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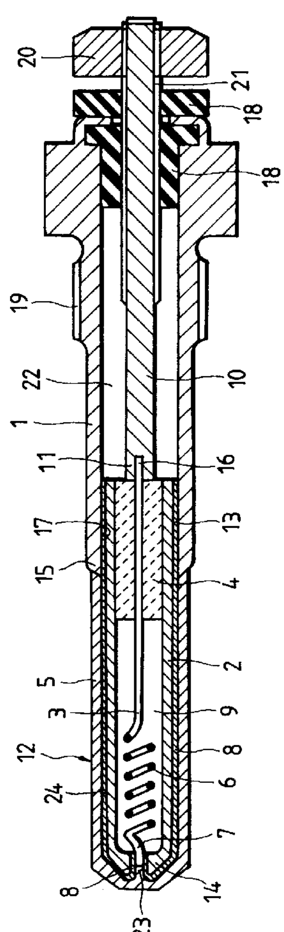
(54) Ceramic glow plug.

(57) This invention provides a ceramic glow plug of current self-control type with a stable strength and a high-temperature strength resistant to thermal shocks. In this ceramic glow plug, the ceramic pipe (2) is secured to the hollow body (1) having the electrode (10) and is formed with the conductive printed layer (8) on its outer surface. One end of the pipe (2) is sealed by the ceramic filler (4) to form the hollow portion (9) inside the pipe In the hollow portion (9) sealed with N_2 gas, the tungsten wire (3) is installed, with one end (7) connected to the conductive printed layer (8) and the other end (16) to the electrode (10). The outer circumferential surface (13) of the pipe (2) is formed with the ceramic outer surface coating layer (5). When the tungsten wire (3) and the conductive printed layer (8) are supplied with electricity, the conductive printed layer (8) functions as the heater portion (12) and the tungsten wire (3) as the current control portion (6).

FIG. 1



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The present invention relates to a ceramic glow plug used with diesel engines.

A glow plug conventionally used in diesel engines consists of a tungsten (W) wire embedded in a ceramics such as silicon nitride. A tungsten (W) wire, for example, has a resistance of 0.1 Ω at room temperature and a current of 120 A for a 12 V power supply. When the glow plug is heated with elapse of time from room temperature to 900°C, the resistance of the tungsten wire is 0.4 Ω and its current is 30 A. Then as the glow plug is further heated, the resistance increases until it stabilizes at 1 Ω, at which time the current is 12 A. In other words, with the conventional glow plug, when a current is supplied from a 12 V battery by issuing a command from a controller, the current value decreases from the initial value of 120 A with an increasing resistance, which increases with the temperature of a heater coil, until the current stabilizes when the resistance becomes 1 Ω. Thus, the current is controlled by the controller so that the resistance of the heater coil of the glow plug is stabilized and held at 1 Ω.

Another type of glow plug was developed which self-controls its resistance at 1 Ω without the use of a controller. Tungsten and nickel have characteristics that the resistance increases with temperature. Thus, tungsten wires and nickel wires limit current flow as the temperature rises. The self-control type glow plug consists of a tungsten coil and a nickel coil connected in series, with the tungsten coil embedded in a ceramics such as Si_3N_4. That is, in the self-control type glow plug, a conductor with a small resistance is arranged in a heating body of the heater coil and is connected to the nickel coil with a large resistance installed on the upstream side of the conductor. When a current flows, the nickel coil of the self-control type glow plug is heated increasing the resistance, which in turn reduces the current thus controlling the amount of heat generated by the heating body of the heater coil.

The conventional self-control type glow plugs include those disclosed in Japanese Patent Publication Nos. 34052/1992 and 19404/1985, and Japanese Patent Laid-Open Nos. 157423/1984 and 106326/1983.

The self-control type glow plug disclosed in the Japanese Patent Publication No. 34052/1992, for example, has a current control resistor connected in series with a heating body to control the heating body temperature when a current is being supplied and the temperature is rising. In this glow plug, the heating coil and the resistor coil are connected in series and embedded in a ceramic sintered material, thus forming an integral ceramic heater. The heating coil is made from a tungsten-rhenium alloy wire which has a positive resistance-temperature coefficient of less than four times, and the resistor coil is made of a pure tungsten wire or a pure molybdenum wire.

A sheathed glow plug disclosed in the Japanese Patent Publication No. 19404/1985 is a self-control type sheathed glow plug, in which a heating coil and a resistor coil are directly connected to each other between the inner bottom of a heat resisting, bottomed metal tube and a center electrode, with the winding pitch of the resistor coil made dense in an area close to a mounting fitting on the central electrode side and coarse in an area close to the heating body side.

These conventional self-control type glow plugs, however, are not satisfactory in terms of strength, heat durability and high-temperature resistance and cannot withstand thermal shocks experienced in a high-temperature combustion chamber of an overheated engine. Because the heating coil made from tungsten carbide wire and the resistor coil made from nickel wire are connected together, have different resistance-temperature coefficients, or have different shapes, the conventional self-control type glow plugs have drawbacks that the nickel wire may be broken due to overheating during use or become deteriorated with elapse of time and that they have a complex structure. Because of these the conventional glow plugs are not satisfactory in terms of production cost and strength.

