

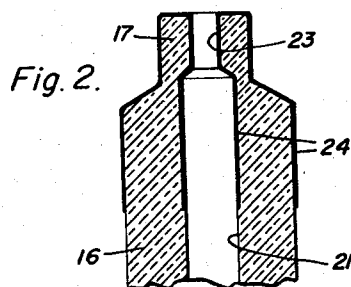
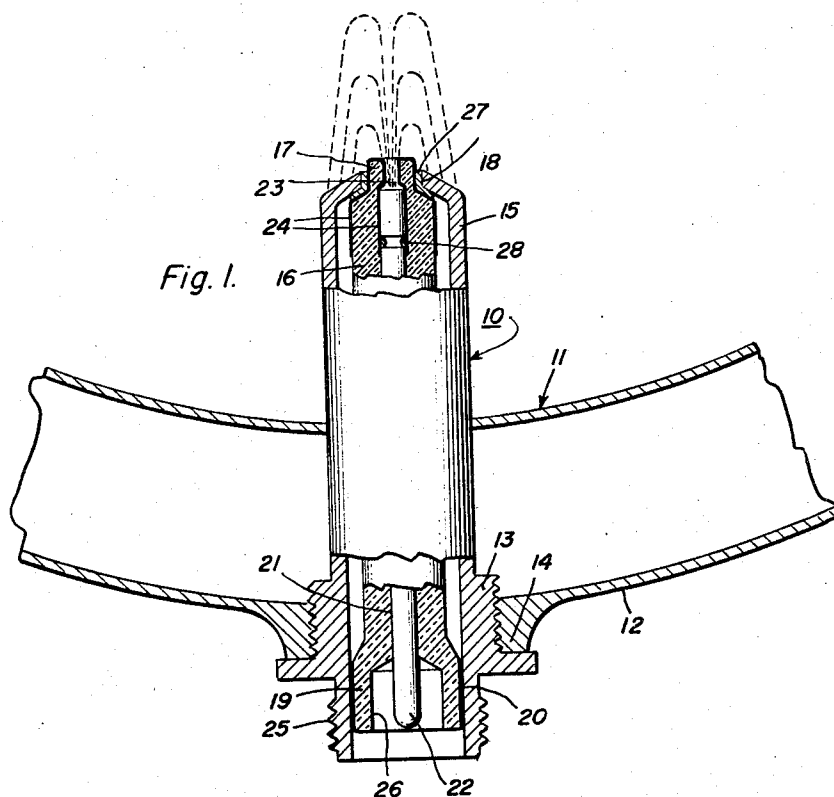
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CONTROLLED RESISTIVITY GLAZE FOR IGNITOR PLUGS

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CONTROLLED RESISTIVITY GLAZE FOR IGNITOR PLUGS

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This invention relates to ignitor devices employed to initiate the combustion of fuel in internal combustion engines, burners, and the like apparatus, but more particularly to an improved resistivity coating for the insulated portions of such ignitors.

Ignitor plugs, commonly referred to as spark plugs, have found wide application wherever quick and positive ignition is desirable. In one instance, the gas turbine, particularly aircraft gas turbines, the spark plug has undergone considerable modification and improvement. This has been necessary because of the peculiar problems associated not only with the combustion of fuel, but also those problems associated with igniting fuel in a fast-moving gas stream, at high altitudes, and at low temperatures. For example, in high altitude ignition, atmospheric pressure is very low in the combustion chamber and the air-fuel mixture is moving by the spark plug at a very rapid rate. It is understood, then, that in order to commence ignition of the air-fuel mixture under these conditions, it is necessary to have a spark not only of high intensity, but also of large volume and good duration. Without these desirable characteristics, high altitude ignition becomes problematical since a small, short duration spark initiates a correspondingly small volume ignition which is easily snuffed by the fast moving and turbulent fuel-air stream. These problems also exist in somewhat diminutive manner in low level and ground operation because the fuel-air stream moves rapidly through a large combustion chamber and the proportion of the volume of the chamber to the spark plug is very small. The ignitor plug in general utilizes a wide air gap between the electrodes to provide a correspondingly longer or larger volume spark. Together with the wide gap, high voltages are used not only to bridge the air gap, but also to provide a strong spark of high intensity. When successively larger air gaps are utilized between electrodes, the voltage required to arc across the gap becomes increasingly and disproportionately higher. This voltage necessary to arc across an air gap is commonly referred to as breakdown voltage. Another way of stating this aspect is to say that the voltage required for arcing across an air gap between two electrodes is substantially higher than the voltage necessary to maintain this arc once it is established.

