This invention relates to an electric resistor and to a method of making such a resistor. It is an object of this invention to provide an improved resistor and an improved method of making the same.

So-called iridized coatings of various metal oxides have been employed in the past for resistors, particularly transparent heating elements. These have been successfully employed in windshields, the heat obtainable by passing a current through the transparent coating being employed to keep the windshield free of ice. They have also been employed successfully in space-heating elements, a relatively large sheet of glass having any desired pattern of metal oxide deposited thereon. In applications such as these, slight variations in the resistance of the iridized coatings is not objectionable since the objective is a reasonable amount of heat distributed with reasonable uniformity over the surface of the glass, or other base, to which the iridized coating adheres.

The application of iridized coatings to resistors of the type commonly employed in electronic apparatus has been limited because of a lack of suitable means for protecting the iridized coating from the atmosphere. Because of the fact that iridized coatings have certain very advantageous characteristics as applied to resistors of the type commonly employed in electronic apparatus, namely, small temperature coefficient of resistance, and stability (when not subjected to the atmosphere), various attempts have been made to find a suitable protective coating for iridized coatings. All of these attempts have been unsuccessful because the protective coatings applied to the iridized coating either were subject to rapid decomposition (especially under severe conditions of temperature and humidity) or permitted the passage therethrough of small amounts of moisture and oxygen.

The present invention contemplates the application of a protective inorganic film fused to the iridized coating. While the invention is particularly applicable to resistors of the type commonly employed in electronic apparatus, it has application to other uses of iridized films and is to be given this broader interpretation except where it is otherwise specified.

It is another object of the present invention to provide an improved iridized coating resistor in which the iridized coating is effectively sealed against the atmosphere. It is another object of the invention to provide an improved method for making such a resistor.

It is another object of the invention to provide an improved iridized coating resistor which is substantially hermetically sealed. It is another object of this invention to provide an improved method of making such a resistor.

It is another object of the invention to provide an improved electrical resistor in which an iridized coating resistance film is effectively protected from the atmosphere by an inorganic film fused thereto. It is another object to provide an improved method for making such a resistor.
eral type of coating and is not to be considered as being limited to any particular molecular arrangement or configuration.

It is believed, for example, that some authorities contend that these so-called "iridized coatings of metallic oxides" contain the metal and oxygen elements in an arrangement which does not constitute a true oxide of metal. Other authorities contend that these coatings are partially metal oxides and partially metal in a pure state or in combination with other elements. Accordingly, the expression "iridized coating of metal oxides" is intended to include this general type of coating regardless of whether the coating is actually a proper metal oxide, speaking in strict chemical terms.

Various metals are frequently employed in the production of such iridized coatings. These include, but are not limited to, tin, indium, cadmium, and various combinations of these three, with or without small additional quantities of zinc, copper, iron, magnesium, cobalt, and vanadium. Moreover, these metals are selected for use in iridized coatings according to the desired characteristics of coating and some of the most popular metals are tin, tin and antimony, and indium.

Since the present invention is not concerned primarily with the selection of a particular metal for forming an iridized coating, the choice of metals is not considered further herein.

The base, as shown in the drawing, is indicated above as being of glass. It may be of ordinary window glass, heat-resistant glass such as Pyrex, ceramics, or any other inorganic insulating material. The base should have a smooth, nonporous surface and should meet the physical requirements called for by the application of the ultimate resistor. For the purpose of this application, the "base" is, of course, the material actually contacting the iridized coating and might be, for example a glass film or other glaze on an underlying metallic foundation.

The glass frit, shown in Fig. 3, may be a conventional frit obtainable on the market. Where the resistor is to be subjected to substantial changes in temperature, it is recommended that the frit have a temperature coefficient of expansion nearly equal to or slightly less than that of the base. In general the frit must be fusible under applied heat which will not be detrimental to the iridized coating 12, the terminals 11 or the base 10. By employing rapid heating of the frit, it is possible to fuse the frit without damage to the other components, and particularly the base, even though the material of the base may have substantially the same melting temperature as the frit.