To make a ceramics glow plug as the self-control type glow plug requires that the resistance in a part of the heater coil on the upstream side of the heater coil's current path increase very sharply. The relation between resistance and temperature in the heater coil is expressed as follows.

$$\rho_{TX} = \rho_{TO}[1 + \alpha(T_X - T_O)]$$

where ρ_{TX} is a resistance of the heater coil at a certain temperature T_X, ρ_{TO} is a resistance of the heater coil at room temperature T_O, and α is a resistance-temperature coefficient.

Normally, the glow plug passes a saturation current at about 1 Ω for a 12 V supply voltage and is maintained at about 900°C. To heat the glow plug instantly, a resistance of approximately 0.1 Ω is required at room temperature. Usually, the tungsten wire used as a heating coil has a resistance-temperature coefficient of the order of 4×10^{-9}, and thus it is not possible to saturate the current at 900°C.

A primary aim of this invention is to solve or at least partially alleviate the above-mentioned problems.

The present invention provides a ceramic glow plug which includes:

a hollow body having a conductor, including an electrode, disposed in a hollow portion thereof;

a ceramic pipe secured to and projecting from the hollow body to form a heater portion, the pipe being closed at a front end portion thereof;

a first coil portion installed in the ceramic pipe;

a second coil portion connected in series with the first coil portion and disposed in the ceramic pipe; and

ceramic fillers sealing the ends of the ceramic pipe;

said ceramics glow plug being characterized in:

that the first coil portion is arranged in contact with an inner wall surface of the pipe;

that the second coil portion is spaced from an inner wall of the pipe; and

that when the first and second coil portions are supplied with electricity, the first coil portion constitutes a heater coil and the second coil portion constitutes a current control coil.

The present invention provides a ceramic glow plug of current self-control type, which comprises:

a current control portion formed of a coiled tungsten wire installed in an area with high heat-insulation so that the amount of heat dissipated from the current control portion is small and a heater portion formed in an area with low heat-insulation so that the amount of heat dissipated from the heater portion is large, thereby forming a current self-control type glow plug that adjusts a current flowing through the heater portion and the current control portion to produce an optimum amount of heat; and more specifically and preferably comprises a tungsten wire installed in a hollow portion of the ceramic pipe and a conductive printed layer. formed on the outer surface of the pipe, or alternatively the inner diameter of a central portion of the ceramics pipe is made larger than the inner diameter of the front end portion, a tungsten wire having a coil outer diameter equal to the inner diameter of the front end portion of the pipe is installed in the pipe, and the front end portion of the pipe is made to serve as the heater portion and the central portion of the pipe is made to serve as the current control portion.

The ceramic glow plug with this configuration has high reliability and can reduce manufacturing cost and secure stable strength.

The present invention also provides a ceramic glow plug, which includes:

a hollow body having a conductor, including an electrode, disposed in a hollow portion thereof;

a ceramic pipe secured to and projecting from the hollow body to form a heater portion, the pipe being closed at the front end portion thereof;

a conductive printed layer containing a tungsten powder and formed over the outer surface of the pipe and of the front end portion of the pipe;

ceramic fillers sealing the ends of the pipe;

a coiled tungsten wire having one end thereof connected to the conductive printed layer and the other end passing through the ceramic filler and connected to the electrode, the coiled tungsten wire also having a current control portion exposed in a hollow portion of the pipe; and

a ceramic outer surface coating layer covering the conductive printed layer on the outer surface of the pipe.

When a current is passed through the tungsten wire and the conductive printed layer, the tungsten wire becomes extremely hot compared with the conductive printed layer because the tungsten wire located in the hollow portion of the pipe is highly thermally insulated and the conductive printed layer is exposed to outside through the ceramic outer surface coating layer. In this ceramics glow plug, as the tungsten wire is heated to high temperatures, its resistance increases reducing the current flowing through the tungsten. In other words, the tungsten wire functions as a temperature control wire, self-controlling the amount of heat dissipated from the ceramic outer surface coating layer to an optimum value.

The outer surface of the pipe is formed with the conductive printed layer printed film. Hence, when the conductive printed layer is supplied with electricity, this layer is heated causing the entire pipe to rise in temperature uniformly. Further, the end of the tungsten wire fitted into the through-hole of the pipe is firmly held connected to the conductive printed layer by the presence of a paste. In this condition, when the ceramic pipe and its associated components are sintered, the conductive printed layer and the tungsten wire are joined firmly with good electric conductivity at the connection.

Further, the conductive printed layer is printed spirally or wholly over the outer surface of the pipe. If a Ni or Mo powder is added to the tungsten powder contained in the paste, the tungsten wire and the conductive printed layer, after being burned, are joined together more firmly because Ni and Mo has good reactivity. The conductive printed layer may also contain a si_3N_4 powder in addition to the Ni or Mo powder.

Another characteristic of this ceramic glow plug is that because a ceramic formed body that constitutes the pipe is sintered with one end of the tungsten wire installed in the ceramic formed body, with the paste containing the tungsten powder printed over the outer surface of the ceramic formed body, and with the ceramic slurry forming the ceramic fillers filled in one end portion of the ceramic formed body, the pipe, the tungsten wire, the conductive printed layer and the ceramic fillers are joined together in good condition.

Further, a liquid polymer precursor that forms the ceramic outer surface coating layer may be applied over the outer circumferential surface of the ceramic formed body that constitutes the pipe and of the paste containing a tungsten powder that forms the conductive printed layer, and these components are sintered simultaneously, so that the conductive printed layer and the tungsten wire are firmly joined to the pipe and that the ceramic outer surface coating layer is joined to the pipe and the conductive printed layer. In this way, the stable construction of this ceramic glow plug can be obtained easily and reliably.

