June 1, 1937.

J. R. FISHER

2,082,102

RESISTANCE ELEMENT

Filed April 25, 1935

FIG. 1

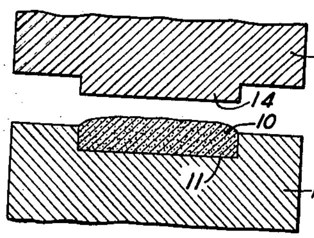


FIG. 2

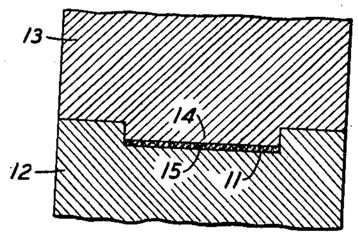


FIG. 3

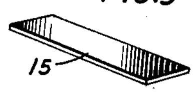


FIG. 5

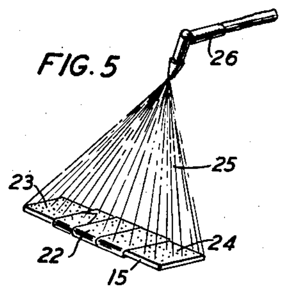


FIG. 6

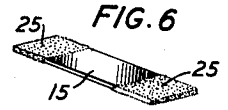


FIG. 7

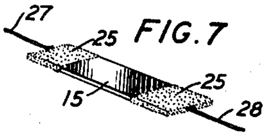
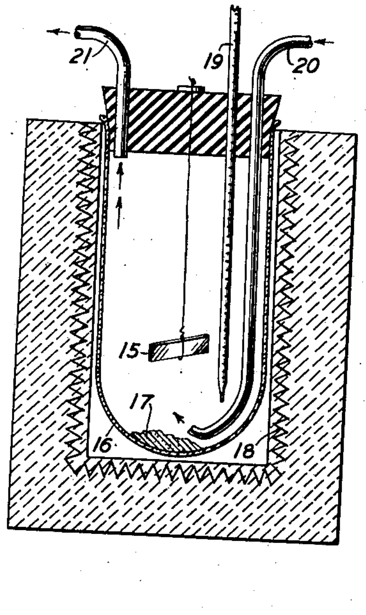


FIG. 4



INVENTOR
J. R. FISHER
BY
J. MacDonald
ATTORNEY

Patented June 1, 1937

2,082,102

UNITED STATES PATENT OFFICE

2,082,102

RESISTANCE ELEMENT

Joseph R. Fisher, Brooklyn, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application April 25, 1935, Serial No. 18,217

6 Claims. (Cl. 201—76)

This invention relates to electrical resistance units.

The object of the invention is to produce a resistance unit of silver sulphide and a method of making the same.

A further object of the invention is the production of a resistance unit which will have a high negative temperature coefficient of resistance; that is, one whose resistance decreases with increase in temperature, over the range of temperatures from room temperature to about 200° C. and whose resistance will be reproducible and reversible, that is, have the same value at a given temperature regardless of the direction from which this temperature is approached.

Another object of this invention is to provide a resistance having a high negative temperature coefficient of resistance whose resistance will be independent of voltage and frequency.

A further object of this invention is the provision of a resistance having a high negative temperature coefficient of resistance which can be easily formed into units having a range of resistance depending upon their size and shape.

Many materials are known to have a high negative temperature coefficient of resistance and this property is possessed in common by all semi-conductors to some degree. However, most of these materials are unsatisfactory for use in electrical control devices either because the change in resistance is not sufficient, or because they are not stable and/or reversible, or because of their refractory nature they are not readily fabricated into a suitable form.

I have discovered that silver sulphide has a combination of properties which make it uniquely suitable for use in electrical devices either as a means of compensating for resistance changes in metallic structures, which have a positive temperature coefficient of resistance, or as a control device to operate when a change in resistance reaches a certain value.

I have discovered that by the following procedure, resistor units may be prepared which are suitable for use in electrical devices of the above-mentioned nature. Chemically pure silver sulphide in the form of a powder, after sieving through a fine mesh screen, is placed in a steel die of suitable size and shape and molded under a pressure of approximately ten thousand pounds or more per square inch in a hydraulic press or some similar device. By the use of a suitably fine powder no heat treatment or binder is necessary, the natural coherence of the particles being sufficient to produce a mechanically strong unit.