The frit must melt to such an extent that the particles in the frit fuse together to form a continuous film. Heat may be applied rapidly and for only a short time, whereby only some portion of the frit melts or softens. Particularly the outer surfaces of the individual particles soften, whereas the inner core of each particle might remain substantially solid. The only essential for complete protection of the iridized coating is that the frit be fused to form a continuous film, fused to the iridized coating. In view of this, differing materials may be incorporated in the frit, and all of the materials in the frit need not melt or fuse at the same temperature. Again, all that is essential for complete protection of the iridized coating is that a sufficient portion of the frit be melted or softened that a continuous film be formed and fused to the iridized coating. Accordingly, the frit may have the characteristics of what is commonly termed a ceramic. When the term "glass frit" is employed herein, it is intended to encompass any inorganic nonconducting frit of which a sufficient portion will melt or soften at a reasonable temperature to cause the formation of a continuous film, fused to the iridized coating.

Several references are made above to a "continuous film." Obviously, the word "continuous" is meant to apply to the fine structure of the film rather than to its over-all arrangement. More specifically, a "continuous film" refers to one in which adjacent particles of frit are melted or fused to a sufficient extent that the metal bridges substantially continuously between adjacent particles wherever the frit is applied. The over-all pattern of the frit as applied may be continuous or discontinuous in different applications.

The frit may be deposited on the iridized coating in any desired manner, but it has been found to be practical to use a screening process. In this case the frit is mixed with a carrier such as 5% ethyl cellulose and 95% pine oil. The over-all mixture may be 25% carrier and 75% frit or to the desired consistency. For convenience in handling, the pine oil may be allowed to evaporate or may be baked out. All elements of the surface treated may be either evaporated or burned up when subsequently subjected to temperatures which fuse the frit.

The frit should be applied heavily enough to provide a fused film of the desired thickness, it being understood that the fused film will be considerably thinner than the applied frit. A film of four mils thickness is recommended for applications where normal voltages are encountered. The film can, however, be made much thinner or thicker where desired.

In the embodiment of the invention disclosed in Figs. 1–5, the terminals 11 are shown applied to the base 10 before the application of the iridized coating 12, the terminals are shown to underlie the extremities of the iridized coatings. Alternatively, however, and as shown in Fig. 6, the iridized coating 13 may be applied first, followed by application of the terminals 11. In this case, parts of the terminals 11 overlie the extremities of the iridized coating 13. There is believed to be little, if any, difference between these alternatives in so far as performance and ease of production are concerned. In either case, the terminals and the iridized coating must be either applied in the desired patterns or must be reduced to the desired patterns after application to the entire surface.

Attention is directed to the fact that some difficulty has been encountered in forming the iridized coating on a silver terminal. Accordingly, if the terminals are to be applied first, as in Figs. 1–5, a metal more noble than silver is recommended. On the other hand, if the iridized film is applied first, as in Fig. 6, silver terminals have been found to make a suitable contact therewith.

Referring to one specific embodiment of the invention known to be satisfactory, the base 10 is composed of ordinary window glass, and the iridized coating 12 is primarily tin oxide. The iridized coating is etched away to provide areas for application of the terminals. The latter comprise glass frit and metallic silver and are fused to the glass base 10 and overlie the ends of the iridized coating. It has been found that satisfactory electrical connection is thereby made between the terminals and the iridized coating, and that leads 22 may be soldered to the terminals to provide a mechanically strong construction. The glass frit for covering the iridized coating is a lead boro silicate glass containing 69% lead oxide, 2% boron oxide, and 22% silica.

In accordance with another embodiment of the invention, the glass film 13s is produced by spraying. In this case the resistor element of Fig. 2 is subjected to a spray of molten glass, producing the resistor element of Fig. 4 directly.

Apparatus for spraying molten glass onto the resistor element of Fig. 2 may be substantially identical to that commonly employed for spraying molten metals. Attention is directed, however, to the fact that molten glass has a very corrosive reaction on any metal which is susceptible to the reaction of molten glass. More specifically, if the metal employed in the construction of the spraying apparatus is susceptible to the formation of oxide at the temperature of the molten glass, the molten glass effectively removes any such oxides whereupon the metal again is exposed to oxidation and subsequent re-
moyal of the oxide film. Constant subjections of such metals to molten glass quickly destroy the metal. Accordingly, any portion of the coating apparatus which is subjected to the molten glass should be plated with platinum. A very thin film of platinum is generally recognized as being strongly resistant to corrosion by molten glasses, frits, and some inorganic acids.

