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PROCESS OF MAKING A SEMI-CONDUCTIVE CERAMIC BODY

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Fig. 1.

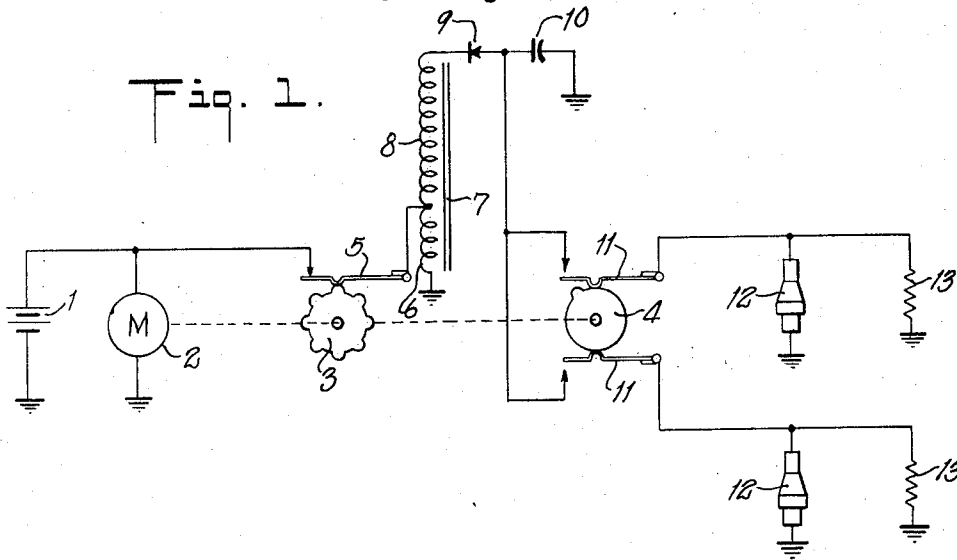


Fig. 2.

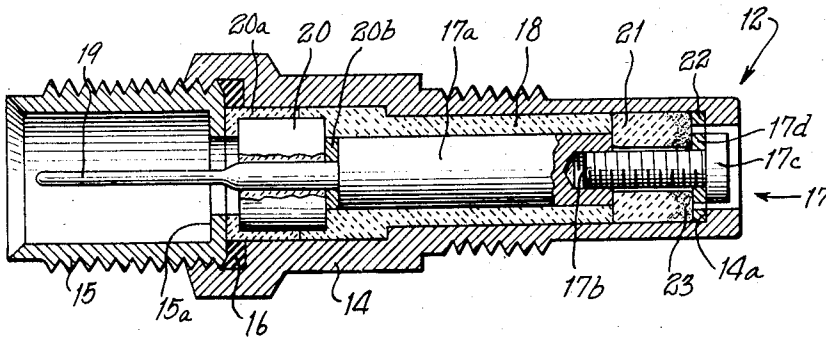
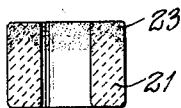


Fig. 3.



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PROCESS OF MAKING A SEMI-CONDUCTIVE CERAMIC BODY

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7 Claims. (Cl. 117—219)

The present invention relates to spark-producing devices or igniters, semi-conductive ceramic elements for use therein and the process of making them. Such devices as herein disclosed are particularly useful in igniting fuel and air mixtures in internal combustion engines and particularly in jet engines of the type used in aircraft. Various phases of the invention have, however, much wider utility, for example, in spark-producing devices in general.

Spark plugs or igniters of the common type used on internal combustion engines have a pair of electrodes separated by an air gap in which the spark is produced. Such igniters commonly include a member of insulating material which is disposed between the electrodes and has a surface adjacent to the air gap. When in use, such igniters are at times subject to a condition commonly termed "fouling," characterized by the formation of a deposit, usually carbonaceous in character, on the insulator surface. The carbon deposit provides a more or less electrically conductive path in parallel with the spark gap and weakens the spark, or may, if sufficiently conductive, prevent the formation of a spark.

