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SPARK PLUG AND PROCESS FOR MAKING THE SAME

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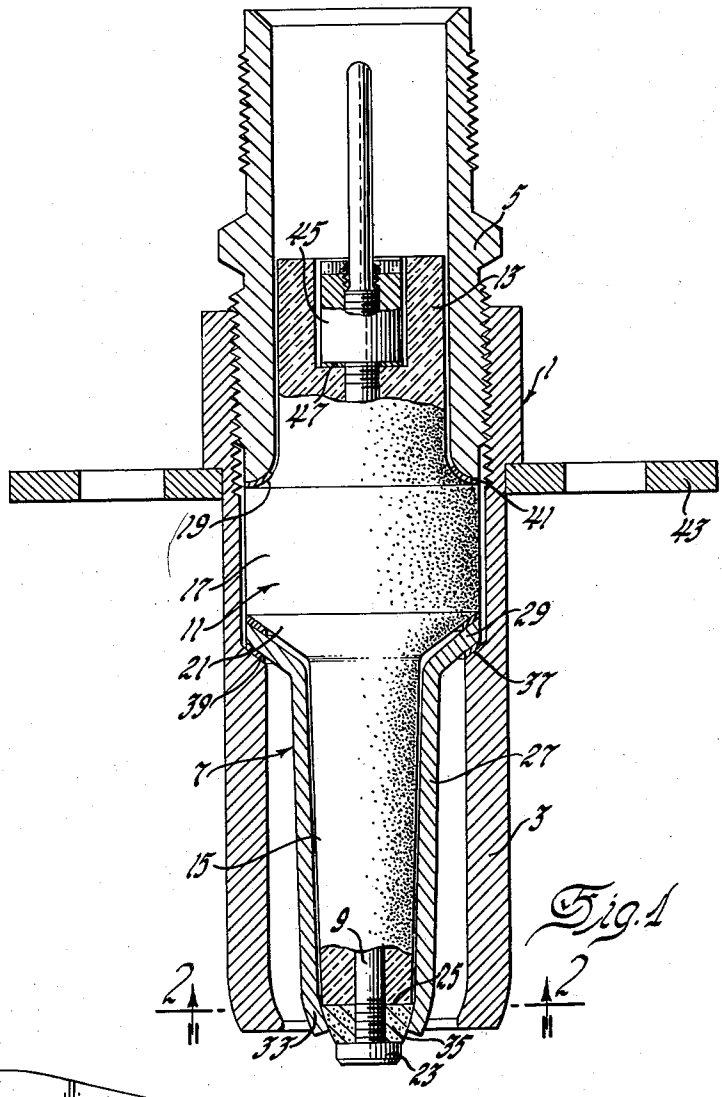


Fig. 1

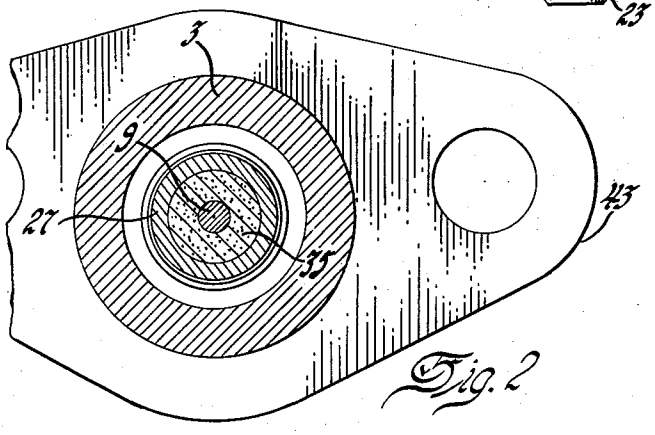


Fig. 2

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SPARK PLUG AND PROCESS FOR MAKING THE SAME

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This invention relates to spark plugs and to the method for making same. More particularly, the invention relates to spark plugs of the low voltage type, which plugs are commonly referred to as low tension or creep gap spark plugs.

One of the goals of internal combustion ignition research is a spark plug which will give an extremely hot spark and which will at the same time be both reliable and have a relatively long life. One of the chronic problems of efficient spark plug operation is that of plug fouling as a result of the combustion process taking place within the cylinder. Conventional type spark plugs utilize a relatively large air gap in combination with a high voltage ignition system. Such systems are susceptible to interference as a result of the plug fouling.

