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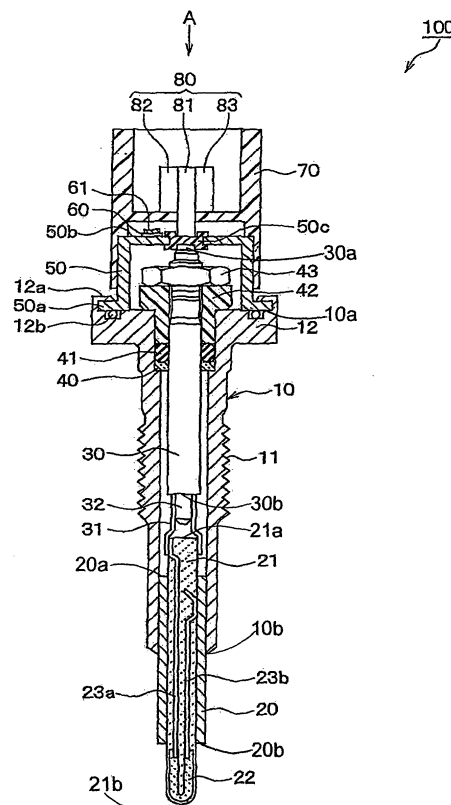
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(54) Glow plug for diesel engine with integrated electronics and heat sink

(57) According to the present invention, a glow plug (100) for a diesel engine is provided which includes a heating element (22), a semiconductor chip (61) that includes therein a power transistor, and a heat sink (50). The heating element (22) is configured to generate heat when supplied with electric power, so as to heat the air-fuel mixture within a cylinder of the diesel engine. The power transistor in the semiconductor chip (61) is configured to be selectively turned on and off so as to intermittently supply electric power to the heating element. The heat sink (50) serves to dissipate heat generated by operation of the semiconductor chip (61) so as to prevent the semiconductor chip from being damaged due to the heat. With such a configuration, it becomes possible to integrate the semiconductor chip (61) into the glow plug (100) while providing the glow plug with a capability of effectively dissipating the heat generated by operation of the semiconductor chip.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1 Technical Field of the Invention

[0001] The present invention relates generally to glow plugs for diesel engines. More particularly, the invention relates to a glow plug for a diesel engine which includes a heating element, a semiconductor chip for control of electric power supply to the heating element, and a heat sink for dissipation of heat generated by operation of the semiconductor chip.

2 Description of the Related Art

[0002] Glow plugs are generally used to improve startability of diesel engines. Specifically, for a typical diesel engine, one glow plug is installed to each of a plurality of cylinders of the engine to preheat the air-fuel mixture within the cylinder, thereby assisting the initial ignition of the air-fuel mixture.

[0003] Further, to separately control the glow plugs for different cylinders, more specifically, to perform open-circuit checks and temperature controls for the glow plugs separately, a controller is provided which includes a plurality of semiconductor chips, one for each of the glow plugs, and a micro computer.

[0004] The semiconductor chips each include a power transistor that is configured to be selectively turned on and off so as to intermittently supply electric power to the corresponding glow plug.

[0005] The controller works to control electric power supply to the glow plugs. Specifically, the controller is configured to receive switching signals sent from an engine ECU (Electronic Control Unit) and turn on and off the power transistors in the semiconductor chips according to the switching signals.

[0006] However, in the above configuration, the semiconductor chips, each of which generates considerable heat during operation, are integrated into a single device, i.e., the controller. Consequently, it is very difficult to effectively dissipate the heat generated, so that if not suitably designed, the controller will be damaged due to the heat, thus making it impossible to reliably supply electric power to the glow plugs.

[0007] To solve such a problem, one may consider integrating the semiconductor chips into the respective glow plugs, instead of the controller.

[0008] For example, Japanese Translation of International Publication No. 2003 - 509652 discloses a glow plug, in which a circuit unit that includes a semiconductor chip is disposed in a housing of the glow plug. The semiconductor chip includes a power transistor configured to be selectively turned on and off so as to intermittently supply electric power to a heating element of the glow plug. When a switching signal and a voltage are provided from an engine ECU to the circuit unit via a wiring har-

ness, the circuit unit turns on and off the power transistor according to the switching signal, so that the voltage is intermittently applied to the heating element, thereby preheating the air-fuel mixture within the engine cylinder.

[0009] However, in such a glow plug, since the semiconductor chip is included in the circuit unit and thus accommodated in the housing together with the circuit unit, it is still difficult to effectively dissipate heat generated by operation of the semiconductor chip. Consequently, if not properly designed, the semiconductor chip will be damaged due to the heat generated.

[0010] Moreover, in recent years, demand for afterglow, which herein denotes to continuously supply electric power to glow plugs to heat the air-fuel mixture after engine start, has been rising. This is because afterglow has the effect of reducing the amount of hydrocarbons included in emissions from diesel engines. Consequently, operation time of semiconductor chips integrated into glow plugs has been accordingly increasing, thus increasing the amount of heat generated.

SUMMARY OF THE INVENTION

[0011] The present invention has been made in view of the above-mentioned problem.

[0012] It is, therefore, a primary object of the present invention to provide a glow plug for a diesel engine which includes an integrated power transistor for electric power supply to a heating element of the glow plug and is capable of preventing the power transistor from being damaged due to heat generated by operation of the power transistor.

[0013] According to the present invention, a glow plug for a diesel engine is provided which includes a heating element, a power transistor, and a heat sink.

[0014] The heating element is configured to generate heat when supplied with electric power.

[0015] The power transistor is configured to be selectively turned on and off so as to supply electric power to the heating element.