The tungsten wire has its coiled current control portion installed in the hollow portion formed at the intermediate part of the pipe, with only the ends of the wire connected to the ceramic filler and the conductive printed layer. This arrangement allows the current control portion of the tungsten wire to be easily heated to high temperatures by the conducting current, making the self-control more responsive and the current control easier.

Because the outer surface of the conductive printed layer is covered with the ceramic outer surface coating layer, which is formed of silicon nitride excellent in heat resistance, the ceramic outer surface coating layer serves as a protective layer for the pipe, improving heat resistance and thermal shock resistance as well as high-temperature strength.

Another feature of this ceramics glow plug is that the paste of tungsten powder is printed spirally over the outer surface of the silicon nitride formed body, that the tungsten wire is attached to the formed body, and that the slurry of silicon nitride is applied over the outside of the printed paste of tungsten powder. This arrangement allows a heater coil to be easily formed over the outer circumferential surface of the pipe and also makes burning easy and assures reliable electric connections. Alternatively, the paste of tungsten powder may be printed over the entire outer surface of the formed body.

Furthermore, the ceramics used to form the pipe and the ceramic fillers may use silicon nitride to improve heat resistance, high-temperature strength and durability. Further, the conductive printed layer may contain a Si_3N_4 powder so as to reinforce the strength of joint between the conductive printed layer and the ceramic outer surface coating layer.

The present invention also provides a ceramics glow plug, which includes:

a hollow body having a conductor, including an electrode, projecting in a hollow portion thereof;

a ceramics pipe secured to and protruding from the hollow body and forming a heater portion;

a first hole portion with a small inner diameter, formed in a part of the pipe corresponding to the heater portion;

a second hole portion with a large inner diameter, formed in another portion of the pipe on the electrode side;

a coiled tungsten wire having a first coil portion that contacts the inner wall surface of the first hole portion and a second coil portion that does not contact the inner wall surface of the second hole portion, the tungsten wire having one end thereof connected to the electrode and the other end connected to the hollow body;

a first ceramic filler filled in the first hole portion where the first coil portion is located to embed the first coil portion; and

a second ceramics filler filled in an end of the second hole portion on the electrode side so as to leave hollow an area where the second coil portion is located.

Because the first coil portion and the second coil portion are formed of a single continuous tungsten wire, simply arranging the tungsten wire in the center of the ceramic pipe and supplying an electric current to the coiled tungsten wire allow the first coil portion to serve as a heater portion and the second coil portion to serve as a current control portion. When an electricity is supplied to the coiled tungsten wire, the heat generated by the first coil portion heats the pipe and is dissipated to the outside but the heat generated by the second coil portion is insulated raising the temperature of the second coil portion. As the temperature increases, the second coil portion suppresses current flow and thus works as a current control portion. That is, when the second coil portion is heated to high temperature, its resistance increases limiting the current flowing through the tungsten wire, thus self-controlling the amount of heat generated by the ceramic pipe to an optimum value.

Further, if the hollow portion of the pipe is sealed with N_2 gas and SiC fiber, there is no need to take measures to prevent oxidation of the tungsten wire, such as coating the wire with SiC, thus simplifying the manufacture process, which in turn will lead to a reduction in the manufacturing cost. This arrangement eliminates the possibility of the tungsten wire being broken from oxidation and improves durability of the wire.

In this glow plug, the ceramics forming the first ceramic filler and the second ceramic filler should preferably use Si_3N_4. Because the ceramics forming the first and second ceramics fillers is Si_3N_4 containing TiO_2, a good heat conductivity is maintained.

Since the first coil portion, which forms the heater portion, is installed in the center of the pipe, the temperature of the whole pipe rises uniformly. Because the first coil portion is placed in contact with the inner wall surface of the pipe and the ceramic filler is filled with the first coil portion buried, the heat conductivity of the heater portion is extremely good.

Another feature of this ceramic glow plug is that the first coil portion and the second coil portion have the same wire form and the same coil outer diameter and are formed of the single continuous tungsten wire, and that the ceramic pipe is formed with the small-diameter first hole portion and the large-diameter second hole portion. Because of this arrangement, simply placing the tungsten wire in the ceramics pipe allows the tungsten wire to be positioned at the center of the pipe, with the first coil portion working as the heater portion and the second coil portion working as the current control portion. It is therefore possible to provide an improved heat generating efficiency and to heat the heater portion uniformly. Furthermore, because the pitch of the first coil portion is smaller than that of the second coil portion, ideal heater portion and current control portion can be obtained.

Such a tungsten wire can be manufactured by using a ceramic coil making jig which has a through-hole in the center and spiral grooves on the outer circumferential surface thereof. Because there are no connections in the wire, the tungsten wire has high electrical reliability and durability and can be fabricated at low cost.

Preferred embodiments of the present invention will be described hereinbelow by way of example only with reference to the accompanying drawings, in which:

Figure 1 is a cross section of a ceramic glow plug as one embodiment of this invention;

Figure 2 is a schematic view showing a paste - which forms a conductive print layer - printed on the outer surface of the ceramic pipe in the ceramic glow plug of Figure 1;

Figure 3 is a cross section of another embodiment of the ceramic glow plug according to this invention; and

Figure 4 is a cross section of a coil making jig used to fabricate the tungsten wire in the ceramic glow plug of Figure 3.