It has become an accepted practice to employ a covering or coating of semiconductive material about or on the spark plug base surrounding the electrodes which constitutes in effect a bridge or closed circuit between electrodes. A coating of this type permits among other features, small local arcs on the base of one electrode progressing irregularly along the semiconductive surface to the other electrode, and once a connection is established, the arc exerts its full energy between the electrodes themselves. A high performance coating is therefore one which will not only permit the aforementioned local arcing, but also one which has a predetermined or controlled resistivity within given limits. Otherwise such a coating with low resistance prevents an arc from be-

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coming established between the electrodes, and a coating with a high resistance provides no local arcing. A preferred coating together with the desired features as set forth for the material must also have the necessary composition and strength characteristics to maintain its functions while resisting extreme temperatures and local operating conditions.

Accordingly, it is an object of this invention to provide an improved, semiconducting surface for ignitor plugs.

It is another object of this invention to provide a coating for ignitor plugs having a controlled resistivity.

It is a further object of this invention to provide a coating for ignitor plugs which maintains a resistivity within the desired ranges when exposed to combustion conditions of gas turbine engines.

It is again another object of this invention to reduce the breakdown voltage of ignitor plugs.

Briefly described, in one form, this invention contemplates coating the normally non-conductive base surrounding the electrodes of an ignitor plug with a semiconductive coating of predetermined constituents to provide controlled resistivity under normal ignitor plug operating conditions.

These and other features and advantages will be better understood when taken in connection with the following description and the drawings, in which:

Fig. 1 illustrates an exemplary ignitor plug having associated therewith the semiconductive coating disclosed by this invention; and

Fig. 2 is a partial view of the insulator of Fig. 1 showing the coating of this invention.

Referring now to Fig. 1, plug 10 is shown as mounted in casing 12 to project into a combustion chamber 11. While various forms of mountings may be utilized, in Fig. 1 the mounting is by means of a threaded portion 13 on the plug 10 which engages a corresponding threaded sleeve 14 in the casing 12.

The ignitor plug 10 includes a sleeve or outer shell 15 having concentrically positioned therein a generally cylindrical insulator 16. In the preferred form of this invention, insulator 16 is an alumina ceramic. Insulator 16 includes at one end, a reduced diameter portion 17 which projects through a generally tapered flange opening 18 in the outer shell 15. At the other end of insulator 16 there is provided an enlarged section 19 which is suitably bonded or joined to the shell 10 at 20. Insulator 16 also includes a central coaxial aperture 21 with an electrode 22 positioned therein. The electrode 22 is positioned in the aperture 21 such that it engages a reduced section 23 of aperture 21 and is maintained in spaced relationship from the extremity of insulator 16.

An electrical connection to the electrodes 22 and 15 is provided by any suitable electrical engaging device such as a pin connection, being received by the threaded portion 25 of shell 15, and entering the enlargement 26 for engagement with electrode 22.

There is thus defined a basic ignitor plug having a centrally positioned positive electrode 22, a sleeve-type negative electrode as a sleeve 15, and an insulator 16 therebetween.

The semiconductive coating or glaze 24 of this invention as more clearly shown in Fig. 2, is applied to the insulator 16, the portion of which projects into the combustion chamber, and covers a length of the internal surface of opening 21 as well as a length of the outer surface of insulator 16.

