SPARK PLUG SEAL HAVING A LOWER COEFFICIENT OF EXPANSION THAN THE CERAMIC INSULATOR CORE

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ABSTRACT OF THE DISCLOSURE
This invention relates to a spark plug metal-glass seal, and a method for making the same. The metal-glass seal composition has a coefficient of expansion lower than the spark plug insulator and contains metal powder having a particle size between 10 and 100 mesh. This hermetic conductive metal-glass seal is formed by heating the metal-glass seal composition to a softening temperature and subsequently cooling it without the application of pressure to the seal composition while it is in a softened state.

This invention relates to spark plugs and more particularly to a fused hermetic metal-glass powder seal for use in the centerbore of a spark plug insulator and a method for making a spark plug having such a seal.

One of the essential requirements of a spark plug is that it be gas tight in order to prevent gas leakage from the combustion chamber of the engine in which it operates. Since gas leakage can occur through the spark plug insulator centerbore, it has always been necessary to provide some adequate sealing means between the center electrode or centerwire structure and the walls of the insulator centerbore. A fused glass powder seal is usually used where a one-piece metal centerwire structure is used. Many spark plugs, however, use a centerwire structure having a plurality of metal parts such as a center electrode and a terminal wire. When a plurality of metal parts is used for the centerwire structure, it is the practice to gasproof the centerwire by means of a conductive seal consisting of a mixture of glass or ceramic material and a conductive metal powder such as nickel, copper and tungsten.

These conductive seals are formed typically by tamping the metal-glass powder mixture into the centerbore above and around the center electrode, heating this mixture to soften the glass portion and then applying pressure with a terminal wire or the semi-fluid seal composition. Upon cooling, the resulting hermetic metal-glass seal bonds to the walls of the centerbore and to the abutting portions of the terminal wire and the center electrode and forms a low resistance conductive path. It is necessary to apply pressure while the seal composition is in the fluid or semi-fluid state with these metal-glass seals in order to obtain a seal which upon cooling is conductive and air-tight. When such a seal composition is heated to the required temperature, the semifluid glass flows around the metal particles completely encasing the metal particles. Metal particles which are completely encased by the glass are not conductive. When the terminal wire is pressed into the heated seal composition, the pressure forces the fluid glass mass from between the metal particles outwardly toward the insulator centerbore walls. As a result, the metal powder particles are in contact with one another thereby forming a conductive path in the seal. Moreover, the mass of glass near the centerbore walls has been appreciably increased thereby wetting the walls sufficiently so that a hermetic seal is formed upon cooling. Therefore, a pressure applied to the fluid metal-glass seal mass effects both a conductive seal and a hermetic seal. Thus, prior to the applicant's invention, the application of pressure to a heated metal-glass seal composition was required to yield a seal which was conductive and air-tight.

The design of spark plugs requiring a hermetic conductive metal-glass seal has been restricted because of the necessity for applying a pressure to such a seal. In view of this, it can be seen that a need exists for a metal-glass seal composition which would form a hermetic conductive seal without the application of pressure.

It is a basic object of this invention to provide a spark plug centerbore metal-glass seal composition which will provide a conductive seal without the application of pressure to the seal composition while it is in the fluid or semi-fluid state.

It is another basic object of this invention to provide a spark plug centerbore metal-glass seal composition which will provide a conductive seal which is air-tight without the application of pressure to the composition while it is in a fluid or semi-fluid state.

It is yet another object of this invention to provide a method of making a spark plug having a hermetic conductive seal without the application of pressure to the seal composition while it is in the fluid or semi-fluid state.

These and other objects are accomplished by a method of manufacturing a spark plug comprising the steps of inserting a centerwire into the centerbore of a spark plug insulator body, and loading and packing a layer of metal-glass powder mixture which covers the centerbore head. This metal-glass powder mixture has a coefficient of thermal expansion lower than the insulator and contains a metal taken from the group consisting of Kovar metal alloy, tungsten and molybdenum. The three essential requirements for a metal-glass seal to be operative in this invention are that the glass powder has a coefficient of thermal expansion lower than the insulator material, that the metal powder must have a coefficient of thermal expansion lower than the insulator material and that the metal powder contain 35 weight percent or more metal particles having a particle size smaller than 10 mesh and larger than 100 mesh. A layer of metal powder is then loaded and packed on top of the metal-glass powder layer. Subsequently, the spark plug assembly is heated until the metal-glass powder becomes at least semi-fluid. Upon cooling this spark plug assembly, the fused metal-glass powder has formed a conductive hermetic seal in the spark plug insulator centerbore.