Now, by referring to the accompanying drawings, embodiments of the ceramic glow plug according to this invention will be described.

The ceramic glow plug consists mainly of a hollow body 1 having a terminal or electrode 10 mounted in a hollow portion 22 through an insulator 18 such as an insulating bushing, a ceramics pipe 2, a tungsten wire 3, a ceramic filler 4 filled in one end of the pipe 2, a ceramic outer surface coating layer 5 which is a protective member arranged on the outer surface of the pipe 2, and a conductive printed layer 8 joined to the outer surface of the pipe 2. The hollow body 1 is made from a metal such as a heat resisting alloy and is formed with a thread 19 for mounting to other component. The electrode 10 is formed with a positioning and fixing screw 21, over which a nut 20 is fitted to position and fix the electrode 10 with respect to the hollow body 1. The ceramics pipe 2 has one part thereof secured to the inner wall surface 17 of the hollow body 1 through the conductive printed layer 8. The ceramics pipe 2 can be joined to the hollow body 1 by metalizing the outer circumferential surface 13 of the ceramic pipe 2 before jointing. This results in a very firm electrical connection between the conductive printed layer 8 and the hollow body 1. A heater portion 12 of the ceramic pipe 2 protrudes from the end 15 of the hollow body 1. The tungsten wire 3 has one end 16 connected to the electrode 10 through a power supply connecting portion 11 and the other end 7 inserted into a through-hole 23 formed in a closed front end portion 14 of the ceramic pipe 2 and electrically connected to the conductive printed layer 8.

In this ceramic glow plug, a conductor having the electrode 10 is projected into the hollow portion 22 of the hollow body 1, and the ceramic pipe 2 making up the heater portion 12 is fixed to and projected from the body 1. An outer surface 24 of the ceramic pipe 2 is joined with the conductive printed layer 8 containing tungsten powder. The end of the pipe 2 on the electrode side is filled with the ceramic filler 4, and at an intermediate portion of the pipe 2 is formed a hollow portion 9. The coiled tungsten wire 3 has its end 7 attached to the conductive printed layer 8 and its other end 16 connected to the electrode 10, and has a coiled current control portion 6 exposed in the hollow portion 9 of the pipe 2 which constitutes a temperature control wire. Further, the ceramic outer surface coating layer 5 is applied over the outer circumferential surface of the pipe 2 and the conductive printed layer 8 formed on the outside of the pipe 2. The ceramic outer surface coating layer 5 forms a protective layer for the heater portion 12.

The conductive printed layer 8, as shown in Figure 2, is formed as a spiral body 25 over the portion of the pipe 2 that forms the heater portion 12 and is also formed continuously over the entire surface of that portion of the pipe 2 that is connected to the body 1. The ceramic powder forming the conductive printed layer 8 includes nickel and molybdenum powder in addition to tungsten powder. Nickel and molybdenum have good reactivity, so that the tungsten wire 3 and the conductive printed layer 8 are sintered together offering firm, good electrical connection.

The ceramics forming the pipe 2, ceramic filler 4 and the ceramic outer surface coating layer 5 employs silicon nitride Si_3N_4 excellent in heat resistance and high-temperature strength. The tungsten wire 3 extends longitudinally uncontacted in the hollow portion 9 of the ceramic pipe 2. The hollow portion 9 is sealed with N_2 gas and SiC fiber for the prevention of oxidation of the tungsten wire 3. Alternatively, in the case where the hollow portion 9 is simply sealed without using N_2 gas, the tungsten wire 3 may be coated with SiC or WC to prevent its oxidation for improved corrosion resistance and durability.

Because the outer surface of the heater portion 12 of the ceramics pipe 2 is covered with the ceramic outer surface coating layer 5 formed of silicon nitride which has good heat resistance, the ceramic layer forms a protective pipe, improving thermal shock and heat resistance and high-temperature strength. Between the ceramic pipe 2 and the ceramic outer surface coating layer 5 is provided the conductive printed layer 8 that extends spirally over the heater portion 12 to form a number of spiral grooves 26. With this arrangement, the ceramic outer surface coating layer 5 on the outer side of the conductive printed layer 8 bites into the grooves 26, reinforcing the joint between the ceramic pipe 2 and the ceramic outer surface coating layer 5.

The ceramic glow plug is manufactured in the following way. First, the hollow body 1 is made from a metal such as a heat resisting alloy and is formed with a thread 19 for mounting to other component. The terminal or electrode 10 is formed with a thread 21 for positioning and fixing with respect to the hollow body 1. The electrode 10 is mounted to the hollow body 1 through the insulator 18 so that it rests in the hollow portion 22. The nut 20 is screwed over the thread 21 to position and fix the electrode 10 with respect to the hollow body 1. Further, one end of the tungsten wire 3 is formed into a straight end 7 and the other end into a straight end 16, with the central portion formed as the coiled current control portion 6.