It has also been proposed to provide an igniter of the so-called "surface gap" type. In such igniters, the electrodes are separated by a semi-conductive member, rather than a member of insulating material. Portions of the surface of this member, including particularly the metal-to-semi-conductor contact area, are believed to be heated by the electric current when a discharge is initiated between the electrodes, and are thereupon believed to give off electrons which aid in breaking down the gap, so that the main discharge follows as a spark between the electrodes and just above the conductive surface. Surface gap igniters have the advantage of a lower voltage requirement for a given spark energy. Furthermore, the heating of the conductive surface during the discharge tends to burn off any fouling deposit. However, in igniters of this type constructed in accordance with the teachings of the prior art, the energy dissipated in the spark may vary considerably under fouling conditions, as the energy dissipated in the fouling deposit varies with its thickness and composition.

In internal combustion engines ignition takes place following a compression stroke in a chamber having a high temperature, a high pressure, and a reasonably uniform mixture of fuel and air. Under such conditions, successful ignition of the mixtures is comparatively easy. As long as some kind of spark occurs, the fuel mixture will ignite.

In jet engines, however, the conditions are quite different and the problem of producing satisfactory ignition of the fuel is considerably more complicated. The pressure may vary widely, for example, between about 3 inches of mercury (absolute) and 250 pounds per square inch (gauge) pressure. The temperatures at the point of ignition also may vary widely, for example, from about -65° F. to about 2000° F. There is commonly a great amount of turbulence in the neighborhood of the igniter,

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and there is a wide variation in the fuel-air ratio of the mixture presented for ignition.

Because of these considerations, it is desirable in such engines to provide ignition apparatus which will produce sparks of uniformly high energy.

In addition to the low temperature requirements during starting conditions, an igniter for a jet engine must be able to withstand very high temperatures, for example, of the order of 1800°-2000° F., during operation of the engine.

The present invention relates to igniters and similar spark producing devices of the surface gap type. One of the principal features of the invention is the use of a semi-conductive material to form the active surface of the surface gap.

The term "semi-conductive materials" is a well recognized generic term for a large group of materials which are neither good electrical conductors nor good electrical insulators. These materials commonly have a negative temperature coefficient of electrical resistance. In other words, their resistance decreases as their temperature increases. This characteristic is just the opposite of the corresponding characteristic of electrical conductors, the resistance of which commonly increases as their temperature increases.

In a surface gap type of igniter, the energy dissipated in the spark, as contrasted to the energy dissipated in the conducting surface, is believed to be determined to a great extent by the emission of electrons from the surface. The greater the quantity of electrons emitted, the quicker the gap through the air breaks down, and the greater the quantity of energy dissipated in the gap rather than in the conducting surface.

While it has been proposed heretofore to produce the ceramic element of such an igniter, either formed in its entirety of semi-conductive material or having a layer thereof on the side facing and in contact with the electrodes of the spark-producing device or igniter, it has been found desirable in accordance with the present invention to employ a ceramic element made of more or less conventional ceramic material which is electrically non-conductive and which is calculated to stand up under the physical strains to which it is exposed, both mechanical and due to temperature, with the surface portion only of this ceramic element made semi-conductive by impregnation. For example, it has been found that if a body which is largely or substantially wholly alumina is surface-impregnated with a suitable metallic oxide which will provide semi-conductive characteristics to the surface portion, the objects desired for a device of this kind will be attained. These objects embrace the ability to withstand any and all physical shocks and vibration to which devices of this kind may be exposed in use as well as the ability to withstand the temperatures to which such devices are exposed in modern jet engines, i. e., temperatures in the order of 1800°-2000° F. as aforesaid. It is further the purpose of the present invention to provide a ceramic element and a sparking device formed therewith, wherein the surface portion of the ceramic element is semi-conductive to the end that it has an electric resistance of the order of about 5,000-30,000 ohms between points which are 0.04 inch apart.

