode of gold alloy wire. A potential difference of from 1.5 to 2.0 volts is applied

between the anode contact or electrode and the cathode contact in the plating basket.

When the plating is sufficient that the steel balls show a grey matte appearance, which indicates a gallium coating thereon in the order of 1 mil thickness, the steel balls are removed from the plating bath, washed and dried. At this stage, the gallium becomes slightly oxidized by the air and exhibits a light grayish color partly due to gallium oxide, a relatively high-resistance material, which must be removed before the low-resistance gallium may be employed as an electrical contacting material. This coating may be removed in several ways, such as by chemically reducing it or preferably, by some physical burnishing operation which removes the oxide coating. A particularly advantageous method for removing this coating has been devised, suitable for use with the particular embodiment of the invention shown and described herein. Thus, before end 18 of cartridge or capsule 12 is constricted, sphere 11, including the oxidized coating of gallium thereon, is placed within cartridge 12. Cartridge 12 is evacuated by means of suitable apparatus connected at constriction 18 and then filled with a suitable known reducing atmosphere, for example hydrogen gas. An alternating-current potential, for example in the order of 60 cycles or more per second, is applied to terminals 16 and 17 and a direct-current potential of several volts is applied between electrodes 13 and 14. This causes sphere 11 to vibrate incessantly in the reducing atmosphere against electrodes 13 and 14. During this action sphere 11 will precess about its center due to the vibration until electrodes 13 and 14 have burnished or polished the entire surface of sphere 11 and distributed the gallium uniformly over the surface. A portion of the gallium oxide will be reduced and the remainder will be flaked off and fall as a high-resistance powder to the bottom of cartridge 12. No adverse effect will be obtained if the powder is allowed to remain loose within the cartridge, but if desired it may be removed by withdrawing it along with the hydrogen atmosphere. If this is done, the cartridge should be refilled with an inert gas such as nitrogen to prevent further formation of oxide on the surface of sphere 11. If allowed to remain within the cartridge, the reducing atmosphere will also serve this function.

It should be noted that the present invention contemplates operation under ambient temperature conditions at which the gallium coating above-described will be liquid. It has been determined that the melting point of gallium is approximately 29.8 degrees centigrade. Under normal conditions, particularly considering the heat which will be generated over a period of operation by electrical sparks in the contact area, this condition of ambient temperature will be readily met. However, under unusual conditions of operation, external heat may be supplied in any well-known manner.

The invention has thus been described with reference to a particular type of contacting device which appears of particular advantage in utilizing the unusual properties of the contacting material gallium in accordance with the invention. It should be readily apparent, however, that many other contact shapes and forms other than the spherical shape herein disclosed may likewise be plated with gallium in the manner described to obtain the desirable results described herein. Furthermore, for the sake of simplicity of description, a type of electrical contacting device in which the restoring contact force has been supplied by gravity has been chosen to illustrate the invention. It should be apparent to one skilled in the art how the invention may be adapted to spring contacting devices or to those contacting devices in which the operating force for either making or breaking of the contact, or both, is supplied by an electromagnetic field.

Fig. 2 shows a particular contacting device in which the operating force is electrostatic and which device may become self-operating in such a way as to generate a

series of high frequency pulses of electrical energy. A capsule comprising a glass cylinder 22 sealed at each of its ends by metal end members 25 and 26, is similar to the capsule 12 of Fig. 1. Extending one at each end within the capsule 22—25—26 are conducting electrodes 20 and 21. As shown in Fig. 2, electrodes 20 and 21 protrude at the bottom and top ends, respectively, of capsule 22 and may be spot welded, for example, to the inside centers of end members 26 and 25. Connections for supplying an electrical potential to the electrodes 20 and 21 may also be connected to the end members 26 and 25. Located within capsule 22 of Fig. 2, are two spheres 18 and 19, each shaped, proportioned, and coated with the metal gallium, in the manner hereinbefore set forth for sphere 11 of Fig. 1. The surface of gallium on spheres 18 and 19 of Fig. 2 is prepared in the manner set out above and the capsule 22 is evacuated or preferably filled with an inert gas such as nitrogen to about 10 atmospheres in accordance with the considerations already defined, before the end members 25 and 26 are sealed to the cylinder 22.