A cylindrical body with one end closed and the other end open is formed of a slurry of silicon nitride. On the outer circumferential surface of the cylindrical body and in the through-hole formed in its closed end, a paste containing a tungsten powder or, if necessary, a mixture of tungsten powder and Ti or Mo powder is printed. That is, the inner wall surface of the through-hole 23 formed in the front end portion of the cylindrical body and the outer circumferential surface of that portion of the pipe 2 that is inserted into the body 1 are wholly printed with the paste. On the outer circumferential surface of that portion of the cylindrical body that forms the heater portion 12, the paste is printed either spirally or wholly. Then, the end 7 of the tungsten wire 3 is inserted into the through-hole 23 at the front end of the cylindrical body and the other straight end 16 is held projected from the cylindrical body.

Next, a ceramic slurry that forms the ceramic filler 4 is filled into the open end of the cylindrical body so that the end 16 of the tungsten wire 3 projects from the filled end. A liquid material such as polymer precursor that forms the ceramic outer surface coating layer 5 is applied to the outer circumferential surface of the cylindrical body and the paste. Then, the tungsten wire 3 is fitted to the cylindrical body, the paste is printed on the outer surface of the cylindrical body, a ceramic slurry is filled into one end of the cylindrical body, and the ceramic slurry is applied to the outer circumferential surface of the cylindrical body. Now, a cylindrical body assembly is obtained. The cylindrical body assembly thus formed is placed in a sintering furnace for sintering to produce a sintered body that forms the heater portion 12. Then the end 16 of the tungsten 3 protruding from the end of the sintered body is connected to the power supply connecting portion 11 of the electrode 10. At the same time, the outer circumferential surface 13 of the end portion of the metalized sintered body is fitted into the hollow body 1 for jointing. In this way, the ceramic glow plug is completed.

Because in this ceramics glow plug, the components of the cylindrical body assembly - including the tungsten wire 3 whose one end is fitted in the ceramic cylindrical body, the conductive paste applied to the cylindrical body, a ceramics slurry filled into one end of the cylindrical body and the ceramics slurry applied over the outer circumferential surface of the cylindrical body - are all burned at the same time, the conductive printed layer 8 is firmly and reliably joined to the pipe 2 and the tungsten wire 3, forming a good electrical connection. Furthermore, the ceramic outer surface coating layer 5 is also securely and reliably joined to the pipe 2.

The ceramic glow plug with the above construction works as follows. When a current is supplied from the electrode 10 to the tungsten wire 3, the conductive printed layer 8 and the body 1, the pipe 2 is heated by the heat of the conductive printed layer 8 because the conductive printed layer 8 is in contact with the pipe 2 and because the coiled current control portion 6 of the tungsten wire 3 is exposed in the hollow portion, which is defined by the closed end of the pipe 2 and the other end of the pipe 2 sealed by the ceramic filler 4. The heat generated by the conductive printed layer 8 is dissipated through the ceramics outer surface coating layer 5. But the heat generated by the coiled current control portion 6 of the tungsten wire 3 is not dissipated and thus the coil 6 becomes extremely hot compared with the conductive printed layer 8. As the coiled current control portion 6 is heated to high temperature, its resistance increases suppressing the flow of current through the tungsten wire 3, thereby self-controlling the amount of heat generated by the heater portion 12. When the temperature of the tungsten wire 3 falls, the current flowing through the tungsten wire 3 increases heating the heater portion 12 by the conductive printed layer 8, thus keeping the amount of heat produced by the heater portion 12 at an optimum value.

In this ceramic glow plug, since the pipe 2 with the embedded conductive printed layer 8 is exposed outside the combustion chamber, the pipe dissipates heat, maintaining the temperature of the heater portion 12 at 900°C, for example, which in turn sets the resistance of the conductive printed layer 8 to 0.4 Ω. Because the tungsten wire 3 is disposed in the sealed hollow portion 9 and thermally insulated, the temperature of the tungsten wire reaches 1800°C and its resistance becomes 0.6 Ω. Hence, in this ceramic glow plug, the total resistance of the tungsten wire 3 and the conductive printed layer 8 is 1 Ω, which stabilizes the current flow.

Next, by referring to Figure 3, another embodiment of the ceramic glow plug according to this invention will be described.

The ceramic glow plug of the second embodiment consists of a hollow body 31 having a terminal or electrode 40 mounted in a hollow portion 52 through an insulator 48 such as an insulating bushing, a ceramic pipe 32, a tungsten wire 33, and ceramic fillers 34, 44 filled in the ends of the pipe 32. The hollow body 31 is made from a metal such as a heat resisting alloy and is formed with a thread 49 for mounting to other component. The terminal or electrode 40 is fitted with a nut 50 for its positioning and fixing with respect to the hollow body 31. The ceramic pipe 32 can be mounted to the hollow body 31 by metalizing an outer circumferential surface 47 of the ceramics pipe 32 and fitting it into an inner circumferential surface 54 of the hollow body 31. This allows the pipe 32 to be joined to the hollow body 31 very strongly. A heater portion 42 of the ceramic pipe 32 protrudes from the end portion 45 of the hollow body 31. The tungsten wire 33 has its one end 46 connected to the electrode 40 through a power supply connecting portion 41 and the other end 43 joined to the inner surface of the hollow body 31 for electrical connection.

The hollow body 31 has a conductor - including the electrode 40 - protruding into the hollow portion 52. The ceramic pipe 32 forming the heater portion 42 projects from and is fixed to the hollow body 31. The ends of the pipe 32 is sealed with the ceramic fillers 34, 44, forming a hollow portion 35 in an intermediate portion of the pipe 32. The hollow portion 35 of the pipe 32 is sealed with N_2 gas and SiC fiber for the prevention of oxidation of tungsten wire 33.