Preferably, the resistor element of Fig. 2 is heated before being subjected to the spray of molten glass, and more particularly, is heated beyond the strain point of the base 10. However, some experiments suggest that if the spray of molten glass is sufficiently hot, the base 10 may be heated in contact.

Where it is desired that certain areas, such as portions of the terminals 11, not be covered by the glass film, these may be shielded from the spray of molten glass by various obvious means including, for example, an independent mask arranged closely adjacent the resistor element, or a removable mask such as paint or an emulsion applied directly to the portions of the terminals 11 which are not to be coated with the glass film.

Attention is directed to the fact that while molten glass has a very corrosive reaction on most metals because of the fact that it removes and apparently dissolves any oxide formed on the surface of such metals, the molten glass applied to the iridized metal oxide coating 12 has been found to have no substantial effect thereon. This is in spite of the fact that the iridized metal oxide coating may be on the order of one-millionth of an inch thick. This would appear to substantiate the contentions of some authorities that the iridized metal oxide coating is not a true metal oxide in strict chemical terms. In any event, it has been found, contrary to reasonable assumption, that molten glass, whether sprayed onto an iridized metal oxide film or deposited in the form of a frit and subsequently fused, has no deleterious effects on the iridized metal oxide coating.

In accordance with still another embodiment of the invention, a glass sheet may be substituted for the glass frit or the sprayed glass to seal the exposed surface of the iridized metal oxide coating. In this case a glass sheet is laid over the resistor element of Fig. 2 and is heated until it is quite soft. Pressure is preferably applied to bring the softened glass sheet into intimate contact with the iridized metal oxide coating at all points.

Some difficulty may be encountered in the practice of this embodiment of the invention in obtaining intimate contact at all points because of the presence of air trapped between the iridized coating, and fusing glass frit having the iridized metal oxide coating. However, if any air pocket is entirely isolated, that is, if the edges of the iridized metal oxide coating and the glass sheet are fused together, no substantial harm results from the entrapped air, at least from the viewpoint of deterioration of the iridized oxide coating.

Preferably the glass sheet employed to seal the iridized metal oxide coating has a temperature coefficient expansion nearly equal to that of the base 10. The glass sheet need not be clear glass but may incorporate materials which do not soften during its application to the iridized metal oxide coating, all as explained above in connection with use of glass frits.

While particular embodiments of the invention have been shown, it will be understood, of course, that the invention is not limited thereto since many modifications may be made, and it is, therefore, contemplated to cover by the appended claims any such modifications as fall within the true spirit and scope of the invention.

The invention having thus been described, what is claimed and desired to be secured by Letters Patent is:

1. The method of making an electrical resistor which comprises depositing an iridized coating of metal oxide on a preformed inorganic insulating base, and fusing a film of glass to the said deposited film of said iridized coating.

2. The method of making an electrical resistor which comprises depositing an iridized coating of metal oxide on a preformed inorganic insulating base, applying glass frit to the surface of said iridized coating, and fusing said frit to form a continuous film over said iridized coating.

3. The method of making an electrical resistor which comprises depositing an iridized coating of tin oxide on a preformed inorganic insulating base, applying glass frit to the surface of said iridized coating, and fusing said frit to form a continuous film over said iridized coating.

4. The method of making an electrical resistor which comprises depositing an iridized coating of tin and antimony oxide on a preformed inorganic insulating base, applying glass frit to the surface of said iridized coating, and fusing said frit to form a continuous film over said iridized coating.

5. The method of making an electrical resistor which comprises depositing an iridized coating of metal oxide on a heated glass base, applying glass frit to the surface of said iridized coating, and fusing said frit to form a continuous film over said iridized coating.

6. The method of making an electrical resistor which comprises depositing an iridized coating of tin oxide on a heated glass base, applying glass frit to the surface of said iridized coating, and fusing said frit to form a continuous film over said iridized coating.

7. The method of making an electrical resistor which comprises depositing an iridized coating of tin and antimony oxide on a heated glass base, applying glass frit to the surface of said iridized coating, and fusing said frit to form a continuous film over said iridized coating.

8. The method of making an electrical resistor which comprises depositing a pair of spaced apart terminals and an iridized coating of metal oxide on a preformed inorganic insulating base with said iridized coating electrically contacting said terminals, applying glass frit to the surface of said iridized coating, and fusing said frit to form a continuous film over said iridized coating.