Other objects and advantages of this invention will be apparent from the following detailed description, reference being made to the accompanying drawing wherein a preferred embodiment of this invention is shown.

The drawing is a longitudinal cross-sectional view of a spark plug embodying the invention. This drawing represents a visual indicating spark plug which is the subject of the copending patent application S.N. 447,318 filed simultaneously with this application and assigned to the assignee of this invention.

Referring now to the drawing, the spark plug 10 comprises a conventional outer metal shell 12 having a ground electrode 14 welded to the lower end thereof. Positioned within the metal shell 12 and secured in the conventional manner is an insulator 16. The insulator 16 is formed with a centerbore having a lower portion 18 of relatively small diameter, a lower centerportion 20 of larger diameter, an upper center portion 22 of still larger diameter, and an upper portion 23 of cylindrical diameter. Nearest the head of the upper center portion 22 the insulator has zones of relatively thin cross sections as shown by annular rings 24.

Positioned in the lower portion 18 of the insulator centerbore is the center electrode 28, the serrated lower end thereof projecting beyond the lower tip of the insulator 16. The center electrode head 30 rests on insulator centerbore
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A metal-glass seal 34 forms a hermetic conductive seal between the center electrode head 30 and the insulator centerbore wall of the lower center portion 20. The composition of this metal-glass seal 34 must be such as to form a hermetic conductive seal without being pressed by a terminal screw or other means as is the usual practice; therefore, this composition, upon heating alone, may form a hermetic conductive seal. A critical component of this metal-glass seal 34 is the metal. The coefficient of expansion for the metal must be lower than the insulator and similar or lower than the glass thereby permitting the glass and the metal of this metal-glass mixture to expand upon heating and contract upon cooling at a lower rate than the insulator. The metal and glass should have a lower coefficient of expansion than the insulator material so that the insulator exerts a small compressive pressure on the metal-glass mixture at all times. Metals having a coefficient of expansion lower than the insulator which may be used are molybdenum, tungsten and Kovar metal alloy. Kovar metal alloy is used in the preferred embodiment. Kovar is a low expansion, iron based alloy with 28 to 30% of nickel and 15 to 18% cobalt and fractional percentages of manganese. The amount of metal powder in the metal-glass mixture ranges from 55 to 70%, the lower figure indicating the minimum amount of metal required to adequately conduct the electrical current and the higher figure making provision for the minimum amount of glass needed for fluidity and sealing purposes.

It is important that the metal and the glass have a similar coefficient of expansion in order to obtain a seal which is air-tight. When the metal and glass have a similar coefficient of expansion the homogenous metal-glass mixture expands at the same rate upon heating and in doing so the relative position of the metal powder in relation to the glass remains the same. Moreover, as the seal composition contracts upon cooling at the same rate, the components contract at the same rate thereby maintaining the same relative position of the metal powder in relation to the glass. In other words, the relative position of the metal and glass remains the same during the entire heating and cooling cycle, the relative position of the metal to glass being one of physical contact during the entire heating and cooling cycle. This similarity in the coefficients of expansion between the glass and the metal permits the glass metal mixture to expand as a unit or mass thereby avoiding the formation of any internal stresses or voids within the mass.

The following table lists the pertinent linear coefficient of expansion data.

<table>
<thead>
<tr>
<th>Material</th>
<th>Linear coefficient of expansion $\times 10^{-4}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumina insulator body</td>
<td>7.0</td>
</tr>
<tr>
<td>Borosilicate glass</td>
<td>6.5</td>
</tr>
<tr>
<td>Kovar metal alloy</td>
<td>6.0</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>4.9</td>
</tr>
<tr>
<td>Tungsten</td>
<td>4.3</td>
</tr>
</tbody>
</table>

As shown in the table, the coefficient of expansion of the borosilicate glass and the Kovar metal alloy used in the preferred embodiment is 6.5 and 6.0 respectively. While the coefficient of expansion value of Kovar is preferred, the coefficient of expansion values of tungsten and molybdenum are sufficiently close to that of the borosilicate glass to effect a hermetic seal in this invention.