The ceramic pipe 32 is formed with a small-diameter first hole portion 38 at a location corresponding to the heater portion 42 and with a large-diameter second hole portion 39 on the electrode side. The tungsten wire 33 is formed of a single wire and consists of a first coil portion 36 that contacts the inner wall surface of the first hole portion 38 and a second coil portion 37 that does not contact the inner wall surface of the second hole portion 39. One end 46 of the tungsten wire 33 is connected to the electrode 40 while the other end 43 is connected to the hollow body 31. Further, the ceramic filler 34 is filled in the first hole portion 38 embedding the first coil portion 36, and the ceramic filler 44 is filled in the end part of the second hole portion 39 of the pipe 32 on the electrode side so as to leave the area where the second coil portion 37 is located hollow 35. The end 46 of the tungsten wire 33 is fitted into a hole 55 formed in the end portion 41 of the electrode 40 and is metalized to provide a good electrical connection with the electrode 40. The other end 43 of the tungsten wire 33 is fitted in a groove 51 formed at the end of the pipe 32 and is metalized for good electrical connection with the hollow body 31.

The first coil portion 36 and the second coil portion 37 of the tungsten wire 33 have the same wire shape and the same coil outer diameter and are made from a single continuous tungsten wire. Further, the first coil portion 36 has a pitch smaller than that of the second coil portion 37. Thus, the tungsten wire 33 can be manufactured very easily and accurately. The first coil portion 36 is capable of generating enough heat to heat the heater portion 42 to elevated temperatures in short time and the second coil portion 37 is suited to controlling current.

The pipe 32 is preferably made from ceramics Si_3N_4 with good heat resistance and high strength. The ceramic fillers 34, 44 are formed of Si_3N_4 having good heat resistance and high-temperature strength and preferably made of Si_3N_4 containing TiO_2 because it improves heat conductivity. When the N_2 gas is not sealed in the hollow portion 35 of the pipe 32, the tungsten wire 33 needs to be covered with SiC or WC to guard against oxidation. This coating can prevent oxidation of the tungsten wire 33 and improve corrosion resistance as well as durability.

The ceramic glow plug with the above construction works as follows. When a current is supplied from the electrode 40 to the tungsten wire 33, the heater portion 42 of the pipe 32 is heated by the heat of the first coil portion 36 because the first coil portion 36 of the tungsten wire 33 is in contact with the inner wall surface of the pipe 32 and the second coil portion 37 is exposed in the hollow portion 35. While the heat generated by the first coil portion 36 is dissipated through the pipe 32, the heat generated by the second coil portion 37 is not dissipated and thus the second coil portion 37 becomes extremely hot compared with the first coil portion 36. As the second coil portion 37 is heated to high temperature, it functions as a current control wire and its resistance increases suppressing the flow of current through the tungsten wire 33, thereby self-controlling the amount of heat generated by the heater portion 42. When the temperature of the second coil portion 37 falls, the current flowing through the tungsten wire 33 increases heating the heater portion 42 by the first coil portion 36, thus keeping the amount of heat produced by the heater portion 42 at an optimum value.

Because the pipe 32 with its inner wall in contact with the outer circumference of the first coil portion 36 is exposed outside the combustion chamber, the pipe 32 dissipates heat, maintaining the temperature of the heater portion 42 at, say, 900°C, which in turn sets the resistance of the first coil portion 36 to 0.4 Ω. Because the second coil portion 37 is disposed in the sealed hollow portion 35 and thermally insulated, the temperature of the second coil portion 37 reaches 1800°C, for example, and its resistance becomes 0.6 Ω. Hence, in this ceramic glow plug, the total resistance of the first coil portion 36 and the second coil portion 37 amounts to 1 Ω, which stabilizes the current flow.

Next, by referring to Figure 4, a ceramic coil making jig 53 to fabricate the tungsten wire 33 of this ceramics glow plug will be explained.

The ceramic coil making jig 53 is a circular cylinder body 56 made of ceramics with a through-hole 57, greater in diameter than the tungsten wire 33, formed in the center and with spiral grooves 58, 59 formed in the outer circumferential surface 60. At the end surface of the cylinder body 56 is formed a groove 61 that extends from the through-hole 57 to the outer circumferential surface 60. The spiral groove 58 is smaller in pitch than the spiral groove 59 and is larger in number than the spiral groove 59. The tungsten wire 33 is manufactured by using the coil making jig 53 as follows. The tungsten wire is passed through the through-hole 57, bent at the groove 61 and then wound along the spiral grooves 58, 59 formed on the outer circumferential surface 60 of the cylinder body 56 Then, electricity is supplied to the ends of the tungsten wire wound on the coil making jig 53 to heat it. The heated tungsten wire is then cooled to obtain the desired form Qf the tungsten wire 33. To remove the tungsten wire 33 from the coil making jig 53, the jig 53 and the tungsten wire 33 are rotated relative to each other to make the inner coil diameter of the tungsten wire 33 larger than the diameter of the cylinder body 56. Now, the tungsten wire 33 can be easily removed from the coil making jig 53.