It is a further object of the present invention, which is attained by following the process thereof using the materials hereinafter set out in detail to provide a ceramic element and an igniter using such element which shall be relatively inexpensive to manufacture, so that such devices may be discarded and replaced after a reasonable life period without unduly increasing the cost of operation of the apparatus with which they are used.

It is a detailed object of the present invention to provide at least one and preferably two firing operations,

each effective on a layer of metallic oxide material, such as or including copper oxide, which shall produce an impregnated semi-conductive surface portion on a non-conductive ceramic body as hereinabove generally referred to.

Other objects and advantages of the present invention will become apparent from a consideration of the following specification and claims, all when taken in connection with the accompanying drawings, in which:

Fig. 1 is an electrical wiring diagram of an ignition system suitable for use with igniters constructed in accordance with the invention;

Fig. 2 is a longitudinal, cross-sectional view of an igniter embodying the invention; and

Fig. 3 is a cross-sectional view of a ceramic element which may be used in the igniter of Fig. 2.

The ignition system illustrated in Fig. 1 includes mechanism for producing a uniform charge as disclosed and claimed in the U. S. Patent to John V. McNulty, No. 2,716,720, issued August 30, 1955, for Engine Ignition Apparatus and Procedure. Systems of this type have the characteristic that charges of electricity for the formation of sparks are delivered to the igniters in carefully measured and regulated quantities of energy, so that uniform sparks may be produced at the igniter, regardless of variations which may occur in the energy supply system, for example, in the potential of the source of electrical energy.

Referring to the drawing, there is shown a battery 1 which supplies electrical energy to a motor 2, drivingly connected to a multiple lobe cam 3 and a single lobe cam 4. The multiple lobe cam 3 operates a switch 5 connected in series between the battery 1 and the primary section 6 of the winding of an auto-transformer 7. The secondary section 8 of the winding of the auto-transformer 7 is connected in series with a circuit which includes a rectifier or other asymmetric element 9, and a condenser 10. Two branch circuits are connected to the condenser 10, each branch including a trigger switch 11 operated by the single lobe cam 4, an igniter 12, and a resistance 13 in parallel with the plug 12.

The motor 2 has a voltage-speed characteristic such that the speed varies directly and linearly as the voltage. Consequently, the time of closure of the switch 5 by the lobe of the cam 3 varies inversely with the voltage of the source 1. Consequently, regardless of variations in the voltage of the source, each closure of the switch 5 delivers a fixed predetermined quantity of electricity to the primary section 6 of the winding of the auto-transformer 7. These measured quantities are stepped up in potential by the auto-transformer, and pass through the rectifier 9 and are stored on the condenser 10. The condenser 10 is discharged each time that the single lobe cam 4 actuates one of the trigger switches 11. Since the single lobe cam 4 is driven by the same motor 2 which drives the multiple lobe cam 3, it will be apparent that each discharge of the condenser 10 is preceded by the same number of charging pulses, determined by the number of lobes on one-half the periphery of the cam 3. The condenser 10 discharges through each igniter 12 and the resistance 13 in parallel, respectively. The resistance 13 is a relatively high resistance, and is effective to discharge the condenser 10 in the event that there is an open circuit at the igniter 12. The purpose of so discharging the condenser 10 is to prevent the accumulation of charges thereon beyond the normal quantity, which might result in the application of abnormal currents and voltages to the igniter 12.