[0016] The heat sink serves to dissipate heat generated by operation of the power transistor so as to protect the power transistor from heat damage.

[0017] With such a configuration, it becomes possible to integrate the power transistor into the glow plug while providing the glow plug with a capability of effectively dissipating the heat generated by operation of the power transistor.

[0018] In a preferred embodiment of the present invention, the glow plug further includes a tubular housing, a tubular sleeve, a rod-like insulator, and a rod-like central shaft.

[0019] The tubular housing has a first end and a second end; it also has a threaded portion formed on an outer periphery thereof so as to be installed to a diesel engine.

[0020] The tubular sleeve has a first end retained in the housing and a second end protruding from the second

end of the housing.

[0021] The rod-like insulator is secured to the sleeve; it has a first end located in the housing and a second end protruding from the second end of the sleeve.

[0022] The rod-like central shaft is accommodated in the housing; it has a first end fixed to the first end of the housing via an insulative fixing member and a second end that is located in the housing.

[0023] The heating element is provided in the insulator on the second end side of the insulator and electrically connected to the second end of the central shaft.

[0024] The power transistor is provided on a substrate and electrically connected to the first end of the central shaft.

[0025] The heat sink is fixed to the first end of the housing and has a surface on which the substrate is disposed.

[0026] With such a configuration, the heat generated by operation of the power transistor will be effectively transferred to the engine block via the substrate, the heat sink, and the housing, so that the power transistor can be prevented from being damaged due to the heat generated, thus improving reliability of the power transistor.

[0027] Preferably, the glow plug further includes a connector that is integrally formed with the heat sink and includes a plurality of terminals. Thus, when a switching signal and a voltage are provided to the power transistor via the terminals, the power transistor is turned on and off according to the switching signal so that the voltage is intermittently applied to the heating element.

[0028] With such a configuration, the connector can be easily mounted to the housing through fixing the heat sink to the housing, thereby improving manufacturing efficiency of the glow plug.

[0029] Moreover, in the glow plug, the substrate, which carries the power transistor, may be so disposed on the surface of the heat sink that the longitudinal direction of the substrate is perpendicular to the surface of the heat sink.

[0030] With such a disposition, it is possible to provide the substrate on the heat sink even when the substrate has a greater length than the heat sink.

[0031] Additionally, in the glow plug, the heat sink may be fixed to the first end of the housing by crimping.

[0032] In another preferred embodiment of the present invention, the glow plug further includes a tubular housing, a tubular sleeve, a rod-like insulator, a rod-like central shaft, and a connector.

[0033] The tubular housing has a first end and a second end; it also has a threaded portion formed on an outer periphery thereof so as to be installed to a diesel engine.

[0034] The tubular sleeve has a first end retained in the housing and a second end protruding from the second end of the housing.

[0035] The rod-like insulator is secured to the sleeve; it has a first end located in the housing and a second end protruding from the second end of the sleeve.

[0036] The rod-like central shaft is partially accommo-

dated in the housing and fixed to the first end of the housing via an insulative fixing member; it has a first end protruding from the housing and the fixing member and a second end that is located in the housing.

[0037] The connector has a hollow electrode formed therein which has an open end.

[0038] The heating element is provided in the insulator on the second end side of the insulator and electrically connected to the second end of the central shaft.

[0039] The power transistor is provided on a substrate and embedded in the connector together with the substrate.

[0040] The heat sink is included in the connector and has a plate-like shape with a first major surface embedded in the connector, on which the substrate is disposed, and a second major surface exposed from the connector to dissipate the heat generated by operation of the power transistor.

[0041] The electrode of the connector is electrically connected to the power transistor and brought into electrical connection with the first end of the central shaft by insertion of the first end of the central shaft in the electrode through the open end thereof.

[0042] With such a configuration, it is possible to obtain the glow plug simply by combining the connector with a conventional glow plug that has no built-in power transistor and heat sink, so that manufacturing cost of the glow plug can be reduced by utilization of the conventional glow plug.

[0043] Further, with such a configuration, the heat generated by operation of the power transistor will be effectively dissipated into the atmosphere via the second major surface of the heat sink, so that the power transistor can be prevented from being damaged due to the heat, thus improving reliability of the power transistor.

[0044] Moreover, the glow plug may further include a metal connector cover covering an outer surface of the connector. The connector cover abuts the second major surface of the heat sink and has an end that is brought into abutment with the first end of the housing by insertion of the first end of the central shaft in the electrode of the connector.

[0045] With such a configuration, part of the heat generated by operation of the power transistor will be directly dissipated into the atmosphere via the outer surface of the connector cover, and the other part of the heat will be transferred to the engine block via the housing.

[0046] Otherwise, the glow plug may further include a metal housing cover covering the first end of the housing and a metal connector cover covering an outer surface of the connector. The housing cover is fixed to the first end of the housing and has a bore formed therein through which the central shaft extends. The connector cover abuts the second major surface of the heat sink and has an end that is brought into abutment with the housing cover by insertion of the first end of the central shaft in the electrode of the connector.

[0047] With such a configuration, part of the heat gen-

erated by operation of the power transistor will be directly dissipated into the atmosphere via the outer surfaces of the connector cover and the housing cover, and the other part of the heat will be transferred to the engine block via the housing.

[0048] Preferably, the glow plug further includes a wiring harness that is integrally formed with the connector and includes a plurality of wires. Thus, when a switching signal and a voltage are provided to the power transistor via the wires, the power transistor is turned on and off according to the switching signal so that the voltage is intermittently applied to the heating element.