9. The method of making an electrical resistor which comprises depositing a pair of spaced apart terminals and an iridized coating of metal oxide on a heated glass base with said iridized coating electrically contacting said terminals, applying glass frit to the surface of said iridized coating, and fusing said frit to form a continuous film over said iridized coating.

10. The method of making an electrical resistor which comprises depositing a pair of spaced apart terminals and an iridized coating of tin oxide on a heated glass base with said iridized coating electrically contacting said terminals, applying glass frit to the surface of said iridized coating, and fusing said frit to form a continuous film over said iridized coating.

11. The method of making an electrical resistor which comprises depositing a pair of spaced apart terminals and an iridized coating of tin and antimony oxide on a heated glass base with said iridized coating electrically contacting said terminals, applying glass frit to the surface of said iridized coating, and fusing said frit to form a continuous film over said iridized coating.

12. The method of making an electrical resistor which comprises spraying a metal salt in a liquid carrier on a heated glass base, applying glass frit to the surface of the resulting iridized coating, and heating said frit to fusing temperature to form a continuous film over said iridized coating.

13. The method of making an electrical resistor which comprises depositing an iridized coating of metal oxide on a glass base, applying a glass frit having substantially the same temperature coefficient of expansion as the said glass base to said iridized coating, and fusing said frit to form a continuous film over said iridized coating.

14. The method of making an electrical resistor which comprises depositing an iridized coating of metal oxide on a preformed inorganic insulating base, and spraying molten glass on the surface of said iridized coating.

15. The method of making an electrical resistor which comprises depositing an iridized coating of tin oxide
on a preformed inorganic insulating base, and spraying molten glass on the surface of said iridized coating.

16. The method of making an electrical resistor which comprises depositing an iridized coating of tin and antimony oxide on a preformed inorganic insulating base, and spraying molten glass on the surface of said iridized coating.

17. The method of making an electrical resistor which comprises spraying a metal salt in a liquid carrier on a heated glass base, and spraying molten glass on the surface of the resulting iridized coating.

18. The method of making an electrical resistor which comprises depositing an iridized coating of metal oxide on a glass base, laying a sheet of glass over said coating, and heat softening said sheet to fuse it to said coating.

19. An electrical resistor comprising a preformed base of inorganic insulating material, an iridized metal oxide resistance film on said base, and a continuous, unitary glass film secured in intimate molecular contact to the surface of said resistance film.

20. An electrical resistor comprising a preformed base of inorganic insulating material, an iridized tin oxide resistance film on said base, and a continuous, unitary glass film secured in intimate molecular contact to the surface of said resistance film.

21. An electrical resistor comprising a preformed base of inorganic insulating material, an iridized tin and antimony oxide resistance film on said base, and a continuous, unitary glass film secured in intimate molecular contact to the surface of said resistance film.

22. An electrical resistor comprising a preformed base of inorganic insulating material, a pair of spaced apart terminals secured to said base, an iridized metal oxide resistance film on said base and electrically contacting said terminals, and a continuous glass film secured in intimate molecular contact to the surface of said resistance film.

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CERTIFICATE OF CORRECTION

Patent No. 2,818,354

Nathan Pritikin et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 54, before "oxide" insert --metal--; column 8, line 9, after "continuous" insert --, unitary--.

Signed and sealed this 4th day of March 1958.

(SEAL)
Attest:
KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents
Disclaimer


Hereby enters this disclaimer to claims 14, 15, 16, and 17 of said patent.

[Official Gazette August 8, 1961.]
UNITED STATES PATENT OFFICE

Certificate

Patent No. 2,818,354
Patented December 31, 1957

Nathan Pritikin and Robert C. Camp

Application having been made jointly by Nathan Pritikin and Robert C. Camp, the inventors named in the patent above identified, for the issuance of a certificate under the provisions of Title 35, Section 256 of the United States Code, deleting the name of the said Robert C. Camp from the patent as a joint inventor, and a showing and proof of facts satisfying the requirements of the said section having been submitted, it is this 25th day of July 1961, certified that the name of the said Robert C. Camp is hereby deleted from the said patent as a joint inventor with the said Nathan Pritikin.

[SEAL]

EDWIN L. REYNOLDS,

First Assistant Commissioner of Patents.