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ELECTRICAL DISCHARGE DEVICE

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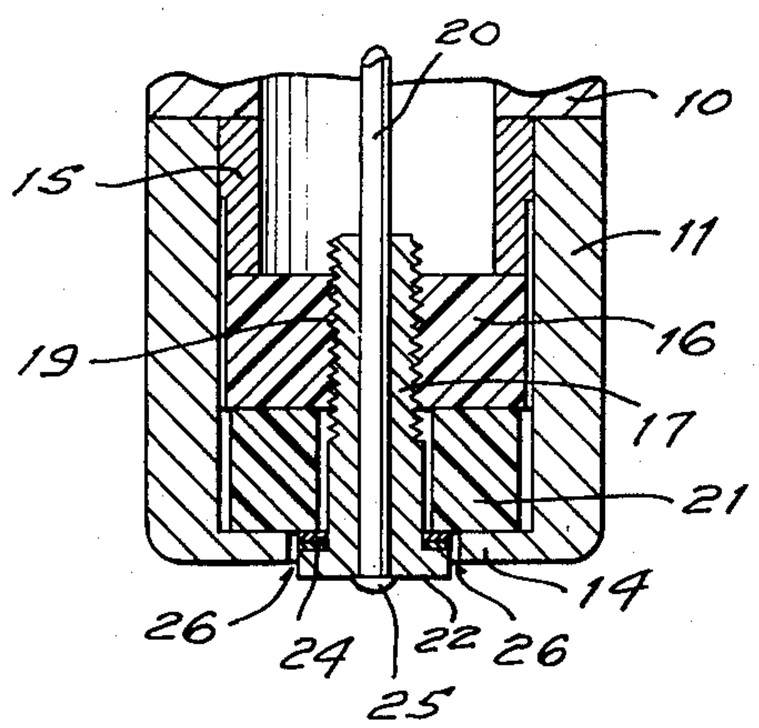