[0049] With such a configuration, the electrical connection between the glow plug and external devices and/or circuits is facilitated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0050] The present invention will be understood more fully from the detailed description given hereinafter and from the accompanying drawings of the preferred embodiments of the invention, which, however, should not be taken to limit the invention to the specific embodiments but are for the purpose of explanation and understanding only.

[0051] In the accompanying drawings:

- FIG. 1 is a partially cross-sectional side view showing the overall structure of a glow plug according to the first embodiment of the invention;
- FIG. 2 is an end view of the glow plug of FIG. 1 along the A direction indicated in FIG. 1;
- FIG. 3 is a schematic view illustrating the overall configuration of an electric power supply system for supplying electric power to glow plugs;
- FIG. 4 is a partially cross-sectional side view showing the overall structure of a glow plug according to the second embodiment of the invention;
- FIG. 5 is a partially cross-sectional side view showing the overall structure of a glow plug according to the third embodiment of the invention;
- FIG. 6 is an end view of the glow plug of FIG. 5 along the B direction indicated in FIG. 5;
- FIG. 7 is a partially cross-sectional side view showing the overall structure of a glow plug according to the fourth embodiment of the invention;
- FIG. 8 is an end view of the glow plug of FIG. 7 along the C direction indicated in FIG. 7; and
- FIG. 9 is a partially cross-sectional side view showing the overall structure of a glow plug according to the fifth embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0052] The preferred embodiments of the present invention will be described hereinafter with reference to FIGS. 1 - 9.

[0053] It should be noted that, for the sake of clarity

and understanding, identical components having identical functions in different embodiments of the invention have been marked, where possible, with the same reference numerals in each of the figures.

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[First Embodiment]

[0054] FIG. 1 shows the overall structure of a glow plug 100 according to the first embodiment of the invention. The glow plug 100 is designed for use in a diesel engine.

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[0055] As shown in FIG. 1, the glow plug 100 includes a tubular housing 10 that is made of a conductive metal material, such as S25C carbon steel. The housing 10 has a first end 10a and a second end 10b, which are opposite to each other in the longitudinal direction of the housing 10.

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[0056] The housing 10 includes a threaded portion 11 formed on an outer periphery thereof, through which the glow plug 100 is to be installed to an engine block and thus the housing 10 is to be grounded.

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[0057] The housing 10 also includes a head portion 12 formed at the first end 10a thereof, to which torque is to be applied by a wrench so as to install the glow plug 100 to the engine block. The head portion 12 has the shape, for example, of a hollow hexagonal prism.

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[0058] A tubular sleeve 20, which is made, for example, of stainless steel, is partially secured in the housing 10 on the second end 10b side. More specifically, the sleeve 20 has a first end 20a, which is located in the housing 10 on the second end 10b side, and a second end 20b that protrudes from the second end 10b of the housing 10.

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[0059] A rod-like insulator 21 is partially retained in the sleeve 20. More specifically, the insulator 21 has a first end 21a protruding from the first end 20a of the sleeve 20 and a second end 21b protruding from the second end 20b of the sleeve 20. The insulator 21 is made, for example, of an insulative ceramic consisting of silicon nitride.

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[0060] A U-shaped heat element 22 is provided in the insulator 21 on the second end 21b side. To opposite ends of the heat element 22, two electrodes 23a and 23b, which extend in the longitudinal direction of the insulator 21, are mechanically and electrically connected. The heat element 22 is made, for example, of an electrically conductive ceramic that consists of silicon nitride and molybdenum disilicide. The electrodes 23a and 23b are made, for example, of tungsten.

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[0061] A rod-like central shaft 30 is accommodated in the housing 10 close to the first end 21a of the insulator 21. More specifically, the central shaft 30 has a first end 30a protruding from the first end 10a of the housing 10 and a second end 30b located in the housing 10. The central shaft 30 is made of a conductive metal material, such as S25C carbon steel.

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[0062] A hollow cylindrical terminal 31 is electrically and mechanically connected to the second end 30b of the central shaft 30 and retained with the help of a cap

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32 that is fixed to the second end 30b.

[0063] The terminal 31 is brought into electrical connection with the electrode 23a, which has an end exposed from the insulator 21 at the first end 21a, by insertion of the first end 21a of the insulator 21 in the terminal 31. On the other hand, the electrode 23b is in electrical connection with the sleeve 20 via an end thereof that is exposed from the insulator 21. Consequently, the electrode 23b is electrically connected to the housing 10 via the sleeve 20.

[0064] At the first end 10a of the housing 10, there are provided a glass seal 40, a packing 41, and an insulation bush 42 between the inner surface of the housing 10 and the outer surface of the central shaft 30. The glass seal 40 is made of glass; the packing 41 is configured with an O-ring; the insulation bush 42 is made, for example, of a phenol resin.

[0065] The insulation bush 42 has a flange portion, by which the insulation bush 42 is prevented from being completely inserted in the housing 10. The insulation bush 42 is urged in the longitudinal direction of the housing 10 toward the first end 10a by a tight engagement between a terminal nut 43 and a threaded portion of the central shaft 30 formed at the first end 30a. Consequently, an airtight seal is obtained at the first end 10a of the housing 10, and the central shaft 30 is secured in the housing 10.

[0066] A heat sink 50 is secured to the first end 10a of the housing 10. Specifically, the heat sink 50 is shaped in a semi-closed hollow cylinder with a flange portion 50a formed at an open end thereof and an end wall 50b that is opposite to the open end. The heat sink 50 is fixed to the head portion 12 of the housing 10 by crimping an end portion 12a of the head portion 12 against the flange portion 50a of the heat sink 50. The heat sink 50 is made, for example, of Al (Aluminum).

[0067] On the outer surface of the end wall 50b of the heat sink 50, there is disposed a substrate 60 that carries a semiconductor chip 61.