As shown in Fig. 2, the igniter 12 comprises an outer shell 14 having at its right-hand end an inwardly projecting flange 14a. The right-hand end of this shell forms the outer or grounded electrode of the igniter. Extending axially within the shell 14 is a central electrode assembly generally indicated at 17 and comprising

a body 17a having on its right-hand end (as seen in Fig. 2) an internally threaded recess in which is inserted a bolt 17b having a head 17c which forms the other electrode of the igniter. A ceramic element 21 having a stratum of semiconductive material 23 on its right-hand surface (as seen in Fig. 2) is retained between the body 17a and the head of bolt 17c. A washer 17d is located under the head 17c of the bolt, between that head and the semi-conductive stratum 23. The bolt 17b and the body 17a are preferably formed of stainless steel. The washer 17d is preferably formed of a nickel manganese alloy known commercially as Nickel-D. This nickel washer provides an electrical contact between the bolt 17b and the semi-conductive impregnated surface portion 23. The washer is also considerably softer and more resilient than the stainless steel, so that it distributes the compressive stress applied to the ceramic element 21 when the bolt is tightened in the body 17a. The ceramic element 21 is thereby stressed only in compression which it is capable of withstanding readily. Shear and tension stresses which might crack the ceramic material are thereby avoided. After the ceramic element 21 and washer 17d are assembled on the end of body 17a by means of the bolt 17b, the bolt and the body may be welded together electrically and a screw slot (not shown) which was formed on the head 17c to facilitate assembly, is ground or machined off.

After the central electrode assembly 17 is complete, it is mounted in the shell 14. A washer 22, of material similar to the washer 17d, is located between the right-hand periphery of the ceramic element 21 and the flange 14a of the shell. A plurality of longitudinally sectional ceramic spacers 18 (shown on the drawing as a single element) are then inserted behind the ceramic element 21.

A terminal 19 is attached to the left-hand end of the body 17a, as by welding. A copper washer 20b encircles the terminal 19 adjacent to the body 17a. A bushing 20 is received in a recess formed in the left-hand end of the spacers 18 and abuts against washer 20b. A collar 20a of suitable insulating or nonconductive material encircles the bushing 20 and abuts against the spacers 18. The collar 20a has an inwardly directed flange on its left-hand end to engage the bushing 20 and hold it in place.

The shell 14 is provided with an internal thread on its left-hand end to receive an externally threaded coupling sleeve 15 which abuts against the collar 20a and holds all the parts firmly in position. A gasket 16 of insulating material is located between the right-hand end 15a (as seen in Fig. 2) of sleeve 15 and a shoulder formed in the shell 14.

When the sleeve 15 is tightened into the shell 14, it forces the collar 20a against the spacers 18, which are in turn forced against ceramic element 21. The ceramic element 21 is thereby held in tight contact with the washer 22. The function of washer 22 is similar to that of washer 17d. That is, it distributes the compressive stress applied to the ceramic element 21 and prevents any tension or shear stress on that element. It also provides good electrical contact between the semi-conductive stratum or impregnated surface portion 23 and the outer electrode shell 14.

There is shown in Fig. 3 a ceramic element 21 having its upper or end surface portion 23 impregnated with a semi-conductive material, so as to provide some surface conductivity, which will be equivalent to a body having an electrical resistance of about 5,000-30,000 ohms between points 0.04 inch apart. In this connection, while a resistance range is given between points a stated distance apart, it will be understood that the distance "0.04 inch" is not necessarily the spacing between the electrodes 17c and 14a. The resistance between such electrodes will, of course, be greater if the distance is greater in accordance with the well-known rule, so that the

actual resistance between electrodes along the surface of the semi-conductor may be made any desirable amount by suitably controlling the radial spacing between the electrodes and taking into account the actual conductivity of the surface portion 23 of the ceramic element, which is semi-conductive as aforesaid.