FIG. 1

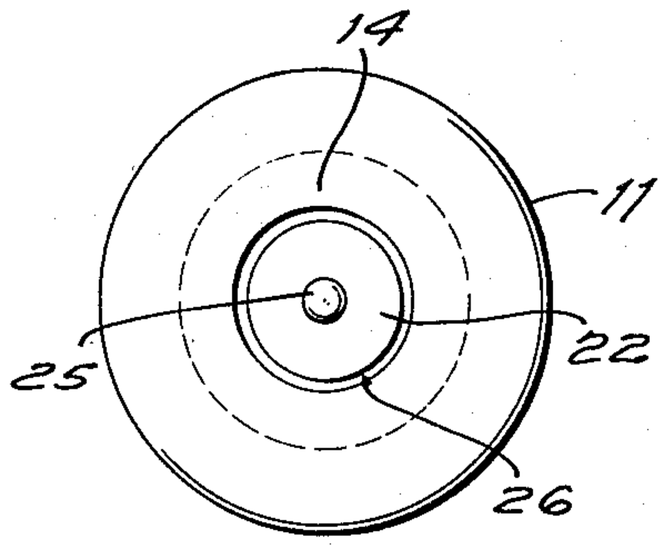

FIG. 3

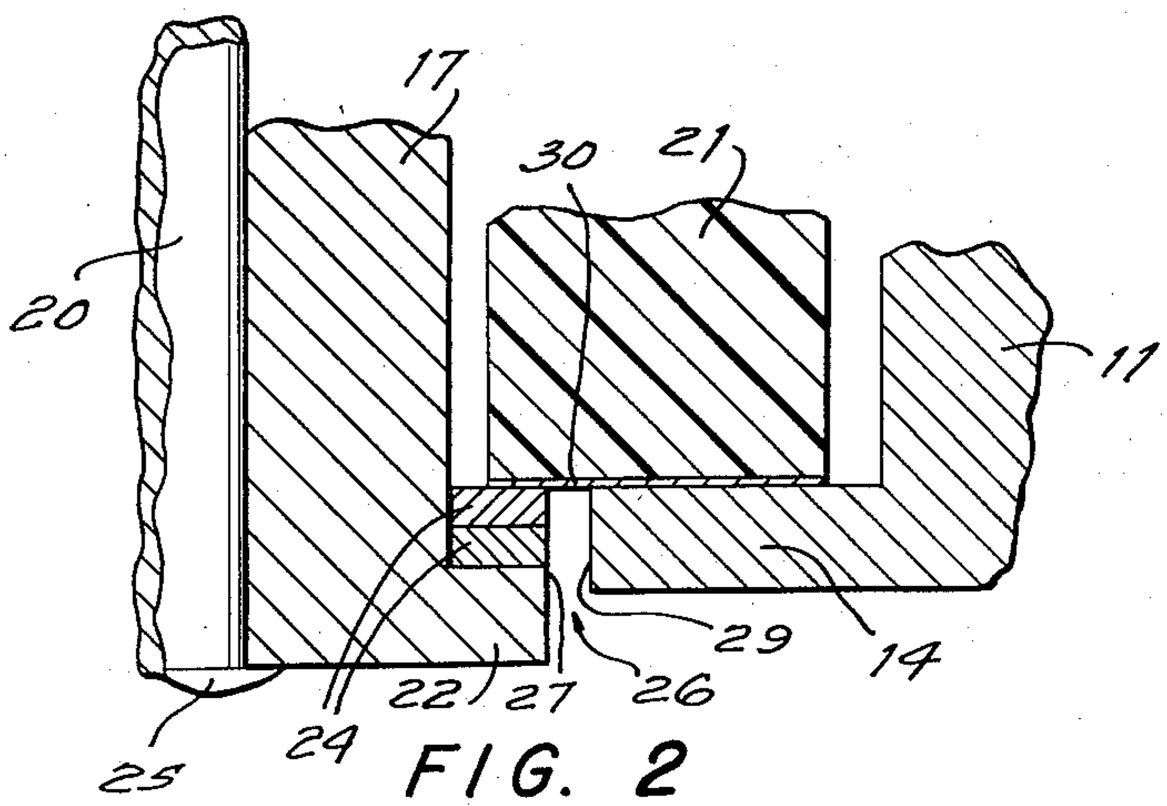

FIG. 2

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ELECTRICAL DISCHARGE DEVICE

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6 Claims. (Cl. 313—131)

This invention relates to electrical apparatus, and more particularly to electrically energized devices adapted for creating electrical spark discharges between spaced electrodes in an electrical circuit.

The invention is of advantage when embodied in a spark plug, as to supply periodic sparks to a cylinder of a piston engine, or to supply a starting spark for a turbine or jet engine. The invention is illustrated herein in an embodiment adapted to supply discharges for an engine, although it will be understood that the device is useful for producing spark discharges for other purposes.

It has previously been proposed to provide spark gaps with an electrically semi-conducting body positioned close to the gap and connected in shunt with the electrodes of the gap. Such combination has been found to create a spark with more energy under lower potential differences than is possible between two conventional spaced metal electrodes of the usual spark plug. The semi-conducting body, in the combination above described, appears to provide for marked ionization of the molecules of the gas between the electrodes in the first portion of the energization of the gap and before the actual discharge occurs. This allows the eventual discharge between electrodes to take place at a decreased potential, and makes it possible for such discharge to have high energy under such lower potential.

The manufacture of some prior spark discharge devices in which the electrodes were shunted with an electrically semi-conducting material has required the preparation and firing of special ceramic mixtures to form ceramic bodies which themselves were semi-conducting. Not only did this require require deviation from the usual ceramic mixing and firing practices, but the electrically conducting properties of the resulting ceramic body were prone to undue variation, and the electrical resistance of such bodies was often unduly high for optimum performance in combination with the electrodes in the manner described. The present invention provides for forming an electrically semi-conducting body which is adapted to be placed near the gap between the electrodes of a spark discharge device and is connected in shunt with such electrodes. The invention allows the use of economical materials and procedures, and the resulting semi-conducting body is under better control as to the type of surface obtained and as to the electrical resistance of the semi-conducting body.

In accordance with the present invention, the ceramic parts of a spark discharge device such as a spark plug can be made conventionally, the semi-conducting body being a layer of electrically semi-conducting material added to the electrode-confronting face of a ceramic part of the device. The addition of such electrically semi-conducting layer is easily and economically carried out, and the desired surface characteristics and electrical resistance of the semi-conducting layer, as well as the degree of bonding between the semi-conducting layer and its ceramic support, are under full control. The electrically

semi-conducting body of the invention, which is present as a film-like layer or coating on a surface of a ceramic body in preferred embodiments of the invention, is characterized by its low electrical resistance, the excellence of the bond between it and the ceramic support, and the smoothness and uniformity of the outer, electrode-confronting surface of such layer. In addition, the production of such layer, and the production of such layer in combination with a ceramic support therefor, are characterized by the ease of control of the process to obtain substantial uniformity of the layer from part to part in commercial production.