[0068] The semiconductor chip 61 includes therein a power transistor (to be simply referred to as PTr hereinafter), such as a P-type MOSFET and an IGBT. As to be described in detail later, the PTr is configured to receive a switching signal from an engine ECU and a voltage from an automotive battery and be turned on and off according to the switching signal so as to intermittently supply the voltage to the heating element 22.

[0069] The heat sink 50 has also a bore formed through the end wall 50b, so as to provide an electrical connection between the semiconductor chip 61 and the central shaft 30. Specifically, a resin member 50c is fitted in the bore and thus fixed to the heat sink 50. The resin member 50c includes a wire (not shown) inset-molded therein, via which the semiconductor chip 61 and the first end 30a of the central shaft 30 are electrically connected.

[0070] The semiconductor chip 61 has a grounding wire that is electrically connected to the heat sink 50. Moreover, a packing 12b is provided between the flange

portion 50a of the heat sink 50 and the head portion 12 of the housing 10, so as to form an airtight seal therebetween.

[0071] A connector 70, which is made, for example, of PBT (Polybutylene Terephthalate), is integrally formed with the heat sink 50. The connector 70 includes a terminal portion 80, through which the semiconductor chip 61 is to be electrically connected with external devices and/or circuits.

[0072] More specifically, as shown in FIGS. 1 and 2, the terminal portion 80 includes three terminals 81 - 83, all of which are electrically connected to the semiconductor chip 61 on one hand. On the other hand, the terminal 81 is to be connected to an automotive battery so as to supply electric power to the heating element 22; the terminal 82 is to be connected to an engine ECU so as to provide a switching signal from the engine ECU to the semiconductor chip 61; the terminal 83 is connected to the engine ECU so as to provide a signal for performing an open-circuit check for the glow plug 100 from the semiconductor chip 61 to the engine ECU.

[0073] In the glow plug 100 having the above-described configuration, heat generated by operation of the semiconductor chip 61 will be externally dissipated in the following way.

[0074] First, the heat is transferred from the semiconductor chip 61 to the heat sink 50 via the substrate 60. Then, since the heat sink 50 is crimp-fixed to the head portion 12 of the housing 10, the heat is transferred from the heat sink 50 to the housing 10.

[0075] Since the housing 10 is fixed to an engine block via the threaded portion 11 thereof, the heat is finally transferred from the housing 10 to the engine block.

[0076] Consequently, it becomes possible to integrate the semiconductor chip 61 into the glow plug 100 while effectively dissipating the heat generated by operation of the semiconductor chip 61 to external.

[0077] Referring now to FIG. 3, which shows the overall configuration of an electric power supply system for supplying electric power to the glow plug 100, operation of the glow plug 100 will be described hereinafter.

[0078] As shown in FIG. 3, the electric power supply system is configured with a plurality of glow plugs 100, an automotive battery 200, and an engine ECU 300.

[0079] The terminal voltage of the battery 200 is regulated to a constant voltage (to be referred to as +B voltage hereinafter) by means of a voltage regulator (not shown), and the +B voltage is then provided to each of the glow plugs 100.

[0080] The engine ECU 300 is of a well-known type including circuits for engine control, such as control of fuel injection timing. The engine ECU 300 is configured to generate a switching signal, which has a high frequency, based on the temperature and pressure within the engine cylinders and output the switching signal to the each of the glow plugs 100.

[0081] Moreover, the engine ECU 300 includes an open-circuit check circuit and a diagnosis circuit.

[0082] The open-circuit check circuit is configured to check an open-circuit in each of the glow plugs 100 and that between each of the glow plugs 100 and the engine ECU 300. Specifically, the open-circuit check circuit has a threshold voltage for open-circuit checking. When an inputted voltage for open-circuit check is not higher than the threshold voltage, the open-circuit check circuit identifies the occurrence of an open-circuit and generates an open-circuit signal that is indicative of the occurrence of the open-circuit. On the other hand, the diagnosis circuit is configured to provide the open-circuit signal from the open-circuit check circuit to a main control circuit of the engine ECU 300.

[0083] For example, as shown in FIG. 3, a voltage at an output terminal of the PTr in the semiconductor chip 61 of each of the glow plugs 100 is outputted to the open-circuit check circuit. Then, the open-circuit check circuit compares the voltage with the threshold voltage and identifies the occurrence of an output-circuit in the glow plug 100 when the voltage is not higher than the threshold voltage.

[0084] In the above-described electric power supply system, each of the glow plugs 100 is supplied with electric power in the following way.

[0085] First, the +B voltage, which is obtained by regulating the terminal voltage of the battery 200, is provided to the terminal 81 of each of the glow plugs 100. At the same time, the switching signal is provided from the engine ECU 300 to the terminal 82 of each of the glow plugs 100.

[0086] Then, according to the switching signal, the PTr in the semiconductor chip 61 of each of the glow plugs 100 is turned on and off, so that the +B voltage is intermittently applied to the heating element 22 via the central shaft 30, the terminal 31, and the electrode 23a, thus heating the air-fuel mixture within the engine cylinder.

[0087] Moreover, in the above electric power supply system, an open-circuit in each of the glow plugs 100 is checked in the following way.

[0088] First, as described previously, the voltage at the output terminal of the PTr in the semiconductor chip 61 of each of the glow plugs 100 is outputted to the open-circuit check circuit of the engine ECU 300 via the terminal 83.

[0089] Then, the open-circuit check circuit determines whether the voltage is higher than the threshold voltage, and when the voltage is not higher than the threshold voltage, it generates the open-circuit signal that is indicative of the occurrence of an open-circuit in the glow plug 100.