The body portion of the ceramic element may be of any suitable ceramic material, having the necessary mechanical strength and resistance to damage by heat. It has been found, however, that a body having at least about 90% alumina is desirable for this purpose. In addition, there may be about 5-7% calcium oxide, about ½ to about 1½% strontium oxide and about 3-5% silica. Specifically, a preferred composition for this body is alumina 90%; alkaline earth oxides 7%, including, for example, specifically, 6% CaO and 1% SrO; and the balance (4%), silica. This material may be fabricated by conventional ceramic methods, including mixing, drying and firing. Due to the fact that a selected part of the surface portion of this material is to be impregnated with other materials as hereinafter set out, it is desirable that the body, the composition of which has been given in detail as a preferred example, shall be made with but a small amount of melting of the ceramic material, so as to have a selectively small amount of glassy matrix bonding together the crystalline particles of the several ceramic oxides used. Such a body may be made, for example, by firing the preferred composition aforesaid for about one hour at about 2850° F. The product of this stage of the process may have a bulk density of about 3.45 (gm./cc.). This product may be ground to any exact size required in cases where such size is critical.

The body portion of the ceramic element and its composition and/or process of formation is susceptible of quite wide variation and is not per se a part of the present invention except when it is suitably combined with the impregnation steps of the process and/or the product thereof. This impregnation is preferably accomplished in two steps, in the first of which a selected portion of the surface of the body portion of the element as aforesaid is impregnated with a material, the essential active ingredient of which is an oxide of copper, such as cuprous oxide (Cu₂O).

As a practical matter, it has been found convenient in effecting this first stage impregnation to spread upon the surface of the area to be impregnated a paste-like material made up as hereinafter set forth of a copper oxide such as Cu₂O with the balance CaO. A preferred composition of these materials, as to the solid material portion thereof, is Cu₂O about 80% to about 90% and CaO about 20% to about 10%. These proportions are not believed to be critical. It is believed that the presence of some CaO may promote the conductivity of the coating or impregnated surface. It is believed that some fusion of the Cu₂O, CaO and Al₂O₃ may occur at about 2100° F., thereby forming (on cooling) a footing having a relatively high resistance but which serves to support the second coating hereinafter set forth.

The making up of a paste-like form of material for the coating operation again is not critical, as merely enough water should be admixed with the dry material to make a paste of the desired consistency. In practice, it has been found that about 10 grams of dry material admixed with about 10 grams of water will make up a paste of a desired consistency for use. It will be understood, of course, that the water is evaporated completely during the subsequent firing and further that any alkaline earth hydroxide formed will be reconverted to the corresponding oxide during and as a result of the firing, so that it is the composition of the original dry materials which is pertinent as to the resulting product.

Subsequent to the application of a thin layer of the paste-like material, which may be, for example, about one mm. in thickness (assuming a paste composition

made up in accordance with the proportions hereinabove given), the next operation is that of firing the coated body. This is preferably effected at a temperature in the range of about 2300° to about 2600° F. and usually for a time period of about ½ hour to 1 hour. It is found that the time-temperature relation may be varied within the limits given usually in a more or less reciprocal manner, i. e., longer times are required for lower temperatures, and vice versa.

The temperature limits chosen are selected so as to be sufficiently high to facilitate adequate penetration or impregnation of the copper oxide into the more or less porous ceramic body. This accounts for the selection of the lower temperature limit as above given, as temperatures substantially below this low limit will not enable the copper oxide to migrate into the interstices of the ceramic body to a sufficient or desired extent. In view of this manner of determining the lower temperature limit, this limit is not narrowly critical.

The upper temperature limit (2600° F.) is selected on the basis of accomplishing a sufficient amount of penetration of the copper oxide into the porous ceramic body without, at the same time, fusing enough of the material present at or adjacent to the surface of the ceramic body so as to make that surface relatively impervious to further penetration of an impregnating material during the second treatment as hereinafter set forth. In general the purpose of the first fire in maturing the first coating is to provide a good base or footing onto which a second coating, fired by a second fire as hereinafter set forth, will be put. A further reason for choosing the upper temperature limited at about 2600° F. as aforesaid is that still higher temperatures might tend to distort the ceramic body. It will be understood that once a desired surface of such a body is coated or impregnated with a semi-conductive material, that surface may not be ground down to correct a distorted shape without at the same time adversely affecting the desired semi-conductive character of the remaining surface.