Claims

1. A ceramic glow plug which includes:
   a hollow body (1, 31) having a conductor, including an electrode (10, 40), disposed in a hollow portion thereof;
   a ceramic pipe (2, 32) secured to and projecting from the hollow body to form a heater portion (12, 42), the pipe being closed at a front end portion thereof;
   a first coil portion (8, 36) installed in the ceramic pipe (2, 32);
   a second coil portion (6, 37) connected in series with the first coil portion and disposed in the ceramic pipe; and
   ceramic fillers (4, 38, 44) sealing the ends of the ceramic pipe (2, 32);
   said ceramics glow plug being characterized in:
   that the first coil portion (8, 36) is arranged in contact with an inner wall surface of the pipe (2, 32);
   that the second coil portion (6, 37) is spaced from an inner wall of the pipe (2, 32); and
   that when the first and second coil portions (8, 36, 6, 37) are supplied with electricity, the first coil portion constitutes a heater coil (8, 36) and the second coil portion constitutes a current control coil (6, 37).

2. A ceramic glow plug according to claim 1, wherein the first coil portion (8) is a conductive printed layer (8) containing a tungsten powder that is formed on the outer surface of the pipe (2), the conductive printed layer (8) is covered with a ceramic outer surface coating layer (5), the second coil portion (6) has one end thereof joined to the conductive printed layer (8) and the other end passing through the ceramic filler (4) and connected to the electrode (10), and the second coil portion (6) is made from a coiled tungsten wire (3) having the current control coil (6) disposed in an intermediate portion (9) of the pipe.

3. A ceramic glow plug according to claim 2, wherein the conductive printed layer (8) is printed either spirally or wholly on the outer surface of the pipe (2).

4. A ceramic glow plug according to claim 2 or 3, wherein the conductive printed layer (8) contains a nickel or molybdenum powder.

5. A ceramic glow plug according to claim 2 to 4, wherein the ceramics forming the ceramic outer surface coating layer (5) is silicon nitride.

6. A ceramic glow plug according to claim 2 to 5, wherein the conductive printed layer (8) contains a Si_3N_4 powder.

7. A ceramic glow plug according to claim 2 to 6, wherein one end of the tungsten wire (3) is arranged in a ceramic formed body that constitutes the pipe (2), a paste containing a tungsten powder is printed on the ceramic formed body to form the conductive printed layer (8), a ceramic slurry is filled in one end of the ceramic formed body to form the ceramic filler (4), and then by burning the ceramic formed body, the pipe (2), the tungsten wire (3), the conductive printed layer (8) and the ceramic filler (4) are all joined together.

8. A ceramic glow plug according to claim 2 to 7, wherein the ceramic formed body constituting the pipe (2) and the paste containing a tungsten powder that constitutes the conductive printed layer (8) are covered at their circumferential surfaces with a liquid material such as polymer precursor that forms the ceramic outer surface coating layer (5), and then are burned to join the ceramic outer surface coating layer (5) to the pipe (2) and to the conductive printed layer (8).

9. A ceramic glow plug according to claim 1 to 8, wherein the intermediate portion (9) of the pipe (2) is sealed with N_2 gas and SiC.

10. A ceramic glow plug according to claim 1 to 9, wherein the ceramics that forms the pipe (2) and the ceramics filler (4) is silicon nitride.

11. A ceramic glow plug according to claim 1, wherein a portion of the pipe (32) corresponding to the heater portion (42) is formed with a first hole portion (38) having a small inner diameter and another portion of the pipe (32) in which the second coil portion (37) is located is formed with a sec-

ond hole portion (39) having a large inner diameter; the first coil portion (36) is arranged in contact with the inner wall surface of the first hole portion (38) and the second coil portion (37) is spaced from the inner wall surface of the second hole portion (39) so that it does not contact the inner wall surface; the ceramic fillers (34, 44) consist of a first ceramic filler (34) that fills the first hole portion (38) where the first coil portion (36) is located to embed the first coil portion (36) and a second ceramic filler (44) that fills an end of the pipe (32) on the electrode (40) side; and the portion of the pipe where the second coil portion (37) is located is an intermediate portion (35) of the pipe (32).

12. A ceramic glow plug according to claim 11, wherein the intermediate portion (35) of the pipe (32) is sealed with N_2 gas and SiC.

13. A ceramic glow plug according to claim 11 or 12, wherein the ceramics that forms the pipe (32), the first ceramics filler (34) and the second ceramic filler (44) is Si_3N_4.

14. A ceramic glow plug according to claim 11 to 13, wherein the ceramics that forms the first ceramic filler (34) and the second ceramic filler (44) is Si_3N_4 containing TiO_2.