[0090] Finally, the open-circuit signal is provided to the main control circuit of the engine ECU 300 by the diagnosis circuit, so that the occurrence of the open-circuit is identified by the main control circuit based on the open-circuit signal.

[0091] To sum up, the glow plug 100 according to the present embodiment includes the heating element 22, the semiconductor chip 61 including therein the PTr, and

the heat sink 50.

[0092] The heating element 22 is configured to generate heat when supplied with electric power, so as to heat the air-fuel mixture within the engine cylinder.

[0093] The PTr in the semiconductor chip 61 is configured to be selectively turned on and off so as to intermittently supply electric power to the heating element 22.

[0094] The heat sink 50 is configured to dissipate heat generated by operation of the semiconductor chip 61 so as to prevent the semiconductor chip 61 from being damaged due to the heat.

[0095] With such a configuration, it becomes possible to integrate the semiconductor chip 61 into the glow plug 100 while providing the glow plug 100 with a capability of effectively dissipating the heat generated by operation of the semiconductor chip 61.

[0096] Consequently, the engine ECU 300 is allowed not to include therein the semiconductor chip 61 and a heat sink for dissipating the heat generated by operation of the semiconductor chip 61 for each of the glow plugs 100, and thus the size of the engine ECU 300 can be accordingly reduced.

[0097] Moreover, in the glow plug 100 according to the present embodiment, the housing 10 is configured to be fixed to an engine block via the threaded portion 11 thereof, the substrate 60 that carries the semiconductor chip 61 is disposed on the heat sink 50, and the heat sink 50 is crimp-fixed to the first end 10a of the housing 10.

[0098] Consequently, the heat generated by operation of the semiconductor chip 61 will be effectively transferred to the engine block via the substrate 60, the heat sink 50, and the housing 10, so that the semiconductor chip 61 can be prevented from being damaged due to the heat, thus improving reliability of the semiconductor chip 61.

[0099] Furthermore, in the glow plug 100 according to the present embodiment, the connector 70 that includes the terminals 81 - 83 is integrally formed with the heat sink 50.

[0100] Consequently, the connector 70 can be easily mounted to the housing 10 through fixing the heat sink 50 to the housing 10, thus improving manufacturing efficiency of the glow plug 100.

[Second Embodiment]

[0101] In this embodiment, a glow plug 100A is provided which has a structure almost identical to that of the glow plug 100 according to the previous embodiment. Accordingly, only the difference in structure between the glow plugs 100 and 100A is to be described hereinafter.

[0102] FIG. 4 shows the overall structure of the glow plug 100A, which is designed for use in a diesel engine as the glow plug 100.

[0103] As shown in FIG. 4, in the glow plug 100A, the insulation bush 42 and the packing 12c are urged in the longitudinal direction of the housing 10 by a heat sink 54 that is crimp-secured to the first end 10a of the housing

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[0104] The heat sink 54 has the shape of a disk with a first major surface 54a, which abuts the insulation bush 42, and a second major surface 54b on which a cylindrical protruding portion 54c is formed.

[0105] On an end surface of the protruding portion 54c, there is disposed the substrate 60 that carries the semiconductor chip 61.

[0106] More specifically, in this embodiment, the substrate 60 has the shape of an oblong plate and is disposed on the end surface of the protruding portion 54c of the heat sink 54 such that the longitudinal direction (or lengthwise direction) of the substrate 60 is perpendicular to the end surface of the protruding portion 54c.

[0107] The semiconductor chip 61 is electrically connected to the central shaft 30 via the substrate 60 and a wire (not shown) that is embedded in the heat sink 54.

[0108] On a side surface of the protruding portion 54c, there is integrally-formed a connector 72.

[0109] The connector 72 includes the terminals 81 - 83, which are electrically connected to the semiconductor chip 61 via wires 62 and the substrate 60.

[0110] In the glow plug 100A having the above-described configuration, heat generated by operation of the semiconductor chip 61 will be transferred to the engine block via the substrate 60, the heat sink 54, and the housing 10, thereby preventing the semiconductor chip 61 from being damaged due to the heat.

[0111] To sum up, in the glow plug 100A according to the present embodiment, the substrate 60 is so disposed on the second major surface 54b of the heat sink 54 that the longitudinal direction of the substrate 60 is perpendicular to the second major surface 54b of the heat sink 54.

[0112] With such a disposition, it is possible to provide the substrate 60 on the heat sink 54 even when the substrate 60 has a greater length than the heat sink 54.

[Third Embodiment]

[0113] In this embodiment, a glow plug 100B is provided which has a structure almost identical to that of the glow plug 100 according to the first embodiment. Accordingly, only the difference in structure between the glow plugs 100 and 100B is to be described hereinafter.

[0114] FIG. 5 shows the overall structure of the glow plug 100B, which is designed for use in a diesel engine as the glow plug 100.

[0115] As shown in FIG. 5, in the glow plug 100B, the first end 30a of the central shaft 30 protrudes from the nut 43 as well as from the housing 10. Further, on the first end 30a of the central shaft 30, there is mounted a connector 71.

[0116] The connector 71 includes a cap portion 71a, an electrode 71b, a wire 71c, a heat sink 51, the substrate 60, the semiconductor chip 61, and a resin-molded portion 71d.

[0117] The cap portion 71a, which shapes the connec-

tor 71, is made, for example, of PBT.

[0118] The electrode 71b is made of a metal material, such as iron, and insert-molded into the cap portion 71a. The electrode 71b has the shape of a hollow semi-closed cylinder with an open end 71b1.