Recently, however, it has been proposed to use a spark plug having a relatively small discharge gap and being so constructed as to provide a low tension discharge path for use in a low voltage ignition system. By using high energies, a hot spark may be obtained such as will inhibit the tendency toward plug fouling normally found in conventional spark plugs. Likewise, by reason of the use of a low system voltage, any fouling which does occur does not have as harmful an effect as that occurring with conventional high voltage plugs. These low tension or creep gap spark plugs comprise a pair of electrodes separated by an insulator body having the surface abutting the spark gap so conditioned as to form a path between the electrodes for permitting a low voltage discharge. Such conditioning has been disclosed as consisting of a coating or layer of semi-conductive material which is sintered or otherwise attached to the insulator surface and as being formed of such materials as metals, metal oxides, metal carbides, carbon, and various mixtures of one or more of these compounds with ceramic materials.

However, it has been found in practice that such low tension spark plugs become inoperative after a very short period of operation. It has been found that the short life of the plugs is due to the wear of the semi-conductive coatings by reason of the fact that the coatings were found to be relatively porous and subject to erosion and spalling under the action of the extreme heat and sparking energies.

One of the objects of this invention is to provide a long-life and efficient spark plug operative at relatively low voltage and high energies to produce an extremely hot spark. Another object of this invention is to provide a low tension spark plug wherein the conditioned surface of the insulator adjacent the spark gap is substantially non-porous and has increased resistance to erosion. Another object of this invention is to provide a low tension spark plug so constructed as to efficiently conduct the heat away from the semi-conductor surface abutting the spark gap. Another object of this invention is to provide a novel method for making low tension spark plugs.

These objects are attained in accordance with our invention by providing a spark plug having a smooth, refractory, substantially non-porous semi-conducting surface on the insulator abutting the spark gap and in adherence to the electrode surfaces which it contacts, the surface being formed by subjecting the semi-conducting composition to high heat and pressure to bring about the fusion and compression thereof.

Other objects and advantages of our invention will be apparent from the hereinafter following description and from the drawing in which Figure 1 is a vertical cross-sectional view of one embodiment of the spark plug of our invention; and Figure 2 is a horizontal cross-sectional view taken on line 2—2 of Figure 1.

Referring now to Figure 1, there is shown a spark plug 1 which includes a shell 3 having a shield sleeve 5 secured within the upper portion thereof, and a central wire subassembly 7 positioned concentrically within the shell 3 and the shield 5.

The subassembly 7 comprises a center electrode 9 positioned in and extending through both ends of a longitudinally extending bore in insulator 11. The insulator 11 is provided with an upper portion 13 extending concentrically within the shield sleeve 5, a lower portion 15 extending within the outer shell 3 and an intermediate portion 17 of larger diameter than both the upper and lower portions thereby forming an upper shoulder 19 and a lower shoulder 21 thereon. The center electrode 9 is provided with a top portion extending into the shield sleeve 5 and being adapted for electrical connection with the ignition cable (not shown) of the system and with a bottom portion or head 23 adjacent the bottom surface 25 of the insulator 11. The insulator 11 and the electrode 9 are positioned within an inner shell 27 which is of a shape generally corresponding to that of the lower portion 15, the insulator being seated in sealed relationship on the upper and outwardly extending portion 29 of the inner shell. A relatively soft heat resistant metal washer 31, i.e. nickel, nickel alloy, is interposed between the upper portion 29 of shell 27 and the shoulder 21 of the insulator and serves to preclude undue localized stress upon the insulator and as a sealing member. The lower portion 33 of the shell 27 extends downwardly and inwardly beyond the bottom surface 25 of the insulator to a point adjacent the center electrode head 23 thus serving as the ground or outer electrode of the spark plug 1. As is clearly shown in Figure 1, a semi-conductor body 35 is provided on the bottom surface 12 of the insulator and between the center electrode 9 and the ground electrode 33 to present a surface portion thereof in abutment with the spark gap formed between the electrodes. The semi-conductor body is adhered to the metal electrodes and may be fused to the insulator as is described more fully hereinafter and is thereby provided with ample heat conducting surfaces for preventing undue heating and softening thereof.

The inner shell 27 is supported concentrically within the outer shell 3 by means of its upper portion 29 which is seated on a ledge 37 formed on the inner surface of the outer shell 3, a nickel sealing gasket 39 being positioned therebetween. In order to seal the subassembly 7 within the outer shell 3, a soft metal gasket 41, i.e. copper, is positioned on the upper shoulder 19 of the insulator 11 and the shield sleeve 5 is provided with an externally threaded portion on its lower end for cooperation with an internally threaded portion on the upper part of the shell 3. In this manner, the sleeve 5 may be threaded tightly into the shell 3 to clamp the insulator 11 in sealed relationship within the shells 3 and 27. The jam nut 45 threaded on the upper portion of the center electrode 9 and bearing on the top of in-

sulator 11 serves to keep the insulator in assembled position and to rigidify the subassembly 7.