One of the objects of the present invention is to provide an improved spark or igniter plug adapted for use in ignition systems for initiating the combustion of gaseous or other combustible charges, as in engines or the like.

Another object of the invention is to provide improved apparatus of the above character which is so constructed that low voltage high energy sparks or arcs may be created across a relatively wide gap considering the magnitude of the voltage.

Still another object of the invention is to provide, in a spark discharge device having an electrically semi-conducting body positioned close to and in shunt with the electrodes thereof, an electrically semi-conducting body of novel composition, such body having a relatively low electrical resistance and having a smooth outer surface close to and confronting the gap.

A still further object of the invention resides in provision of an improved combination of an electrically semi-conducting layer of material and a ceramic support to which the layer is bonded.

Another object of the invention lies in the provision of an improved coating composition adapted to produce an electrically semi-conducting layer of the above indicated character; in one preferred embodiment of the invention there is employed in improved vehicle for the layer-forming solids of such coating composition, such improved vehicle being such that there is no adverse effect on the dispersing powers of the dispersing and suspending agent regardless of the order of addition of the ingredients to the coating composition.

A still further object of the invention lies in the provision of a method of making the novel, improved electrically semi-conducting body of the invention and of making the combination of such electrically semi-conducting body with a ceramic support to which it is bonded.

The above and further objects and novel features of the present invention will more fully appear from the following detailed description when the same is read in connection with the accompanying drawings. It is to be expressly understood, however, that the drawings are for the purpose of illustration only and are not intended as a definition of the limits of the invention.

In the drawings, wherein like reference characters refer to like parts throughout the several views,

Figure 1 is a fragmentary view in vertical axial section of the lower or inner end of a spark plug providing a spark gap, the central conductor of such device being shown in elevation,

Figure 2 is a fragmentary view similar to Figure 1 but on a much enlarged scale and showing one zone of the spark gap, and

Figure 3 is a bottom view of the device shown in Figures 1 and 2.

The single embodiment of the invention illustrated in the accompanying drawings is in the form of a spark gap or sparking device commonly known as an igniter plug or spark plug adapted for use in ignition systems for initiating sparks to ignite combustible mixtures, such as

in internal combustion engines or the like. The engines may be of the reciprocating piston type, wherein the spark plug periodically discharges a spark in its cylinder, or of the turbine or jet type, wherein the spark plug is employed to start combustion in the engine, after which the combustion is self-sustaining.

In Figure 1 there is shown the bottom or inner, gap-containing end of a spark plug. When the plug is installed in an engine, such bottom end of the plug is in direct communication with the combustion chamber of the engine. The spark plug has a metal upper, main body shell, a portion of which is shown at **10**, and a metal lower hollow cylindrical shell **11**. Shells **10** and **11**, which may be made of a nickel-steel alloy, are butt-welded together, to form, in effect, an integral housing, after assembly therein of the inner parts shown in the lower end of the spark plug and now to be described.

The lower end of sleeve portion **11** is provided with a radially inwardly directed flange **14**, the radially inner edge surface **29** of which is cylindrical and lies coaxial of the shell **11**. Surface **29** of flange **14**, as will be apparent hereinafter, forms one electrode of the annular spark gap **26** of the spark plug. The other, inner electrode of the spark gap is supported in the spark plug and is insulated from the metallic shell thereof as follows.

An inner metal sleeve **15**, which may also be made of nickel-steel alloy, has a driven fit with the inner surface of shell **11** and has its upper end abutting the lower end of the radially inner portion of the upper shell **10**, as shown. An annular sleeve-like ceramic insulating member **16**, made of fused or sintered alumina or the like, is positioned within shell **11** with the upper end of the insulating member against the lower end of sleeve **15**. A central tubular metal electrode **17**, which may also be made of nickel-steel alloy, has threaded engagement at **19** with the central bore of insulating member **16**. The central electrode **17** and the insulating member **16** are in part held in the position shown by a central metal conductor **20**, which may be also made of nickel-steel alloy. The conductor is centered and is held from axial movement at its upper end in a conventional manner by an upper insulator (not shown) within the upper portion of shell **10** of the spark plug. Conductor **20** is held in tension between such upper insulating member of the spark plug and the central electrode **17**, being attached to and making electrical connection with such central electrode as by a weld **25**, which attaches the lower end of the conductor to the lower surface of the central electrode.