In the event that pure silver sulphide free from excess silver or sulphur is not available, ordinary silver sulphide may be used. However, if ordinary silver sulphide powder is used the following treatment is necessary. After the resistor has been formed and is removed from the mold, it is given a heat treatment, that is, by heating it first in sulphur vapor at between 300 and 400° C. for approximately an hour and then subjecting it to an atmosphere of pure dry nitrogen gas at between 200 and 300° C. for about an hour. Without this treatment the resistor may contain more or less sulphur than is required to exactly combine with the silver which will cause a resulting change in resistance with use.

Referring now to the drawing:

Fig. 1 illustrates, in cross-section, one form of die which may be used for forming applicant's resistance element, before force has been applied to the upper member;

Fig. 2 is a view, similar to Fig. 1, except that the upper member has been forced down and has compressed the powdered material located in the recessed portion of the lower member;

Fig. 3 is the resistance element immediately following its removal from the die;

Fig. 4 is a view in cross-section illustrating the heat treating apparatus;

Fig. 5 illustrates one method of applying a conducting surface to the ends of the resistance element;

Fig. 6 illustrates the resistance element after it has been sprayed with molten metal in accordance with the method shown in Fig. 5; and

Fig. 7 shows the completed resistance element with the terminal wires secured to the conducting surface of the resistor.

In accordance with the preferred form of the applicant's invention, a quantity of chemically pure silver sulphide, in the form of a powder 10 is placed in the recess 11 of the lower die member 12, as shown in Fig. 1. When this recess 11 has the required amount of powder placed therein, the upper die member 13 is brought downward thus causing the raised portion 14 of the upper member 13 to compress the powder 10 and enter the recess 11, as shown in Fig. 2. Sufficient pressure is exerted on the upper member 13 to compress the powder 10 into a coherent mass 15, as shown in Fig. 3, no binder or other material being necessary.

Applicant has found that pressures somewhere in the neighborhood of ten thousand pounds per square inch have proved very satisfactory, the resulting resistances being very strong mechanically.

After the resistance unit 15 has been removed from the die block 12, it may in some instances be desirable to heat treat the unit before securing the terminals thereto. This heat treatment is done by subjecting the unit 15 to a sulphur vapor which is heated to a temperature of between 300 and 400° C. for approximately one hour and then heating it in an atmosphere of pure dry nitrogen gas between 200 and 300° C. for about an hour.

Applicant may employ any suitable closed vessel which may be heated to the desired temperature for heat treating his resistances. However, he has found the apparatus shown in Fig. 4 very satisfactory.

As shown in Fig. 4 the resistance unit 15 is suspended in the vessel 16, this vessel containing a small quantity of sulphur 17, the sulphur 17 is caused to vaporize by means of the heating element 18 which raises the temperature in the vessel 16 to a temperature somewhere in the neighborhood of 300 or 400° C. This temperature is held at approximately this level for about an hour, the heat in the interior of the vessel being registered on the thermometer 19, the heated sulphur vapor in the vessel thoroughly saturating the unit 15. After the unit has been in this vapor a sufficient length of time, the temperature is lowered to approximately 200 or 300° C. and dry nitrogen gas is introduced through the inlet 20, the gas passing through the tube 20 down into the vessel and escaping through the outlet 21, thus driving off the sulphur vapor and allowing the resistance unit to be saturated with the correct amount of sulphur. After the resistance unit has been confined in this dry nitrogen gas atmosphere for the required length of time, which is approximately an hour, it is ready to have the terminal or lead-in wires secured thereto.

Due to the character of the resistance unit the well-known method of mounting connections thereto cannot be used. It is therefore necessary to provide a different method of making contact with the resistance unit.