As shown on the drawing, the plug 1 is adapted to be mounted on the engine by means of a mounting pad 43 secured to the shell 3 by any suitable means such as welding. In order to assist in removing heat from the subassembly 7, the shell 3 may be provided with one or more apertures for passing cooling air into the annular space between the inner and outer shells and over the spark gap area.

The insulator 11 which is positioned adjacent the spark gap should be formed of a material having high heat resistance in order to withstand the high temperatures encountered in normal operation. Though other materials may be used, it is preferred to use a sintered alumina-type insulator because of its high mechanical strength, high heat resistance and high fusing temperature.

It is to be understood that the specific structure of the spark plug shown and described herein is given merely for purposes of illustration and that numerous other embodiments and modifications are possible and are within the full and intended scope of the invention. The only characteristics of the spark plug structure are that it be provided with an insulator having a surface portion positioned between the electrodes and adjacent the spark gap so as to provide a dense, refractory, substantially non-porous semi-conducting surface abutting the spark gap as a path for the electrical discharge, the surface portion being adhered to the electrode surfaces.

We have discovered that the improved low tension spark plug of our invention may be formed by utilizing a semi-conductor composition which exhibits properties of thermoplasticity on being heated to a temperature of from about 1500° F. to about 2200° F. and which hardens to a relatively non-porous, refractory material on cooling. The resultant composition should be resistant to corrosive effects of the combustion gases and to the wear effects of the extremely high sparking temperatures and energies.

We have found that compositions comprising semi-conductor materials such as the stanno-titanate compositions described in copending application S.N. 357,906 filed May 27, 1953, various carbides as silicon carbide, germanium, various sulfides and such conductor materials as copper, nickel, etc., in admixture with glass exhibit the desired properties on being hot-pressed to the fusion point of the glass followed by cooling. While we prefer the use of glass as the constituent imparting properties of thermoplasticity, it should be understood that other materials such as calcium fluoride may be used.

Our preferred compositions are those comprising admixtures of the stanno-titanate semi-conductor materials in glass not only for the reason that hot-pressing produces the desired physical characteristics but also since these compositions may be readily controlled as to resistance value by control of the amount of reducing agent, i.e., aluminum, carbon, contained therein and since they exhibit stabilized electrical characteristics such as the voltage and temperature coefficients of resistivity. Thus, the use of a glass base stanno-titanate semi-conductor composition for forming the bottom surface portion of the insulator results in a low tension plug having relatively long life and stable electrical characteristics.

As is disclosed in copending application S.N. 406,338, filed January 26, 1954, various types of glass may be used such as barium-borate, magnesium-borate, and boro-aluminum-silicate or alkali-boro-silicate type glass, an example of the latter being the commercially available Corning #774 glass. We have found that the barium-borate and magnesium-borate type glasses are too soft for use alone as the hot plastic and bonding ingredient in our semi-conductor compositions. This undesirable characteristic may be overcome by mixing the soft glass with such hard glass as the alkali-boro-silicate type glass. Examples of the types of glass referred to are shown in the following table:

Corning #774 alkali-boro-silicate (boro-aluminum-silicate) glass

	Percent
SiO_2	79.12
$R_2O_3(Al_2O_3\text{-}Fe_2O_3)$	2.12
MgO	0.29
CaO	0.17
Na_2O	3.72
B_2O_3	14.40
Ignition loss	0.18

Magnesium-borate glass

B_2O_3	95
MgO	5

Barium-borate glass

B_2O_3	75
BaO_2	25

The range compositions of stanno-titanate semi-conductor material found best suited for our purpose is as follows:

	Parts
TiO_2	15–60
SnO_2	0–50
Ta_2O_5	Up to 15
MoO_3	0–10
Al_2O_3	20–40

the preferred composition being:

TiO_2	60
SnO_2	20
Ta_2O_5	10
MoO_3	4
Al_2O_3	40

It should be noted that vanadium pentoxide may be used in place of Ta_2O_5 and that tungsten oxide may be used in place of MoO_3. Likewise, such materials as magnesia, mullite, zircon, chrome oxide, etc. may be used in place of Al_2O_3.