The lower end of central electrode **17** is provided with a circular, outwardly directed flange **22**, such flange having a diameter smaller than the inner diameter of flange **14** on shell **11**. The two flanges define between them an annular spark gap **26** of the desired radial width. Flange **22** of the center electrode also serves to support washer-like members **24**, shown as having an outer diameter the same as the outer edge surface **27** of flange **22**. Members **24**, which form a portion of the inner electrode, are preferably made of erosion resistant material, such as platinum, tungsten, nickel, tantalum, or the like. Members **24** also serve to position a second annular ceramic body **21**, having an electrically semi-conducting surface **30** on its lower face, body **21** being held in compression between the upper surface of upper member **24** and the lower surface of insulating body **16**. As shown more clearly in Figure 2, the semi-conducting layer **30** extends across and is in intimate contact with the upper surface of upper member **24** and with the upper surface above flange **14**.

Judging from test data, and from visual inspection of the spark plug during test operations, when an electrical potential difference is impressed between electrode-forming flanges **14** and **22**, there is initially an appreciable leakage of current between electrodes through semi-conducting layer or body **30** before an actual spark discharge takes place between faces **27** and **29** of the spark gap. During such initial period, before the actual spark discharge, the gases confined within the annular space defined by surfaces **27**, **29**, and **30** are ionized to a substantial extent by the current passing through layer **30** from one electrode to the other. When the potential between electrodes has built up sufficiently to cause a spark discharge to occur, the discharge takes place in the form of a hot spark of high energy. The discharge appears to start at a zone or zones located close to semi-conducting layer **30**. In the later stages of the discharge, the spark tends to project or shoot outwardly from gap **26** to a marked extent, producing a relatively large volume of incandescent gases which function to ignite combustible mixtures much more efficiently than does the conventional spark between metal electrodes unshunted by a semi-conductor of electricity.

In accordance with preferred embodiments of the invention, the electrically semi-conducting body which shunts the electrodes of the spark gap is, as above noted, in the form of a film-like coating layer **30** on the ceramic support **21**. The layer **30** is composed at least predominantly of a fired mixture of copper oxide and iron oxide in which the respective oxides lie within ranges to be defined. In preferred embodiments of the invention particularly disclosed herein, the copper oxide employed is cuprous oxide (Cu_2O), and the iron oxide is ferric oxide (Fe_2O_3), and the firing of the mixture of such oxides is carried out at such temperature and for such a length of time that one or both such oxides are sintered, that is, heated to a point of incipient fusion, the liquid vehicle in which such oxides are preferably applied is driven off, the resulting electrically semi-conducting layer **30** is compacted into a smooth surfaced coating layer, and such layer is bonded to the surface of the ceramic support **21**.

In order to function satisfactorily in electrical discharge devices such as spark plugs, an electrically semi-conducting layer shunting the electrodes of such plug must have an at least relatively smooth and unblemished outer surface confronting the gap, a relatively low resistivity both initially and during the life of the plug under the varying temperatures and other service conditions encountered during use of the plug, and must be well bonded to the refractory ceramic member on which it is supported. Unless such semi-conducting layer is smooth and substantially free from imperfections, it will not function substantially uniformly over the area of the spark gap. Unless such layer is of relatively low resistivity, it will not strongly ionize the gas between the electrodes prior to the spark discharge. Unless the layer is well bonded to the ceramic support, it will soon flake or spall off such support under arduous service conditions.

It has been found that under certain conditions of firing an electrically semi-conducting layer made up of a sintered mixture of from 68% to 98% by weight cuprous oxide and from 2 to 32% by weight ferric oxide is satisfactory. A somewhat more generally satisfactory semi-conducting layer is formed when such sintered mixture is composed of from 84 to 96% by weight of cuprous oxide and from 4 to 16% by weight ferric oxide, such preferred range allowing the use of higher firing temperatures. In a specific preferred embodiment disclosed herein, the semiconducting layer **30** is composed of 92% by weight cuprous oxide and 8% by weight ferric oxide.