When a copper-glass mixture, copper having a coefficient of thermal expansion about three times as great as glass, is heated and cooled the resulting mass has stresses and voids therein. As the copper-glass mixture is heated, the copper expands at a faster rate and tends to pull or draw away from the glass mass in turn would leave void spaces near the copper particles. When this copper-glass mixture is cooled, the copper will contract at a faster rate and those areas of contact between the glass and the copper which still existed at the high temperature would be subjected to the copper metal shrinking or pulling away from the glass-copper contact areas thereby creating more void spaces or regions of stress. As indicated by the above description, the resulting mass of copper-glass mixture which had been heated and cooled would result in a mass containing a number of void spaces and regions under stress. Such a metal-glass mass containing these void spaces would have a tendency to leak. In addition, the regions under stress would be subject to fracturing and leaking while in use. The use of a metal having a coefficient of expansion similar to glass eliminates the voids and stresses discussed above.

The metal powder must contain at least 35 weight percent particles having a size smaller than 10 mesh and larger than 100 mesh as measured by the Tyler standard screen scale in order to obtain electrical conductivity in the fused metal-glass and in obtaining a hermetic seal. The particles referred to above would pass through a 10 mesh screen but would not pass through a 100 mesh screen. As discussed earlier, the metal powder typically used in conductive metal-glass seals, for example 250 mesh size, is completely coated on all sides by the glass when the glass becomes heated to a semi-fluid state. However, when the metal particles are larger, for example minus 35 to plus 100 mesh, the larger size of the metal particles has a tendency to inhibit the glass from completely coating it. In other words, the minus 35 to plus 100 mesh size particles are so bulky that when the glass flows it does not cover the metal particles completely. As a result, some of the non-glass covered metal particle portions come in contact with other non-glass covered metal particle portions. This contact by the non-glass covered metal particles makes the seal conductive. It has been observed that not all of the metal particles have to be larger than 100 mesh size to make the seal conductive. In the preferred embodiment, Kovar metal powder containing 36 weight percent of particles having a minus 35 to plus 100 mesh screen size has been found to work very satisfactorily. However, Kovar metal powder which did not have any metal particles larger than 100 mesh size did not work satisfactorily in this invention. The concentration range of metal particles having a size smaller than 10 mesh and larger than 100 mesh required for this invention is from 35 weight percent to 100 percent of the metal powder.

The presence of metal particles which are larger than 100 mesh size also enables the glass to sufficiently wet the insulator walls thereby forming a hermetic bond between the insulator walls and the metal-glass mass. It is believed that the size of these large metal particles permits only a certain number of these large metal particles to be in physical contact with the insulator walls. As a result, there is a sufficient amount of glass located between these large metal particles to adequately wet the insulator walls to insure an air-tight bond between the metal-glass mass and the insulator walls.

As has been mentioned earlier, the glass used in this metal-glass seal composition should have a coefficient of expansion lower than the insulator. The glass must have a coefficient of expansion lower than the insulator and similar to or somewhat higher than the metal in order to form an air-tight bond with the insulator wall and to prevent the formation of voids and stresses within the metal-glass mass. A borosilicate glass powder, Corning 7052 glass, having a composition of 65% SiO$_2$, 23% B$_2$O$_3$, 5% Al$_2$O$_3$, and 7% Na$_2$O works well in this metal-glass seal. The amount of borosilicate glass powder ranges from 30 to 45%. The mesh size of the glass powder does not appreciably affect the performance of the seal, a mesh a size of 200 for the glass powder was found to be satisfactory.

Other components in metal-glass seal composition are a flux and a binder. The amount of flux in the metal-glass mixture ranges from 1 to 4%. Boric anhydride is used in the preferred embodiment although any borate glass may be used. A binder which prevents oxidation of the metal
is burned off during the heating of the metal-glass mixture. The amount of binder in the mixture ranges from 1 to 3%. Hydrogenated cottonseed oil was used in the preferred embodiment although other binders such as carboxyl methyl cellulose, 1201 wax, and dextrin may be used.