The semi-conductor material in accordance with this invention may be prepared, after weighing out the desired amounts, by thoroughly dry mixing in a Lancaster mill, the constituents being of such size as to pass a 325 mesh screen (43 microns) with most particles being less than 10 microns. The batch is then placed in a suitable container and calcined at a temperature of around 1400° C. in an atmosphere that may be slightly oxidizing, though this is not essential and we do not wish to be limited thereto. For example, a reducing atmosphere may be used thereby giving further control of the resistivity of the material. The calcined material is then ground to the desired state of subdivision, preferably finer than 200 mesh. If desired, the material may be briquetted before firing.

The addition in very small quantity of such reducing agents as powdered aluminum and carbon, the latter having a particle size of about 0.3 micron and being available commercially as Thermax, enables almost precision-like control of the resistance of the final product, the resistance being lowered as the amount of reducer is increased. The amount of reducer added should be so small as to exist in the product as a discontinuous phase and function not as a conductor material but solely as a reducing agent. Though the exact nature of the interaction of the materials in the composition is not known, it is theorized that the glass phase acts to form a multitude of reaction bombs each containing reducer and semi-conductor material which react in the course of hot-pressing the desired element to form a glass-like, vitrified, semi-conducting structure. The reaction in the glass-phase apparently also results in the materials being integrated therewith.

It has been noted that the aluminum has a greater effect in reducing the resistance than has the carbon and

very satisfactory results are obtained by using quantities of each, though it should be understood that this is not essential.

The range of glass phase semi-conductor compositions found to be most suitable for low tension spark plug applications is as follows:

	Parts
Glass	25–40
Semi-conductor material	25–75
Filler	0–40
Reducing agent	0–6

Examples of preferred compositions are:

	Parts		
Alkali-boro-silicate glass	35	25	25
Semi-conductor material (preferred composition)	65	75	75
Filler (Chromium oxide)	2		
Aluminum	2	3	1
Carbon (Thermax)	2	3	1
Bentonite	3	3	3

The semi-conductor composition may be prepared in granular form by first dry mixing the materials and then adding water to make a plastic mass. The plastic mass is then forced through a 20 mesh screen and the resulting granules dried. The dried material is then regranulated through a 28 mesh screen and the material retained between 28 and 100 mesh is used. This sizing has been found to produce granules which are most suitable for uniform volumetric feed. Alternatively, the materials may be dry mixed and formed into a free-flowing slip by addition of water. The slip is then passed into a spray-drying tower where the desired agglomerates are formed.

In the hot-pressing operation the semi-conductor composition is heated to the temperature necessary to develop the plastic flow characteristics of the glass phase. Various types of glass require different temperatures and we have found that a temperature of 1550° F. to 1900° F. suffices for most glasses. Likewise, a pressure sufficient to cause the glass to flow into the mold contour and produce a relatively non-porous structure is applied, the composition being kept under pressure while cooling until the glass has become rigid. We have found that a pressure of 300 p.s.i. or greater is suitable.

The fluidity of the final composition, as exhibited during the hot-pressing operation, is controlled by the presence of a filler or diluent material which does not react chemically with the other constituents of the composition. We have been able to obtain very satisfactory results with a −48 to +100 mesh mullite though other materials such as borolon, zircon, chromium oxide and aluminum oxide, etc. may be used. The filler or diluent material may be added to the semi-conductor composition or may be only that amount present in the semi-conductor (stanno-titanate) material. It has been noted that the filler also increases the temperature resistance of the formed element after hot-pressing, the composition becoming more refractory and less fluid than on the first heating.

Since the glass phase semi-conductor composition is best handled in a granulated form, a binder such as bentonite, a very plastic aluminum silicate, is added to bond the particles together during processing.

In forming the low tension spark plug of the type shown on the drawing, a sufficient quantity of the semi-conductor composition, for example, any of the glass base stanno-titanate compositions described, is cold-pressed in a mold to produce a preform of the desired size and shape. The preform used to hot-press the semi-conductor body 35 shown in Figure 1 was prepared by pressing about 0.30 gm. of the semi-conductor composition, in powder form, in a steel mold at pressures of the order of 1000 p.s.i. or greater. An annular preform ring about ¼" high by ⅜" wide by 1/16" thick was thus obtained.

The preform is placed around the center electrode 9 and the inner shell 27, the outer electrode is brought into position, the three pieces being positioned in the pressing die. The insulator 11 is then lowered gently onto the preform so as not to crack or deform it.