The glaze coating may be applied to the insulator 16 in any suitable manner, for example, by spraying, brushing, or dipping, the method employed in this invention including dipping and then heat treating or firing. In order to provide a positive electrical connection between

the coating and the electrodes 15 and 22, a bushing 27 of good electrical conducting properties, for example, nickel, is positioned between the sleeve 15 and the insulator 16 at the combustion chamber end thereof. Bushing 27 may be sealed to the glaze coating 24 by means of a suitable high temperature brazing material, such as silver solder, which is fusible to both the glaze coating 24 and the nickel bushing 27. Silver solder may also be employed in a groove arrangement 28 between electrode 22 and insulator 16.

A preferred glaze comprises a suitable glass base together with a metallic oxide in the spinel structure which is semiconductive when utilized in the glass base as fired. The glass base is understandably required to be of a very high melting point, well above 1,000 C., and possessed of capabilities of adhering to the alumina ceramic insulator at this temperature. It has been found that a suitable glass base comprises the elements given in the following tables.

TABLE I

Components	Representative Batch
SiO ₂ , 50% by weight.	Silica sand or powdered flint, 100 parts by weight.
B ₂ O ₃ , 10% by weight.	Barium carbonate, 78 parts by weight.
Al ₂ O ₃ , 10% by weight.	Alumina hydrate, 31 parts by weight.
BaO, 30% by weight.	Boric acid, 36 parts by weight.

The glass base composition as given above may be varied over a wide range and yet retain the desired characteristics, for example, good thermal correlation to the base or covering surface. This thermal correlation refers to the difference in the thermal expansion and moduli of elasticity of the glass as compared to the covering surface. The difference need not be minute, but sufficient so that the glass will bond but not spall, craze or crack, and tolerate the normal thermal shock encountered in service. Best results are obtained when the glass base has a lower thermal coefficient of expansion than the alumina ceramic or other base surface. In this respect, the glaze will be in compression at lower temperatures, thereby strengthening the composite structure. In comparison, the glass base as given has a thermal expansion coefficient of about 5.2×10^{-6} centimeters per centimeter per degree C., compared to about 8.5×10^{-6} centimeters per centimeter per degree C. for most alumina ceramics.

The glass base should also be high in flow temperatures, so that the glass will not flow under spark plug service temperatures. The glass base as given has a standard fiber-softening temperature of about 853 C., compared to 820 C. for borosilicate laboratory ware glass, and 696 C. for ordinary soda lime glass. It remains highly viscous over a wide temperature range which permits firing on alumina ceramic bodies at 1250-1450 C. without destruction by volatilization or by seepage into the base surface. The electrical resistivity at service temperatures of 500 or 600 C. should be sufficiently high so as not to invalidate the electrical resistivity properties sought in the spinel. The glass should furthermore have good chemical properties to resist attack by the combustion gases, steam, lead oxide, and other corrosive agents encountered in service.

These desirable characteristics are retained in glass compositions varying over the range given in the following table.

TABLE II

	Percent by weight
BaO	20-50
Al ₂ O ₃	1-30
B ₂ O ₃	0-25
SiO ₂	balance

A further exemplary composition taken from the abovementioned Table II ranges is given as follows:

TABLE III

Composition	
SiO ₂ , 45% by weight. BaO, 45% by weight. Al ₂ O ₃ , 10% by weight.	Sand, 100 parts by weight. Barium carbonate, 129 parts by weight. Alumina hydrate, 34 parts by weight.

The specific example as given in Table III has the particular advantage of permitting firing on alumina bodies above 1500 C., and also permits a single-fire application with alumina bodies. The glass bases as heretofore explained and described are further capable of several inclusions and exclusions. The BaO may be partially or completely replaced by other alkaline earth oxides or combinations, including, for example, SrO, CaO, MgO and BeO. Further elements may be included up to approximately 5 weight percent, Li₂O, Na₂O, K₂O, and about 3 weight percent of transitional element oxides Fe₂O₃, NiO, V₂O₅, TiO₂, CeO₂, and MnO. However, those oxides with high vapor pressures above 500-1,000 C. are undesirable, for example, PbO, ZnO, CdO, As₂O₅, etc.