[0119] Upon insertion of the first end 30a of the central shaft 30 in the electrode 71b through the open end 71b1, the connector 71 is integrated into the main body of the glow plug 100B and the electrode 71b is brought into electrical connection with the central shaft 30.

[0120] The wire 71c is insert-molded into the cap portion 71a to electrically connect the terminal 71b with the semiconductor chip 61a.

[0121] The substrate 60 carries the semiconductor chip 61.

[0122] The heat sink 51 has the shape of a plate with a first major surface 51a, on which the substrate 60 is disposed, and a second major surface 51b that is opposite to the first major surface 51a.

[0123] The resin-molded portion 71d is so molded to cover the semiconductor chip 61, the substrate 60, and most area of the first major surface 51a of the heat sink 51.

[0124] The resin-molded portion 71d, the semiconductor chip 61, the substrate 60, and the heat sink 51 are together embedded in the cap portion 71a such that only the second major surface 51b of the heat sink 51 is exposed, as shown in FIGS. 5 and 6, from the cap portion 71a.

[0125] Moreover, the glow plug 100B further includes a wiring harness 71e that is integrally formed with the connector 71. The wiring harness 71e includes a plurality of insert-molded wires, via which the +B voltage is provided to the semiconductor chip 61, the switching signal is provided from the engine ECU 300 to the semiconductor chip 61, and the voltage at the output terminal of the PTr in the semiconductor chip 61 is provided to the open-circuit check circuit of the engine ECU 300.

[0126] In the glow plug 100B having the above-described configuration, heat generated by operation of the semiconductor chip 61 will be dissipated to external in the following way.

[0127] First, the heat is transferred from the semiconductor chip 61 to the heat sink 51 via the substrate 60.

[0128] Then, since the heat sink 51 has the exposed second major surface 51b, the heat is directly dissipated into the atmosphere via the second major surface 51b.

[0129] As to the ways of supplying electric power and checking an open-circuit for the glow plug 100B, since they are the same as those for the glow plug 100 according to the first embodiment, the description thereof is thus omitted here.

[0130] To sum up, in the glow plug 100B according to the present embodiment, the connector 71 includes the semiconductor chip 61, the heat sink 51, and the hollow electrode 71.

[0131] The connector 71 is integrated into the main body of the glow plug 100B by insertion of the first end

30a of the central shaft 30 in the electrode 71 b.

[0132] With such a configuration, it is possible to obtain the glow plug 100B simply by combining the connector 71 with a conventional glow plug that has no built-in semiconductor chip and heat sink, so that manufacturing cost of the glow plug 100B can be reduced by utilization of the conventional glow plug.

[0133] Moreover, in the connector 71, the semiconductor chip 61 is disposed on the first major surface 51a of the heat sink 51 via the substrate 60 and the second major surface 51b of the heat sink 51 is exposed.

[0134] Consequently, heat generated by operation of the semiconductor chip 61 will be effectively dissipated into the atmosphere via the second major surface 51b, so that the semiconductor chip 61 is prevented from being damaged due to the heat, thus improving reliability of the semiconductor chip 61.

[0135] In addition, the connector 71 further includes the integrally-formed wiring harness 71e, by which the electrical connection between the glow plug 100B and external devices and/or circuits is facilitated.

[Fourth Embodiment]

[0136] In this embodiment, a glow plug 100C is provided which has a structure almost identical to that of the glow plug 100B according to the third embodiment. Accordingly, only the difference in structure between the glow plugs 100B and 100C is to be described hereinafter.

[0137] FIG. 7 shows the overall structure of the glow plug 100C, which is designed for use in a diesel engine as the glow plug 100B.

[0138] As shown in FIG. 7, in the glow plug 100C, there is provided a heat sink 52 that covers the outer surface of the connector 71 as a metal connector cover.

[0139] The heat sink 52 includes an end 52a that is brought into abutment with the first end 10a of the housing 10 by insertion of the first end 30a of the central shaft 30 in the electrode 71b of the connector 71.

[0140] Moreover, as shown in FIGS. 7 and 8, the heat sink 52 further includes a recessed portion 52b that abuts the second major surface 51b of the heat sink 51.

[0141] In the glow plug 100C having the above-described configuration, heat generated by operation of the semiconductor chip 61 will be dissipated to external in the following way.

[0142] First, the heat is transferred from the semiconductor chip 61 to the heat sink 51 via the substrate 60.

[0143] Then, since the heat sink 51 has the second major surface 51b that abuts the recessed portion 52b of the heat sink 52, the heat is transferred from the heat sink 51 to the heat sink 52.

[0144] Consequently, part of the heat is directly dissipated into the atmosphere via the outer surface of the heat sink 52, while the other part of the heat is transferred to the engine block via the housing 10.

[0145] To sum up, in the glow plug 100C according to the present embodiment, the heat sink 52 is provided, in

addition to the heat sink 51, to more effectively dissipate heat generated by operation of the semiconductor chip 61 as well as to cover the connector 71.

5 [Fifth Embodiment]

[0146] In this embodiment, a glow plug 100D is provided which has a structure almost identical to those of the glow plugs 100 - 100C according to the previous embodiments. Accordingly, only the difference in structure between the glow plug 100D and the glow plugs 100 - 100C is to be described hereinafter.

[0147] FIG. 9 shows the overall structure of the glow plug 100D, which is designed for use in a diesel engine as the glow plugs 100 - 100C.

[0148] As shown in FIG. 9, in the glow plug 100D, there is provided a heat sink 53 that covers the first end 10a of the housing 10 as a metal housing cover.

[0149] The heat sink 53 has the shape of a semi-closed hollow cylinder. The heat sink 53 is fixed to the first end 10a of the housing 10 by crimping such that the first end 30a of the central shaft 30 extends through a bore 53a formed in an end wall 53b of the heat sink 53.