The assembly is then heated to bring the temperature up to that sufficient to develop the plastic flow characteristics of the glass phase and is held at such temperature for a period of time, a pressure sufficient to compress the plastic mass into a dense, non-porous structure being then applied by application of force to the top of the insulator 11. In the case of an alkali-boro-silicate glass such as Corning #774, it has been found that a temperature of from 1600 to 1850° F. at a pressure of about 320 p.s.i. or greater is suitable. It should be noted that in accordance with our invention, the insulator itself serves as the ram during the hot-pressing operation. In this manner, the semi-conductor mass forms a monolithic structure with the insulator 11 and adheres firmly to the metal electrodes. The assembly is then cooled under pressure to a temperature of about 1000° F. at which point the rigid subassembly may be removed from the die and is ready for assembly within the outer shell 3 in the aforesaid manner.

We have found that the time at which the preform is held at the plasticizing temperature has a direct influence on the flow characteristics. If this time or "soaking period" is prolonged beyond a certain point, the glass may react sufficiently with some of the ingredients of the semi-conductor material to cause the glass phase to become more refractory, that is, more viscous with a decrease in flow characteristics. This property is desirable since the final semi-conductive body then requires a higher temperature before any deformation or softening is encountered. A soaking period of from 1 to 15 minutes in most cases yields the desired results, a period of from 5 to 10 minutes having been found necessary in the case of Corning #774 glass. If the soaking period is too long, the semi-conductive body becomes too refractory to compress into place.

The atmospheric conditions in the furnace are of importance in that a slightly oxidizing condition gives greater electrical consistency than that obtained when using a controlled atmosphere such as nitrogen. In the latter case, an enclosed bomb is used during the hot-pressing operation.

We have likewise found it necessary to have a separator of a non-reactive material between the insulator 11 and the semi-conductor preform in order to prevent cracking of the insulator tip on cooling. A small preform disk of talcum powder inserted between the two elements has been found suitable. However, the talcum does not permit a monolithic assembly between the insulator and the preform and the subassembly is then not as rigid as it might be. We have found that by substituting fluorspar for the talcum a very rigid assembly can be obtained without causing the insulator tip to crack.

As has been described above, we obtain a hard, smooth, non-porous semi-conductor surface on the spark plug insulator by using a semi-conductor material in a glass phase. Though our preferred embodiment as described is a glass-filler-semi-conductor material-reducing agent composition, other semi-conductor materials and/or conducting metals may be used with glass or other material having properties of thermoplasticity as described. The glass phase serves as the hot plastic and bonding ingredient. It permits the semi-conductor composition to be hot-pressed into place and to bond to the ceramic and metal parts and form a semi-conductor surface portion abutting the spark gap which has the desired physical and electrical properties. Since the semi-conductor composition adheres to the metal electrodes and may be fused to the bottom surface of the insulator, greatly improved heat conductivity is obtained with resultant longer life for the plug.

It should be understood that though we have described our invention in terms of a particular structure, various modifications will be apparent from the above description and it is intended that such variations be within the scope of our invention as defined by the claims which follow.

We claim:

1. In a process for forming a low tension spark plug of the type comprising a center and outer electrode having a spaced apart end portion defining a spark gap therebetween, an insulator separating said electrodes and having the bottom surface thereof adjacent the gap, the steps of making a preform of a semi-conductor composition, positioning said preform about said center electrode, assembling said outer electrode about said preform and said center electrode, positioning said electrodes with a predetermined gap between their ends, said preform being in contact with the surface of said electrodes and abutting said gap, positioning a separator disk on the upper surface of said preform, positioning said insulator about said center electrode and resting on said disk, applying heat to said preform to raise the temperature thereof to the softening point and applying pressure on said insulator to compress the preform to a dense substantially non-porous mass, and cooling said composition while maintaining the application of pressure until said composition hardens, said composition being adherent to said electrodes to form a good heat conducting path therebetween.

2. The process as set forth in claim 1 wherein said composition is held at the softening temperature for a small but sufficient period of time to permit said composition to become more refractory.

3. The process as set forth in claim 2 wherein the temperature and pressure are maintained, respectively, at about 1700 to 1850° F. and upwards of about 300 p.s.i., the time period being from 5 to 10 minutes and the separator disk being formed of fluorspar.

References Cited in the file of this patent

UNITED STATES PATENTS

1,281,429	Sullivan	Oct. 15, 1918
1,363,843	Crowther	Dec. 28, 1920
2,064,089	Stemmeler	Dec. 15, 1936
2,360,287	Smith	Oct. 10, 1944
2,377,481	Christie	June 5, 1945
2,578,754	Smits	Dec. 18, 1951
2,592,754	Smits	Apr. 15, 1952
2,699,158	Purdy et al.	Jan. 11, 1955
2,712,685	Johnson et al.	July 12, 1955
2,717,438	Schwartzwalder et al.	Sept. 13, 1955

FOREIGN PATENTS

157,552	Australia	June 12, 1952