Within the broad ranges first given above, the lumping of copper oxide in the coating composition during the firing operation is reduced sufficiently to yield a commercially useful electrically semi-conductive coating. When ferric oxide is employed in the mixture in an amount somewhat exceeding 2% by weight of the mixture, such lumping of the copper oxide during the firing operation is eliminated. Depending upon the firing temperature, the resistivity of the layer decreases as the iron oxide content increases to approximately 16% by weight. Higher concentrations of iron oxide (16 to 32%) increase the resistivity of the semi-conducting layer rapidly as the firing tempera-

tures increase, but sintered layers of a mixture with such higher oxide content are useful when they are fired at lower temperatures, as will be seen in the following examples and tables. The semi-conducting layers resulting from mixtures within the second, narrower, ranges given above are generally preferred because of the lower resistances which they have when fired at relatively high temperatures, such high firing temperatures, in turn, promoting the formation of a strong bond between the semi-conducting layer and the ceramic support therefor.

The composition of preferred embodiments of coating composition in accordance with the invention, and the preferred manners of making an electrically semi-conducting film-like body or layers therefrom, are set out below in the following examples and tables, which are given by way of illustration only and are not to be construed as limiting the invention.

EXAMPLE I

A paint-like coating material having the following composition was prepared:

Solids:

(1)	Cu_2O	24	g.—92.3% by weight.
(2)	Fe_2O_3	2	g.—7.7% by weight.

Vehicle:

(3)	Glycerol	8.7	grams.
(4)	Tergitol #4	3	drops.
(5)	Water (distilled)	26	drops.
(6)	HCl (conc.)	17	drops.
(7)	Marasperse N	.78	grams.

Notes:

(1) Baker's cuprous oxide 97.1% Cu_2O.
(2) Fisher's ferric oxide 99.7% Fe_2O_3.
(3) Baker's Chemical Company.
(4) Union Carbide & Carbon Corporation, trade name for wetting agent.
(7) Marathon Corporation, trade name for dispersant and suspending agent.

In the coating composition of Example I the glycerol was present in an amount approximating one-third the total weight of the oxides, and the Marasperse N was present in an amount equalling 3% of the total weight of the oxides. The "drops," by which the volumes of Tergitol #4, water, and hydrochloric acid are given, were drops from a standard analytical burette. The number of drops of Tergitol #4 was 13% of the number of grams of the total oxides; the number of drops of water equaled the total number of grams of the oxides; and the number of drops of hydrochloric acid was equal to two-thirds the number of grams of the total oxide content.

The coating composition of Example I was prepared by stirring the materials in the amounts given in the same sequence as they are listed in the table above. In the liquid vehicle given in this example, which is made up of the last five ingredients, it is important that the Marasperse N not be added until the reaction between the Cu_2O and the HCl has been completed, since otherwise the acid is apt to neutralize the suspending powers of the Marasperse N.

In making the element composed of the ceramic member **21** and the semi-conducting coating **30** thereon, the body **21** was first made by conventional ceramic practice, as by molding and sintering alumina. One annular face of such body, after it had cooled, was then painted with the above composition. The thus coated body **21** was then fired in an electric resistance heating furnace having Globar resistance units, the heating being conducted at such rate as to raise the temperature of the furnace at a rate of 400° F. per hour to a final temperature of pyrometric cone **4** "down" (2200° F.), after which body **21** with coating **30** thereon was removed from the furnace after the furnace had cooled to 1000° F. Body **21** was then allowed to cool in the atmosphere. When cool, such body was ready for installation in a spark plug in the manner shown in the drawings and above described.

EXAMPLE II

This method of making body **21** with electrically semi-conducting coating **30** thereon is essentially the same as that given above in Example I except that instead of withdrawing pieces **21** with coating **30** thereon from the furnace after the furnace had cooled down to 1000° F., the fired bodies were allowed to remain in the furnace and to cool slowly to room temperature.

The surface coating **30** of the body resulting from the method of Example II was also satisfactory, but exhibited resistivities which were appreciably higher than those of the semi-conducting layers obtained by the method of Example I.