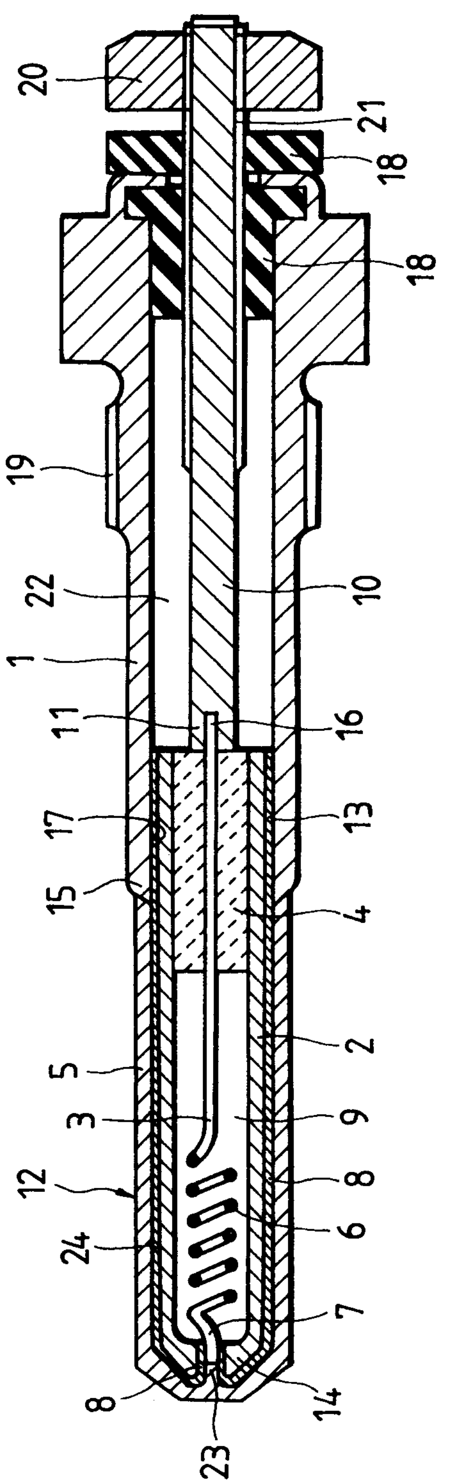
15. A ceramic glow plug according to claim 11 to 14, wherein the first coil portion (36) and the second coil portion (37) have the same wire form and the same coil external diameter and are made from a single continuous tungsten wire (33).

16. A ceramic glow plug according to claim 11 to 15, wherein the first coil portion (36) has a coil pitch smaller than that of the second oil portion (37), with the coil pitch of the first coil portion (36) dense and that of the second coil portion (37) coarse.

17. A ceramic glow plug according to claim 11 to 16, wherein the tungsten wire (33) is manufactured by using a ceramic coil making jig (53), which has a through-hole (57) in the center and spiral grooves (58, 59) on the outer circumferential surface (60) thereof.

18. A ceramics glow plug according to claim 1 to 17, which is used as an auxiliary device for starting a diesel engine.

FIG. 1



F/G. 2

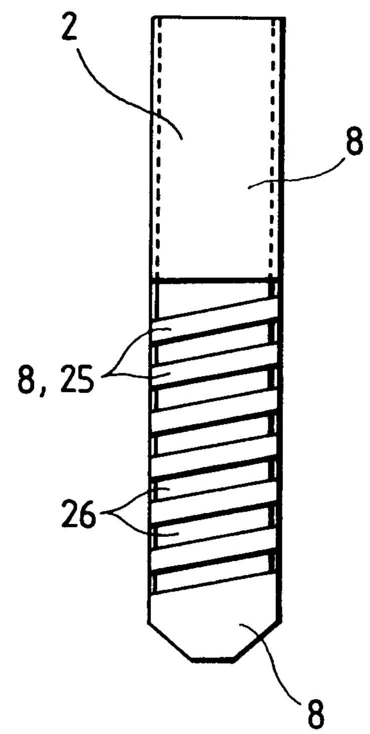


FIG. 3

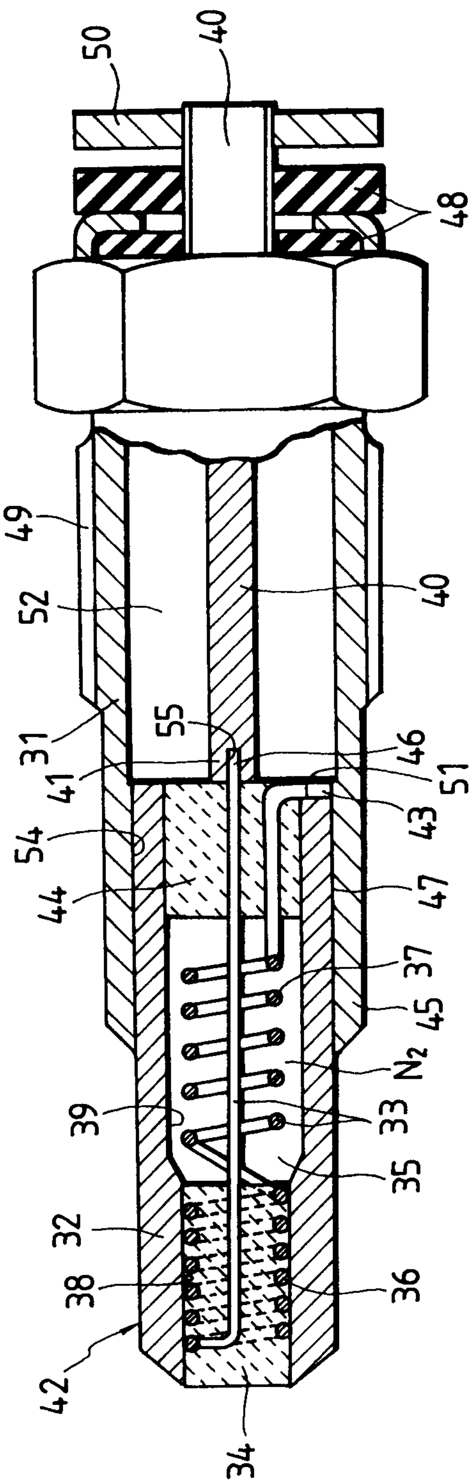

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FIG. 4