A metal-glass powder mixture which worked well is as follows:

<table>
<thead>
<tr>
<th>Parts by wt.</th>
<th>Corning 7052 glass or equivalent (Kimball)</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boric anhydride</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Kovar powder</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Hydrogenated cottonseed oil</td>
<td>3</td>
</tr>
</tbody>
</table>

On top of the metal-glass seal 34 is a layer of metal powder 36 which serves the lower electrode in the insulator body chamber. The lower electrode 36 may be any conductive metal such as copper, nickel, iron, platinum, silver, tungsten, and Kovar with Kovar powder being used in the preferred embodiment. Above the lower electrode 36 is a sealed insulator body chamber 38 which extends up to the electrode and exhaust stem assembly 40. The insulator body chamber 38 contains an inert gas. The electrode and exhaust stem assembly 40 consists of a Kovar metal tube whose lower portion extends outwardly in a conical fashion similar to a funnel so that the lower flanged end of the tube has a diameter similar to the diameter of the insulator centerbore at the position of the ledge 41. The flanged end of the electrode and exhaust stem assembly 40 is positioned on top of the insulator centerbore ledge 41, ledge 41 connecting the upper center portion 22 with the upper portion 23 of the insulator centerbore. The upper end of the electrode and exhaust stem assembly 40 is welded shut thereby making that end of the assembly 40 air tight. Glass seal 42 forms a hermetic seal between the upper surface of the lower portion of the electrode and exhaust stem assembly 40 and the insulator centerbore wall of the upper portion 23.

The terminal 44 encloses and covers the upper portion of the electrode and exhaust stem assembly 40 and fits over the top end of the insulator body 16. The lower end of the terminal 44 is crimped over the insulator body under rib 43 thereby locking the two elements tightly together. The terminal 44 may be in electrical contact with the electrode and exhaust stem assembly 40, in which case, the current is conducted through the electrical contact. However, if the terminal 44 is not in electrical contact with exhaust stem assembly 40 the current jumps the gap between the terminal 44 and the electrode and exhaust stem assembly 40.

During the sparking operation of the visual indicating spark plug described in the drawing, the current passes from the spark plug terminal 44 to the electrode and the exhaust stem assembly 40. As the current traverses the chamber 38 separating the electrode and exhaust stem assembly 40 from the metal electrode 36, the inert gas is energized, thereby resulting in a glowing insulator body which projects light through the translucent insulator wall 24 to indicate to an observer the presence of a high voltage in the spark plug. The current then passes from the metal electrode 36 through the metal-glass seal 34, through the centerwire electrode 28, across the gap to the side electrode 14, and then to the shell 12 where it is grounded to the engine block (not shown).

The invention, when applied to the terms of a method for making a spark plug having a hermetic conductive metal-glass seal in the insulator centerbore without the application of pressure to the seal composition while it is in a fluid or semi-fluid state. As shown in the drawing, the centerwire electrode 28 is inserted into the centerbore of the insulator body 16. A centerwire electrode head 30 rests upon the insulator ledge 32. A metal-glass seal powder load 34 ranging from 0.25 to 0.35 gram is placed on top of the centerwire head 30 in the centerbore portion 20 in the conventional manner and tamped. The composition of this metal-glass powder 34, as discussed in detail earlier, must have a coefficient of expansion lower than the insulator body and must contain metal particles having a particle size smaller than 10 mesh and larger than 100 mesh. A layer of 0.10 to 0.20 gram of Kovar metal alloy powder 36 is placed on top of the metal-glass powder seal 34 and tamped. Other metal powders, such as iron, nickel, and so forth, may be used for the metal powder layer 36. Subsequently, the insulator is heated in air at approximately 1740°F. for 10 minutes in order to soften the metal-glass powder layer 34. Upon cooling, the fused metal-glass powder layer 34 has formed a hermetic conductive metal-glass seal which conducts electricity from the center electrode 28 to the metal powder layer 36, all three elements being a part of the centerwire structure. Other steps which are well known in the art may be followed before and after the heating step in order to complete the spark plug.

The term "fused" as used herein is intended to encompass softening up to and including liquid-faction.

While the invention has been described in terms of a specific embodiment, it is to be understood that the scope of the invention is not limited thereby except as defined in the following claims.