For the purpose of standardizing resistivity tests on various semi-conducting layers made in accordance with the invention, test ceramic bars of fused or sintered alumina were employed, such bars having a length of 1½ inches, a width of .468±.005 inch, and a thickness of ⅛ inch. After the top surface of respective test bars had been painted with various coating compositions to be indicated below in various tables, the bars were fired in a Globar electric kiln to the desired peak temperature at a rate of rise of 400° F. per hour. After the initial firing of the coating compositions on the ceramic bars, and after withdrawal of the bars from the furnace, or alternatively, cooling the bars in the furnace to atmospheric temperature, "electrodes" were applied by masking the center of each bar with a strip of .750 inch tape and painting the exposed end surfaces with Hanovia #232 platinum paint. A final, rapid firing to 1525° F. firmly bonded the platinum to the painted bar.

The formula

$$K=\frac{RW}{L}$$

was used to calculate the surface resistivity for each bar, where

K=resistivity (ohms per in.^{2})
R=resistance measured between electrodes
L=distance between electrodes (inches), and
W=width of surface between electrodes (inches).

Contact was made with the electrodes by means of sharp probes. Measurements were made with a Simpson 372 ohmmeter. All measurements were made at room temperature (75 to 80° F.). A voltage of 1½ volts was employed between the contact electrodes of the test equipment.

The following Table I, giving the electric resistivities of test samples made as above described and fired in accordance with Example I, with a constant (24 g.) content of Cu_2O in the coating composition of Example I, shows the results of variation in percentage of ferric oxide in the coating composition and also the effect of variation in the peak temperature at which the specimens were fired.

Table I

[Resistivity of coating, ohms/in.^{2}]

Percent Fe_2O_3 by weight of oxides in coating composition	Final Firing Temperature, ° F.					
	2050	2100	2140	2200	2260	2320
2	17,000	16,000	15,000	15,000	16,000	600,000.
4	9,000	12,000	8,000	11,000	9,000	6 megohms.
8	5,000	6,000	4,000	5,000	6,000	7 megohms.
16	4,000	6,000	9,000	30,000	520,000	
32	8,000	44,000	63,000	23 megohms.	Infinite	

Table I above, shows quite clearly the effect of varying the ferric oxide content of the coating composition. The compositions containing, respectively, 16 and 32% Fe_2O_3 form a good bond with their ceramic support,

and have a low resistance when fired at a peak temperature of 2050° F. The fact that they increase in resistivity with the increased firing temperatures, however, make them a second choice when compared with the compositions containing 4 and 8%, respectively Fe_2O_3, such latter two compositions maintaining low resistivities when fired up to and including a peak temperature of 2260° F.

The following Table II shows the surface texture of each electrically semi-conducting layer on each of the test specimens set out in Table I.

Table II

[Degree of lumping]

Percent Fe_2O_3 by weight of oxides in coating composition	Final Firing Temperature, ° F.					
	2050	2100	2140	2200	2260	2320
2	minor	minor	minor	smooth	minor	smooth
4	do	smooth	smooth	do	smooth	Do.
8	smooth	do	do	do	do	Do.
16	do	do	do	do	do	Do.
32	do	do	do	do	do	Do.

Legend:
Major—Numerous large lumps or globs.
Minor—Not more than 5 lumps or pimples per test area.
Smooth—No lumps, pimples, or other blemishes.

It will be seen by comparison of the test results set forth in Tables I and II, and bearing in mind that within limits a better bond is obtained between the ceramic support and the semi-conducting layer the higher the final firing temperature, that the semi-conducting layer containing 8% Fe_2O_3 and 92% Cu_2O shows the best all around qualities. Test speciments of such composition show smooth electrically semi-conducting layers for all the specimens fired at any temperature between and including 2050° F. and 2320° F. The resistivity of such electrically semi-conducting layer of this specimen does not rise appreciably unless a peak firing temperature of 2260° F. is exceeded (Table I). It will be seen, however, that each of the specimens set forth in Tables I and II has a useful semi-conducting layer when the peak firing temperatures are correctly chosen for the particular composition of its coating layer. This is especially true of the coating compositions having a percentage of Fe_2O_3 by weight of total oxides in the coating composition lying between and including 4 and 16.