It has been found that the electrical resistance of surfaces impregnated with either pure CuO or with pure Cu₂O are both relatively high (that with Cu₂O further being higher than that with CuO); whereas those surfaces impregnated with a mixture of CuO and Cu₂O is relatively lower. This last is somewhat surprising and is probably analogous to the effect on the melting point of mixtures of materials having a low melting eutectic. A relatively low resistance semi-conductive material is desired in accordance with the present invention, so that it is desired that the surface impregnation be by a mixture of CuO and Cu₂O.

It is also known from published data that the melting point of Cu₂O is about 2255° F.; while CuO decomposes at about 1879° F., probably yielding Cu₂O and oxygen. Thus at a relatively high temperature, the only copper oxide material which is stable is Cu₂O. In view of the fact that a mixture of these two materials is desired, and as it would be practically impossible to stop a reducing action at some desired intermediate point, it has been found impractical to start with CuO and then use a reducing action during the firing. What is done according to the present invention is to start with Cu₂O and then use a fire which is preferably on the oxidizing side of neutral, and in any event is non-reducing. For this reason, therefore, the atmosphere during the first firing operation is non-reducing and is preferably oxidizing. Due to the fact, however, that in most instances at least, the present process contemplates not one, but two, firing operations, the first firing could be effected in a substantially neutral atmosphere and the desired oxidation conditions adjusted during the second firing operation. However, as it is very difficult to maintain an exactly neutral atmosphere and as a reducing atmosphere is practically undesired, due to the fact that it is not desired to pro-

duce any metallic copper in the coating, the preferred condition to be established and maintained during the first firing is an oxidizing atmosphere.

When prepared in this manner, the impregnated surface will be semi-conductive and will have a conductivity of the order such that the electrical resistance between two points 0.04 inch apart is from about 1 to about 10 megohms. While this degree of conductivity may be adequate for some purposes, a much higher degree of conductivity is usually found desirable for spark-producing devices, which is a principal use for the product of the present invention. For this reason, therefore, it is usually desirable, if not absolutely necessary, that a further treatment be given the ceramic elements so as to render the semi-conductive surface thereof more conductive than it is after the first treatment as aforesaid.

In accordance with the present invention, a second treatment is carried on, preferably in a manner similar to that just described for the first treatment, with the exception, however, that the essential active ingredients of the dry oxide materials used in the second coating, which is fired onto the selected portion of the surface, is somewhat different than in the first treatment and the firing temperature is in a lower range and further that the atmosphere in which this second firing takes place must be oxidizing in character. In accordance with the present invention, the essential active ingredients for the second coating are cuprous oxide (Cu_2O) and an alkaline earth metal chromate, such as calcium chromate (CaCrO_4).

The proportions for the active materials as aforesaid in the second coating according to the present invention are copper oxide (Cu_2O) from about 80% to about 90%, and alkaline earth metal chromate (CaCrO_4) from about 20% to about 10%. These proportions and possible variations thereof will be illustrated further in examples which follow.