1. A spark plug comprising an insulator having a centerbore therethrough, a fused hermetic metal-glass seal of high electrical conductivity in said centerbore, said seal being positioned perpendicularly to the longitudinal axis of said centerbore and bonded to the insulator walls to prevent the flow of gas through the centerbore, said seal having a coefficient of expansion lower than said insulator which is sufficient for said insulator to exert a compressive force on said seal, said seal containing metal particles having a size smaller than 10 mesh and larger than 100 mesh said metal particles ranging from 35 weight percent to 100 weight percent of the metal powder.

2. A spark plug comprising an insulator head and a centerbore therethrough, a fused hermetic metal-glass seal of high electrical conductivity in said centerbore, said seal being positioned perpendicularly to the longitudinal axis of said centerbore and bonded to the insulator walls to prevent the flow of gas through the centerbore, said seal having a coefficient of expansion lower than said insulator which is sufficient for said insulator to exert a compressive force on said seal, said seal containing metal particles having a size smaller than 10 mesh and larger than 100 mesh said metal particles ranging from 35 weight percent to 100 weight percent of the metal powder.

3. A spark plug comprising an insulator having a centerbore therethrough, a fused hermetic metal-glass seal of high electrical conductivity in said centerbore, said seal being positioned perpendicularly to the longitudinal axis of said centerbore and bonded to the insulator walls to prevent the flow of gas through the centerbore, said seal having a coefficient of expansion lower than said insulator which is sufficient for said insulator to exert a compressive force on said seal, said seal containing metal powder having a coefficient of expansion lower than said insulator, said seal containing metal powder having metal particles having a size smaller than 10 mesh and larger than 100 mesh, said metal particles ranging from 35 weight percent to 100 weight percent of the metal powder.

4. A spark plug as described in claim 1 wherein said metal is taken from the group consisting of Kovar, tungsten and molybdenum.

5. A spark plug comprising an insulator having a centerbore therethrough, a fused hermetic metal-glass seal of high electrical conductivity in said centerbore, said seal being positioned perpendicularly to the longitudinal axis of said centerbore and bonded to the insulator walls
to prevent the flow of gas through the centerbore, said seal having a coefficient of expansion lower than said insulator which is sufficient for said insulator to exert a compressive force on said seal, said seal comprising 55 to 70% of a metal taken from the group consisting of Kovar, tungsten and molybdenum and the balance substantially glass, said seal containing metal powder having metal particles having a size smaller than 10 mesh and larger than 100 mesh, said metal particles ranging from 35 weight percent to 100 weight percent of the metal powder.

6. A spark plug comprising an insulator having a centerbore therethrough, a center electrode positioned in the lower end of said insulator centerbore, a fused hermetic metal-glass seal positioned in said centerbore perpendicularly to the longitudinal axis of said centerbore above and around the upper portion of said center electrode and bonded to said insulator and said center electrode, said seal having a coefficient of expansion lower than said insulator which is sufficient for said insulator to exert a compressive force on said seal, said seal comprising 55 to 70% of a metal taken from the group consisting of Kovar, tungsten and molybdenum and the balance substantially glass, said seal containing metal powder having metal particles having a size smaller than 10 mesh and larger than 100 mesh, said metal particles ranging from 35 weight percent to 100 weight percent of the metal powder, 30 to 45% glass having a coefficient of expansion lower than said insulator, 1 to 4% flux and 1 to 3% binder, a metal powder layer positioned in said centerbore above and in electrical contact with said seal, said seal conducting electricity between said center electrode and said metal powder layer.

7. A spark plug comprising an insulator having a centerbore therethrough, a center electrode positioned in the lower end of said insulator centerbore, a fused hermetic metal-glass seal positioned in said centerbore perpendicularly to the longitudinal axis of said centerbore above and around the upper portion of said center electrode and bonded to said insulator and said center electrode, said seal having a coefficient of expansion lower than said insulator which is sufficient for said insulator to exert a compressive force on said seal, said seal comprising 55 to 70% of a metal taken from the group consisting of Kovar, tungsten and molybdenum and the balance substantially glass, said seal containing metal powder having metal particles having a size smaller than 10 mesh and larger than 100 mesh, said metal particles ranging from 35 weight percent to 100 weight percent of the metal powder, 30 to 45% glass having a coefficient of expansion lower than said insulator, 1 to 4% flux and 1 to 3% binder, a metal powder layer positioned in said centerbore above and in electrical contact with said seal, said seal conducting electricity between said center electrode and said metal powder layer.

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