The liquid vehicle employed as a carrier for the oxides in each of the methods set out in Examples I and II above includes hydrochloric acid. The presence of such acid, as noted, makes it necessary to observe a definite sequence in the addition of ingredients in forming the painting compositions there given. Further, coating compositions including hydrochloric acid show appreciable settling after standing for several days, so that they must be stirred vigorously before being used. An alternative, improved vehicle for the mixture of cuprous oxide and ferric oxide to form coating compositions in accordance with the invention is given in the following table.

EXAMPLE III

Solids:

Cu_2O	24 g.—92.3% by weight.
Fe_2O_3	2 g.—7.7% by weight.

Vehicle:

Glycerol	8.7 g.
Tergitol #4	3 drops.
Water (distilled)	43 drops.
Marasperse N	.78 g.

The alternative coating composition set out in Example III is not fluid, but it is smooth and easy to apply. Perhaps because it is inherently thicker than the composition employed in Examples I and II, and thus produces thicker fired coatings on the ceramic pieces, the resulting fired semi-conducting coatings have lower resistivities than those of the first two examples. Such resistivities are given in Table III below.

As set forth in Example I, one preferred method is to cool the fired specimens in the furnace down to 1000° F., and then to withdraw them from the furnace to allow them to cool rapidly in the atmosphere. An alternative procedure, set forth in Example II, allows the test pieces to cool to atmospheric temperature in the furnace. As shown in Table IV below, in general those fired coated ceramic pieces, which were coated with a composition having the alternative vehicle without hydrochloric acid, set out in Example III, and which were quickly cooled from 1000° F. in accordance with Example II, had superior, lower surface resistivities.

Table III

[Resistivities of slow and quick cooled coating compositions with and without hydrochloric acid]

Coating Composition	Bar No.	Ohms/in.²	
		Quick Cooled	Slow Cooled
1. Example I (with acid)	1	6900	10,600
	2	6200	11,200
	3	6900	6,200
	Average	6700	9,300
2. Example III (without acid).	1	5000	7,500
	2	6200	5,600
	3	5600	7,500
	Average	5600	6,900

When ceramic pieces coated with compositions such as set out above were fired in a gas fired kiln, such as a gas fired Remmey kiln, rather than an electrical resistance furnace as set forth above, a still lower average resistivity of the semi-conducting coating was obtained, as shown by the results of Example IV, set forth in Table IV.

EXAMPLE IV

Test bars were coated with the composition set forth in Example III. The test bars were fired at a rate of 400° F. rise per hour in the gas fired Remmey kiln, to a peak temperature of pyrometric cone 4 "down" (2200° F.). The gas was turned off and the blower left on to accelerate the cooling. Platinum paint was applied to form "electrodes" on the bars in the same manner as in Examples I and II, the bars thereafter being fired in the same manner as in Example I. Table IV shows the results of measuring the surface resistance of each bar and calculating the surface resistance in ohms/in.².

Table IV

Bar No:	Resistivity (ohms/in.²)
1	3100
2	3000
3	3100
4	3100
5	3000
Average	3060
Standard deviation	±100
Percent variation	3.3

The lower average resistivity of the above specimens, as compared to those of Table I, was probably caused by either one or both of two factors: lower free oxygen content of the gaseous atmosphere of the Remmey kiln and/or a quicker cooling cycle from peak temperature caused by leaving the air blower on in the Remmey kiln.

Although it is not desired to confine the invention to the following theory or explanation, it is believed that the results, set out above, obtained by sintering ferric oxide, in amounts in the ranges set forth, with cuprous oxide to form an electrically semi-conducting layer or film are brought about by the functioning of ferric oxide as a flux, which both stops the lumping of the copper

oxide and bonds the sintered layer more effectively to the ceramic base, and also acts to supply "impurity ions" to the crystal lattice of the sintered cuprous oxide. As to the latter effect, it seems logical to assume that the pronounced drop in the resistivity of the electrically semiconducting coatings made in accordance with the invention is caused by ferric ions entering the crystal lattice of the cuprous oxide and furnishing either one or two extra electrons for conductivity. The number of such extra electrons per atom would depend upon the valence state of the copper if the iron exists throughout the firing operation as "Fe^{+++}."