Preparation of a suitable glass base includes melting the components in a crucible of, for example, platinum or ceramic, at a temperature between 1550 and 1600 C. Thereafter, the melt is quenched, either in water or in air, and crushed, ground, or otherwise reduced, for example in a ball mill or a like apparatus, sufficient to pass through a 150-mesh screen. The glass base as described is mixed with a suitable quantity of metallic oxides and water, to form a slip-type mixture. The proportion of the spinel composition or the metallic oxides may be varied to provide a control over the electrical resistivity values, both at room temperature and at service temperature, because the resistivity of the composite glaze is predominantly controlled by the resistivity of the spinel phase. Representative ferrite spinels have resistivity values at room temperature ranging from 10⁴ ohms per centimeter to 10¹¹ ohms per centimeter. Accordingly, a composition can be selected which has a selected value for any particular condition of operation. Of the oxides utilized as the spinel, there is to be included magnetite, zinc ferrite, manganese ferrite, and nickel ferrite. These may be added directly to the glass base as mixtures of oxides in the desired proportions or may be pre-reacted to form the spinel.

A preferred form of this invention includes 70 weight percent of the glass base of Table I and 30 weight percent of spinel, the limit being that the volume proportion of spinel must be sufficient to make the spinel a continuous phase but not to the degree that the glaze does not melt and flow during application. As little as 25 weight percent and as much as 50 weight percent have been employed with good results. The slip mixture thus prepared may be applied to the alumina ceramic by the well known methods in the glazing art, such as suspending the glaze composition in a suitable solvent such as a water-alcohol mixture, and then applying the mixture by dipping, brushing, or spraying. After the slip is applied to the alumina ceramic insulator 16, it is fired to maturity in an air atmosphere by rapidly heating to a temperature between approximately 1275 and 1350° C. and maintaining the temperature for about 3 to 5 minutes. Single insulators can be cooled rapidly to room temperature. The measured thickness of this coating preferably ranges between 3-6 mils. It has been found feasible to carry out the firing in either intermittent or continuous furnaces on a much slower schedule. For example, several insulators may be placed in a cold furnace after which the temperature is increased to 1350° C. over a period

of 24 hours, cooled quickly to about 1000° C., and then cooled to room temperature at the natural rate of the furnace.

Upon testing the above preferred coating, it was discovered that the breakdown voltage across the air gap between the ignitor electrodes is reduced by 1,000 volts and more, and the coating proved superior in the life and performance tests in jet engine ignition systems.

Example 1

A specific example of a preferred coating includes 70% by weight of the aforementioned glass slip as given in Table I and 30% by weight of Fe_3O_4 magnetite. The slip was prepared and applied in conformance with the process outlined above, and was found to have a resistance of about 11 megohms over a 1-inch path at room temperature, and a corresponding resistance of 20,000 ohms at 1,000 F. or 538 C.

Example 2

A glass slip was prepared from a 70% weight of the glass slip in Table I together with 24% Fe_3O_4 magnetite, and 6% zinc oxide. The slip was prepared and applied to the ignitor plug as in the process outlined above and the coating found to give a resistivity of $\frac{1}{2}$ megohm at room temperature and 2500 ohms at 1,000 F.

Example 3

An improved coating was prepared from 70% by weight of the glass base as given in Table I, 23% Fe_2O_3 , and 7% NiO . The slip was prepared and applied to the ignitor plug in accordance with the above process and provided a coating having a resistivity of 30,000 ohms at 1,000 F. and 4 megohms at room temperature.

Example 4

Glass slips were prepared at random from the ranges given in Table II and after application to alumina ceramic bases were found to compare favorably with the glazes of Examples 1-3 above.

The coating of any of the above examples may be improved by applying the glaze in a series of thin layers with furnace firings between the application of each layer. Such sandwich-type firing provides a lower room temperature resistance for a given glaze and also an improved reproducibility.

The semiconductive glaze as provided by the above examples is particularly adaptable to the alumina ceramic insulators which heretofore have presented some difficulty when coated with a porcelain glaze. Furthermore, it is to be noted that the metallic oxides are in spinel condition after firing the glaze in an air atmosphere.