As shown in Fig. 5 the resistance unit 15 has the center portion covered by a tape or some other similar material 22. The exposed portions 23 and 24 of the unit are now sprayed with a molten metal 25, for example tin from the gun 26, which by the way, is the well-known Shoop process. Thus, a coating of metal is applied to each end of the resistance unit 15 as shown in Fig. 6. The lead-in wires 27 and 28 are then secured to the tin coated portions of the resistance unit by soldering or any other suitable method.

A resistance unit formed in accordance with the above method is simple and inexpensive to manufacture and the uniformity of the finished product is assured.

It will be understood that I do not limit myself to the precise apparatus herein disclosed as the same may be changed, modified or altered without departing from the spirit of the invention and I am only limited by the scope of the appended claims.

What is claimed is:

1. A method of producing resistors having a high negative temperature coefficient of resistance, for use in electrical circuits, which consists in placing a quantity of silver sulphide powder between a pair of dies, applying sufficient pressure to said dies to compress the silver sulphide powder into a coherent mass, removing the resistance from the lower die, heating it in an atmosphere of sulphur vapor for a period of approximately one hour at 300 or 400° C. and then heating it in a stream of pure dry nitrogen at 200 or 300° C. for approximately one hour.

2. A method of producing resistors having a high negative temperature coefficient of resistance, for use in electrical circuits, which consists in placing a quantity of silver sulphide powder between a pair of dies, applying a pressure of approximately ten thousand pounds per square inch to said powder by means of said dies to form the silver sulphide powder into a coherent mass, removing the resistor from the lower die, heating it in an atmosphere of sulphur vapor for a period of one hour at approximately 300 or 400° C. and then heating it in a stream of pure dry nitrogen at a temperature of approximately 200 or 300° C. for about one hour.

3. A method of producing resistors having a high negative temperature coefficient of resistance, for use in electrical circuits, which consists in placing a quantity of silver sulphide powder between a pair of dies, applying sufficient pressure to said dies to compress the silver sulphide powder into a coherent mass, removing the resistor from the lower die, heating it in an atmosphere of sulphur vapor for approximately one hour at 300 or 400° C. and then in a stream of pure dry nitrogen at a temperature between 200 or 300° C. for about an hour, removing the resistance unit from the heat treating vessel, masking out a portion of said resistance and spraying the exposed portion with molten metal to provide contacts thereon.

4. A method of producing resistors having a high negative temperature coefficient of resistance, for use in electrical circuits, which consists in placing a quantity of silver sulphide powder between a pair of dies, applying a pressure of approximately ten thousand pounds per square inch to said powder by means of said dies to form the silver sulphide powder into a coherent mass, removing the resistor from the lower die, heating it in an atmosphere of sulphur vapor for a period of approximately one hour at 300 or 400° C., and then heating it in a stream of pure dry nitrogen at a temperature between 200 and 300° C. for about an hour, masking out a portion of said resistance and spraying the exposed portion with molten metal to provide contacts thereon.

5. A method of producing resistors having a high negative temperature coefficient of resistance, for use in electrical circuits, which consists in placing a quantity of silver sulphide powder between a pair of dies, applying sufficient pressure to said dies to compress the silver sulphide powder into a coherent mass, removing the resistor from the lower die, heating it in an atmosphere of sulphur vapor for approximately one hour at 300 or 400° C. and then heating it in a stream of pure dry nitrogen at a temperature between 200 or 300° C. for about an hour, removing the resistance unit from the heat treating vessel, masking out a portion of said resistance, spraying the exposed portion with molten metal to provide contacts thereon and then securing lead wires to said coated surfaces.

6. A method of producing resistors having a high negative temperature coefficient of resistance, for use in electrical circuits, which consists in placing a quantity of silver sulphide powder between a pair of dies, applying a pressure of approximately ten thousand pounds per square inch to said powder by means of said dies to form the silver sulphide powder into a coherent mass, removing the resistor from the lower die, heating it in an atmosphere of sulphur vapor for a period of approximately one hour at 300 or 400° C., and then heating it in a stream of pure dry nitrogen at a temperature between 200 and 300° C. for about an hour, masking out a portion of said resistance, spraying the exposed portion with molten metal to provide contacts thereon and then securing lead wires to said coated surfaces.

JOSEPH R. FISHER.