[0150] Upon insertion of the first end 30a of the central shaft 30 in the electrode 71b of the connector 71, the connector 71 is integrated into the main body of the glow plug 100D. Consequently, the electrode 71b is brought into electrical connection with the central shaft 30, and the end 52a of the heat sink 52 is brought into abutment with the end wall 53b of the heat sink 53.

[0151] In the glow plug 100D having the above-described configuration, heat generated by operation of the semiconductor chip 61 will be externally dissipated in the following way.

[0152] First, the heat is transferred from the semiconductor chip 61 to the heat sink 51 via the substrate 60.

[0153] Then, since the heat sink 51 abuts the heat sink 52, the heat is transferred from the heat sink 51 to the heat sink 52.

[0154] Since the end 52a of the heat sink 52 abuts the end wall 53b of the heat sink 53, the heat is further transferred from the heat sink 52 to the heat sink 53 that is fixed to the housing 10.

[0155] Consequently, part of the heat is directly dissipated into the atmosphere via the outer surfaces of the heat sinks 52 and 53, while the other part of the heat is transferred to the engine block via the housing 10.

[0156] To sum up, in the glow plug 100D according to the present embodiment, the heat sink 53 is provided, in addition to the heat sinks 51 and 52, to more effectively dissipate heat generated by operation of the semiconductor chip 61 as well as to cover the housing 10.

[Other Embodiments]

[0157] While the above particular embodiments of the invention have been shown and described, it will be understood by those who practice the invention and those

skilled in the art that various modifications, changes, and improvements may be made to the invention without departing from the spirit of the disclosed concept.

[0158] For example, in the electric power supply system described in the first embodiment, the engine ECU 300 is configured to provide the same switching signal to the plurality of glow plugs 100. 5

[0159] However, the engine ECU 300 may also be configured to provide one switching signal for each of the glow plugs 100, which is generated based on the temperature and pressure within a corresponding one of the engines cylinders. 10

[0160] Moreover, in the fourth and fifth embodiments, the end 52a of the heat sink 52 abuts and can be moved away from the first end 10a of the housing 10 or the end wall 53b of the heat sink 53. 15

[0161] However, the end 52a of the heat sink 52 may also be fixed to the first end 10a of the housing 10 or the end wall 53b of the heat sink 53 by, for example, welding. 20

[0162] Such modifications, changes, and improvements within the skill of the art are intended to be covered by the appended claims.

[0163] According to the present invention, a glow plug for a diesel engine is provided which includes a heating element, a semiconductor chip that includes therein a power transistor, and a heat sink. The heating element is configured to generate heat when supplied with electric power, so as to heat the air-fuel mixture within a cylinder of the diesel engine. The power transistor in the semiconductor chip is configured to be selectively turned on and off so as to intermittently supply electric power to the heating element. The heat sink serves to dissipate heat generated by operation of the semiconductor chip so as to prevent the semiconductor chip from being damaged due to the heat. With such a configuration, it becomes possible to integrate the semiconductor chip into the glow plug while providing the glow plug with a capability of effectively dissipating the heat generated by operation of the semiconductor chip. 25 30 35 40

Claims

1. A glow plug comprising:

a heating element configured to generate heat when supplied with electric power;
a power transistor configured to be selectively turned on and off so as to supply electric power to said heating element; and
a heat sink serving to dissipate heat generated by operation of said power transistor so as to protect said power transistor from heat damage. 50

2. The glow plug as set forth in Claim 1 further comprising: 55

a tubular housing having a first end and a second

end, said housing also having a threaded portion formed on an outer periphery thereof so as to be installed to a diesel engine;

a tubular sleeve having a first end retained in said housing and a second end protruding from said second end of said housing;

a rod-like insulator secured to said sleeve, said insulator having a first end located in said housing and a second end protruding from said second end of said sleeve; and

a rod-like central shaft accommodated in said housing, said central shaft having a first end fixed to said first end of said housing via an insulative fixing member and a second end that is located in said housing,

wherein

said heating element is provided in said insulator on said second end side of said insulator and electrically connected to said second end of said central shaft, said power transistor is provided on a substrate and electrically connected to said first end of said central shaft, and

said heat sink is fixed to said first end of said housing and has a surface on which said substrate is disposed.

3. The glow plug as set forth in Claim 2 further comprising a connector that is integrally formed with said heat sink and includes a plurality of terminals, wherein when a switching signal and a voltage are provided to said power transistor via said terminals, said power transistor is turned on and off according to said switching signal so that said voltage is intermittently applied to said heating element. 35

4. The glow plug as set forth in Claim 2 or Claim 3, wherein said substrate, which carries said power transistor, is so disposed on said surface of said heat sink that a longitudinal direction of said substrate is perpendicular to said surface of said heat sink. 40

5. The glow plug as set forth in any one of Claims 2 to 4, wherein said heat sink is fixed to said first end of said housing by crimping. 45

6. The glow plug as set forth in Claim 1 further comprising:

a tubular housing having a first end and a second end, said housing also having a threaded portion formed on an outer periphery thereof so as to be installed to a diesel engine;

a tubular sleeve having a first end retained in said housing and a second end protruding from said second end of said housing;

a rod-like insulator secured to said sleeve, said insulator having a first end located in said hous-

ing and a second end protruding from said second end of said sleeve;
 a rod-like central shaft partially accommodated in said housing and fixed to said first end of said housing via an insulative fixing member, said central shaft having a first end protruding from said housing and said fixing member and a second end that is located in said housing; and
 a connector having a hollow electrode formed therein which has an open end,

wherein

said heating element is provided in said insulator on said second end side of said insulator and electrically connected to said second end of said central shaft, said power transistor is provided on a substrate and embedded in said connector together with said substrate,
 said heat sink is included in said connector and has a plate-like shape with a first major surface embedded in said connector, on which said substrate is disposed, and a second major surface exposed from said connector to dissipate said heat generated by operation of said power transistor, and
 said electrode of said connector is electrically connected to said power transistor and brought into electrical connection with said first end of said central shaft by insertion of said first end of said central shaft in said electrode through said open end thereof.