Here again the proportions of the ingredients of the solid material for the second coat are not believed to be critical, but may be varied to a substantial degree. The purpose of the several ingredients is believed to be substantially the same as to the copper oxide ingredient as in the first coat, i. e., to provide an impregnating material which is itself a semi-conductor and which will impart semi-conductive characteristics to the treated surface portion of the ceramic body. The alkaline earth chromate is believed to act as an oxidizing agent and possibly also as an oxygen carrier during the second firing as further described hereinafter. Again it is preferred that the material be applied in paste-like form, this, however, being merely a matter of convenience as again the liquid used to make the paste (usually water) is completely evaporated during the subsequent firing, and further any hydrolysis products will be reconstituted as oxides incident to the firing. In this connection, it is noted that the alkaline earth metal chromate (CaCrO_4) may be considered as two oxides, CaO and CrO_3 , this being a common way of considering ceramic materials, irrespective of the actual physical state in which they are introduced or to which they are converted by the firing and/or melting operations. Practically, it has been found that if 10 grams of the dry material mixture as aforesaid are mixed with 10 grams of water, a paste-like composition of a practical and workable consistency for use will be produced. This paste-like composition is preferably spread onto the same or a part of the same area which was coated in the first coating and firing step to a thickness of about one mm. prior to the second firing operation per se. In this second firing operation, after first drying out the liquid in the paste coating, the temperature is brought up to the range of about 1900° to about 2300° F. and held there for about $\frac{1}{2}$ hour to about 1 hour for the firing operation per se. Here again it will be understood that the time of firing is usually varied inversely with the temperature, so, for example,

at the lower temperature limit, the longer firing time is usually employed, and vice versa.

The atmosphere in which the second firing is conducted must be oxidizing in character, as distinguished from either neutral or reducing. This, in conjunction with the presence of an oxidizing agent (the alkaline earth chromate), establishes positive oxidizing conditions. The purpose of this is believed, in accordance with present theories, to result in the conversion of some of the Cu_2O initially present to CuO . It is recognized that CuO tends to decompose at the temperatures at which the second firing takes place. However, the presence of positive oxidizing conditions, possibly coupled with the presence of an active oxidizing agent or oxygen carrier causes the positive conversion of some Cu_2O to CuO and/or prevents the reverse action (decomposition of CuO) from taking place, so that it is the present theory that the resulting material (i. e., that produced following the cooling after the second fire) contains on the treated surface a mixture of CuO and Cu_2O . Such a material as aforesaid has an electrical resistance lower than that either of pure Cu_2O or of pure CuO . It is also reasonably certain that the presence of positive oxidizing conditions substantially prevents the reduction of oxides of copper to elemental copper and, therefore, retains the semi-conductive character of the coated or impregnated surface, as distinguished from a fully conductive surface which would result if the copper thereon were in elemental form.

As a result of the second firing operation, there is produced a finished ceramic body, the coated or impregnated surface portion of which is semi-conductive and has an electrical conductivity of the order such that the resistance between two points 0.04 inch apart is about 5,000–30,000 ohms. This treated body may then be assembled into a spark-producing device or igniter as hereinabove described and used in the manner in which such devices are conventionally used in jet engines.

From the point of view of the product of the present process, whether that product be considered the igniter as a whole or whether it be considered merely an impregnated ceramic element, this product is believed to be one which can be made by several different processes. For example, in addition to the process hereinabove described, it is believed that a surface-impregnated ceramic body as hereinafter claimed and which will have the functional characteristics of the body just described, may also be made, for example, by depositing metal as such on the surface of a ceramic body, for example, by metallizing or electrodeposition; and thereafter some or all of this metal may be converted to an oxide form by some type of oxidizing treatment, usually heating to high temperature in an oxidizing atmosphere. The present invention does not specifically include such processes for manufacturing such a product, but is intended to include the product, irrespective of the method by which it was manufactured.

The invention is further illustrated by the following specific examples:

Example I

This example is given to illustrate the making of a stable type of a ceramic body having a semi-conductive coating thereon with a resistance within the range given hereinabove, but in a higher portion of this range. This product was made as hereinafter set out by firing in the higher ends of the temperature ranges for each of the two firings. As a result, some copper was believed to be lost by volatilization. A product made in this way, however, has a stable resistance, i. e., one which will not increase its resistance during a normal use.