The spheres 18 and 19 are shown in Fig. 2 in an at rest position in which the spheres are in contact with each other and with electrode 20 due to the force of gravity. However, when a high direct-current potential is applied between electrodes 20 and 21, with a polarity, as shown in Fig. 2, of minus and plus, respectively, sphere 19 will become negatively charged and will then be immediately attracted by electrostatic force to the positively charged electrode 21. Upon contact with electrode 21, sphere 19 will become positively charged. Thereupon, an electrostatic attraction will be set up between the positively charged sphere 19 and the negatively charged sphere 18. The spheres will leave their respective electrodes, meeting at a point mid-way between the electrodes and will discharge to produce a damped radiation at a wavelength which is 2Π times the diameter of the spheres. After they are discharged, they are again attracted to their respective electrodes where they recharge with a subsequent repetition of the discharge process.

It may be shown that the pulse power in watts obtainable from the series of discharges between the spheres is equal to $2.21\lambda NE^2\times 10^{-4}$ where E is the potential difference in volts between the two electrodes 20 and 21, where N is the number of discharges per second, and where λ is the wavelength of the radiation when two spheres mutually discharge each other. A substantial portion of this power may be launched in a wave-guide transmission system, such as wave-guide section 23 of Fig. 2, by locating capsule 22 within the wave guide 23 and extending it transversely thereacross. A piston, such as 24, tunes the impedance of guide 23 to that of the generator.

In all events, it is to be understood that the above-described arrangements are illustrative in specific embodiments of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. An electrical contacting device comprising a pair of metallic elements, a base metal member arranged to make contact with both of said elements, an electroplated layer of the element gallium upon said base metal member to make electrical connection between said elements, and means for moving said base metal member away from said elements to break said electrical connection.

2. An electrical contacting device comprising a pair of metallic electrodes, a sphere of base metal resting upon at least one of said electrodes, an electroplated layer of the element gallium upon said sphere, and means for raising said sphere off said electrode.

3. An electrical contacting device comprising a pair of metallic electrodes, a sphere of base metal resting upon one of said electrodes, a second sphere of base metal rest-

ing upon said first-named sphere, a coating of the element gallium upon each of said spheres, a direct-current potential connected between said pair of electrodes, and means for raising said spheres off said electrode comprising the electrostatic field set up between said spheres and the other of said pair of electrodes.

4. In combination, an electrical contacting device having metallic contacting elements, an electroplated layer of the element gallium upon at least one of said elements, means for enclosing said contacting elements in an atmosphere of an inert gas, and means for operating said contacting device with the elements so enclosed.

5. An electrical contacting device comprising a pair of metallic electrodes, a base metal member contacting at least one of said electrodes, an electroplated layer of the element gallium on said base metal member, and means for moving said base metal member out of contact with said electrode.

6. An electrical contacting device comprising a pair of metallic electrodes, a first base metal member contacting one of said electrodes, a second metal base member contacting said first base metal member, a coating of the element gallium upon at least one of said base metal members and means for moving said first base metal member out of contact with one of said electrodes.

7. In combination a pair of base metal electrical contacting members, and an electroplated layer of the element gallium upon at least one of said members.

8. An electrical contacting device as in claim 5 wherein the base metal member is in the form of a sphere.

9. An electrical contacting device comprising, in combination, a pair of metallic electrodes, a first movable base metal member contacting one of said electrodes, a second movable base metal member contacting said first base metal member, a coating of the element gallium upon at least one of the said movable base metal members, and a means for moving said second base metal member out of contact with said first base metal member and into contact with said second electrode.

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