The atomic diameter of iron is close to that of copper. Ions of nearly the same atomic diameter are more apt to enter the crystal lattice of a solid of similar sized atoms to form a solid solution than are atoms of markedly different atomic diameters. The ions thus entering may occupy space in the lattice by either fitting between the original atoms or by replacing them from their original positions. In the forming of semi-conductors, it is desirable that the latter phenomenon takes place, so that the bonding is by way of covalent or ionic attraction. If the "impurity ions" have more electrons in their outer shell than are needed for covalent bonding, the resultant material is semiconducting. The unused or 'free" electrons are then available for conduction of electric current.

Regardless of the correctness of the theory or theories set out above, semi-conducting layers or bodies in accordance with the present invention display relatively little or no lumping of the paint during fusion, a relatively low resistance in spite of an elevated firing temperature to secure good bonding of the layer to a ceramic support, and such semi-conducting layers are stable under heat and varying atmospheres. Further, the paint or coating composition by which the semi-conducting layer is applied may be easily handled in production, and yields substantially uniformity from piece to piece and operator to operator. Also, the method of the invention is economical to carry out, since the steps are simple and easily controlled.

Although only a limited number of embodiments and modifications of the invention have been illustrated in the drawings and mentioned or described in the foregoing specification, it is to be expressly understood that the invention is not limited thereto. Various changes, including changes in relative sizes, design and arrangements of the parts illustrated, and percentages of compositions and sequence of steps, temperatures, etc. in the method, may be made without departing from the spirit and scope of the invention as will now be understood by those skilled in the art.

What is claimed is:

1. An electrical discharge device having opposed spaced electrodes forming a discharge gap, a ceramic insulator body, and a coating of electrically semi-conducting material bonded to a surface of the insulator body and positioned close to said gap and connected in shunt with the opposed electrodes, said coating consisting essentially of a sintered mixture of about 92% by weight of cuprous oxide and about 8% by weight of ferric oxide.

2. An electric discharge device having opposed spaced electrodes forming a discharge gap, a ceramic insulator body, and a coating of electrically semi-conducting material bonded to a surface of the insulator body and positioned close to said gap and connected in shunt with the opposed electrodes, the semi-conductive material consisting essentially of a sintered mixture of from 68 to 98% by weight of cuprous oxide and from 2 to 32% by weight of ferric oxide.

3. An electric discharge device having opposed spaced electrodes forming a discharge gap, an alumina ceramic insulator body, and a coating of electrically semi-conducting material bonded to a surface of the insulator body and positioned close to said gap and connected in shunt with the opposed electrodes, the semi-conductive material consisting essentially of a sintered mixture of from 84 to 96% by weight of cuprous oxide and from 4 to 16% by weight of ferric oxide.

4. An electric discharge device having opposed spaced electrodes forming a discharge gap, said electrodes forming two opposed walls of an outwardly open cavity, an alumina ceramic insulator body, and a coating of electrically semi-conducting material positioned across the electrodes to close the inner end of the cavity, said coating being connected in shunt with the opposed electrodes, the coating being bonded to the insulator body, said coating consisting essentially of a sintered mixture of from 84 to 96% by weight of cuprous oxide and from 4 to 16% by weight of ferric oxide.

5. The method of forming a ceramic insulator body for an electric discharge device having opposed spaced electrodes forming a discharge gap, said ceramic insulator body having a coating of electrically semi-conducting material bonded to a surface of the insulator body and positioned close to said gap and connected in shunt with the opposed electrodes, said method comprising dispersing and suspending finely divided solids consisting essentially of from 68 to 98% by weight of cuprous oxide and from 2 to 32% by weight of ferric oxide in a liquid vehicle to form a paint-like composition, depositing such composition on said surface of the insulator body, and firing the thus coated insulator body to drive off the vehicle, to sinter the solids, and to bond the resulting layer to the insulator body.

6. The method of forming a ceramic insulator body for an electric discharge device having opposed discharge electrodes forming a discharge gap, said ceramic insulator body having a coating of electrically semi-conducting material bonded to a surface of the insulator body and positioned close to said gap and connected in shunt with the opposed electrodes, said method comprising dispersing and suspending finely divided solids consisting essentially of from 84 to 96% by weight of cuprous oxide and from 4 to 16% by weight of ferric oxide in a liquid vehicle to form a paint-like composition, depositing such composition on said surface of the insulator body, and firing the thus coated insulator body at from 2200 to 2260° F. to drive off the vehicle, to sinter the solids, and to bond the resulting layer to the insulator body.

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