The invention thus discloses an ignitor or spark plug having normal insulator portions coated with a preferred semiconductive coating, to thus provide a high intensity spark of considerable length with substantially reduced air gap breakdown voltage. This reduction in air gap breakdown voltage may be described as a direct result of the coating. The glaze coating is in good electrical contact with both electrodes and promotes the formation of an ionized path through the air between electrodes, thus permitting an arc discharge between the relatively wide spaced electrodes and at much lower potential than if no glaze is used. The conductivity of the glaze must therefore be less than the unionized air and greater than the ionized air, and must additionally possess resistance to heat, arcing, and other related operating conditions. In addition to the formation of ionized paths, this coating may provide a point-to-point arcing along the glazed surface between the electrodes to thereafter provide a full intensity spark between the electrodes free from the glaze.

It will be understood that numerous modifications may be made of this invention by those skilled in the art without actually departing from the scope of the invention itself. Therefore, I aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An ignitor plug for jet engines and the like combustion apparatus comprising in combination, a pair of electrodes separated from each other by means of an air gap, an electrical insulator insulating one of said electrodes from the other, and a semiconductive coating on said insulator and in contact with each of said electrodes, the said coating including a fusible glass base containing a spinel, the fusible glass base having a composition of BaO , 20-50% by weight, Al_2O_3 , 1-30% by weight, B_2O_3 , 0-25% by weight, SiO_2 , balance, and the amount of said spinel being sufficient to be the continuous phase after firing.

2. The invention as claimed in claim 1 wherein said fusible glass base has the composition of SiO_2 50% by weight, B_2O_3 10% by weight, Al_2O_3 10% by weight, and BaO 30% by weight.

3. The invention as claimed in claim 1 wherein said fusible glass base has the composition of SiO_2 45% by weight, BaO 45% by weight, and Al_2O_3 10% by weight.

4. The invention as claimed in claim 1 wherein said coating includes about 25% to 50% spinel.

5. The invention as claimed in claim 1 wherein said spinel is selected from the group consisting of magnetite, zinc ferrite, manganese ferrite, and nickel ferrite.

6. The invention as claimed in claim 1 wherein said spinel is Fe_3O_4 .

7. The invention of claim 1 wherein the said coating includes 70% by weight of a fusible glass base and 30% by weight of Fe_3O_4 , said glass base having the composition of SiO_2 50% by weight, B_2O_3 10% by weight, Al_2O_3 10% by weight, and BaO 30% by weight.

8. An ignitor plug for jet engines and the like combustion apparatus having a pair of electrodes separated from each other by means of an air gap, an alumina ceramic insulator insulating one of said electrodes from the other and a semiconductive coating on said alumina insulator and in contact with each of said electrodes, said coating including a fusible glass base containing a spinel, said glass base having the composition of SiO_2 50% by weight, B_2O_3 10% by weight, Al_2O_3 10% by weight, BaO 30% by weight, and said spinel being Fe_3O_4 , the proportion of the glass base and the spinel being about a 70% to 30% ratio.

9. The invention as claimed in claim 8 wherein said coating further includes NiO with the proportion by weight percent being 70, 23 and 7 percent (%).

10. The invention as claimed in claim 8 wherein said coating includes 70% by weight fusible glass, 24% by weight Fe_2O_3 , and 6% by weight ZnO .

11. An alumina insulator having a semiconductive coating thereon, said coating comprising about 70% glass having the composition of Table I (SiO_2 50% by weight, Ba_2O_3 10% by weight, Al_2O_3 10% by weight, BaO 30% by weight) and 30% Fe_3O_4 spinel, said coating being further characterized by consisting of a series of individually fired thin coats, the range of the glass components being B_2O_3 , 0-25% by weight; Al_2O_3 , 1-30% by weight; BaO , 20-50% by weight; SiO_2 , balance.

12. An alumina insulator for electrical ignitors having a semiconductive coating thereon, said coating comprising by weight about 70% glass having the constituents of 50% SiO_2 , 10% B_2O_3 , 10% Al_2O_3 , 30% BaO , and 30% Fe_3O_4 , said coating being further characterized by comprising a series of individually fired thin coats.

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