In accordance with this example, the material forming the first coating applied to the ceramic body was made up of 86% Cu_2O and 14% CaO . The first firing was conducted under somewhat oxidizing conditions, for about one hour, at about 2600° F. After cooling, a second

coating layer was applied onto the same area to which the first coating was applied. The second coating layer was made up of 86% Cu_2O and 14% CaCrO_4 . The second firing is carried on in the temperature range of about 2050° F. to about 2350° F. for one hour in an oxidizing atmosphere. The product thus prepared is preferred in most instances for the purpose of making igniters as herein set forth.

Example II

When it is desired to make a low impedance type igniter, i. e., one which can be operated with a low breakdown voltage, the teachings in this second example may be followed. In accordance therewith, the first coating to be applied to the basic ceramic body consisted essentially of 91% Cu_2O and about 9% CaO . The first firing was carried on for about one hour at about 2300° F. in a slightly oxidizing atmosphere. The second coating applied in this instance consisted essentially of about 91% Cu_2O and about 9% CaCrO_4 . The second firing was carried on in the temperature range of about 1950° F. to 2050° F. for about one hour. The product was found to have the characteristics described in this example.

There is herein shown and described an igniter construction including a coated or impregnated ceramic body having a semi-conductive surface. A process for making such a ceramic body has been described in detail. The theories presently believed to be correct as to what occurs during the several steps of the process, have been set out. It will be understood that irrespective of the actual correctness of the theories or lack thereof, the process steps particularly described will produce the stated results in a reproducible manner. Many equivalents of the process steps and other features herein set out will occur to those skilled in the art, particularly in the light of the foregoing disclosure. We do not wish to be limited, therefore, except by scope of the appended claims, which are to be construed validly as broadly as the state of the prior art permits.

What is claimed is:

1. The process of making a ceramic element usable in a spark-producing device, which comprises the steps of applying to a predetermined surface portion of a body of non-conducting refractory oxide material a first coating, the essential active ingredients of which are cuprous oxide and calcium oxide, firing said first coating on said body in a non-reducing atmosphere for about one-half hour to an hour at a temperature in the range of about 2300° F. to about 2600° F.; thereafter applying onto at least a part of said predetermined surface portion a second coating, the essential active ingredients of which are cuprous oxide and an alkaline earth metal chromate, and firing said second coating onto said body in an oxidizing atmosphere for about one-half hour to an hour at a temperature in the range of about 1900° F. to about 2300°

F., so as to produce on said selected portion of said element an impregnated area having an electrical resistance of about 5,000–30,000 ohms between points 0.04 inch apart.

2. The process of making a ceramic element in accordance with claim 1, in which the time of firing of each of said coatings is varied substantially inversely with the variation in the temperature of firing, within the stated ranges as to both time and temperature respectively.

3. The process of making a ceramic element in accordance with claim 1, in which said first coating is fired in an oxidizing atmosphere.

4. The process of making a ceramic element in accordance with claim 1, in which the active ingredients of the first coating consist essentially of:

Cu_2O About 80% to about 90%
 CaO About 20% to about 10%

5. The process of making a ceramic element in accordance with claim 1, in which the active ingredients of the second coating consist essentially of:

Cu_2O About 80% to about 90%
 CaCrO_4 About 20% to about 10%

6. The process of making a ceramic element in accordance with claim 1, in which the active ingredients of the first coating consist essentially of Cu_2O , about 86% and CaO , about 14%; and in which the active ingredients of the second coating consist essentially of Cu_2O , about 86% and CaCrO_4 about 14%; in which the temperature of the first firing is about 2600° F., and the temperature range of the second firing is about 2050°–2350° F., both firings being for about one hour and both being in oxidizing atmospheres.

7. The process of making a ceramic element in accordance with claim 1, in which the active ingredients of the first coating consist essentially of Cu_2O , about 91% and CaO , about 9%; and in which the active ingredients of the second coating consist essentially of Cu_2O , about 91% and CaCrO_4 about 9%; in which the temperature of the first firing is about 2300° F., and the temperature range of the second firing is about 1950°–2050° F., both firings being for about one hour and both being in oxidizing atmospheres.

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