7. The glow plug as set forth in Claim 6 further comprising a metal connector cover covering an outer surface of said connector, said connector cover abutting said second major surface of said heat sink and having an end that is brought into abutment with said first end of said housing by insertion of said first end of said central shaft in said electrode of said connector.

8. The glow plug as set forth in Claim 6 further comprising:

a metal housing cover covering said first end of said housing, said housing cover being fixed to said first end of said housing and having a bore formed therein through which said central shaft extends; and
 a metal connector cover covering an outer surface of said connector, said connector cover abutting said second major surface of said heat sink and having an end that is brought into abutment with said housing cover by insertion of said first end of said central shaft in said electrode of said connector.

9. The glow plug as set forth in any one of Claims 6 to 8 further comprising a wiring harness that is integrally formed with said connector and includes a plurality

of wires, wherein when a switching signal and a voltage are provided to said power transistor via said wires, said power transistor is turned on and off according to said switching signal so that said voltage is intermittently applied to said heating element.

FIG. 1

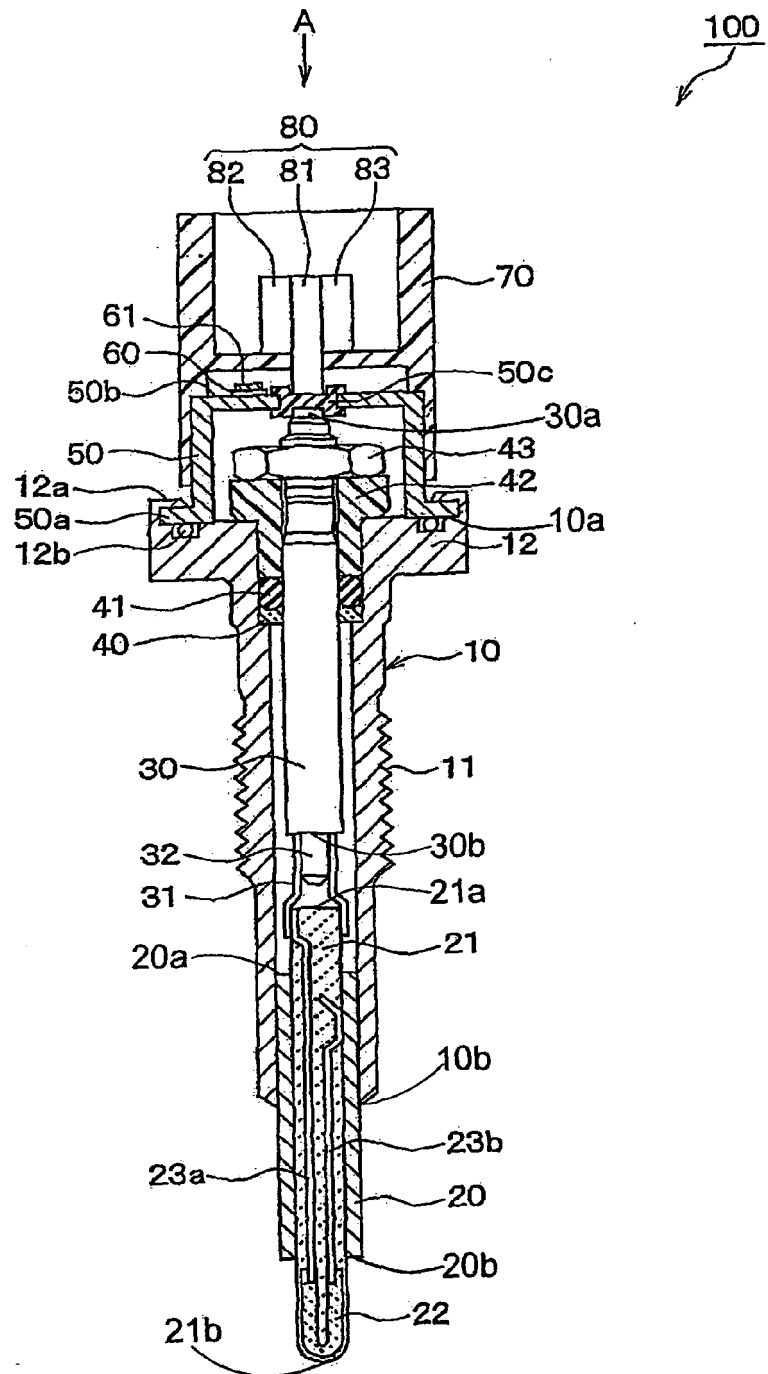


FIG. 2

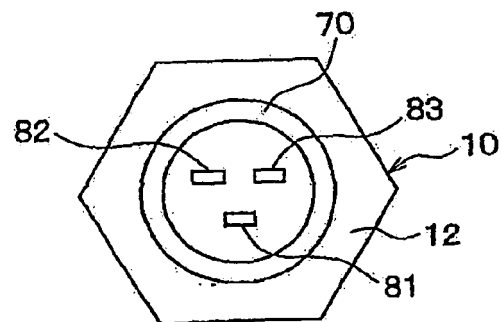


FIG. 3

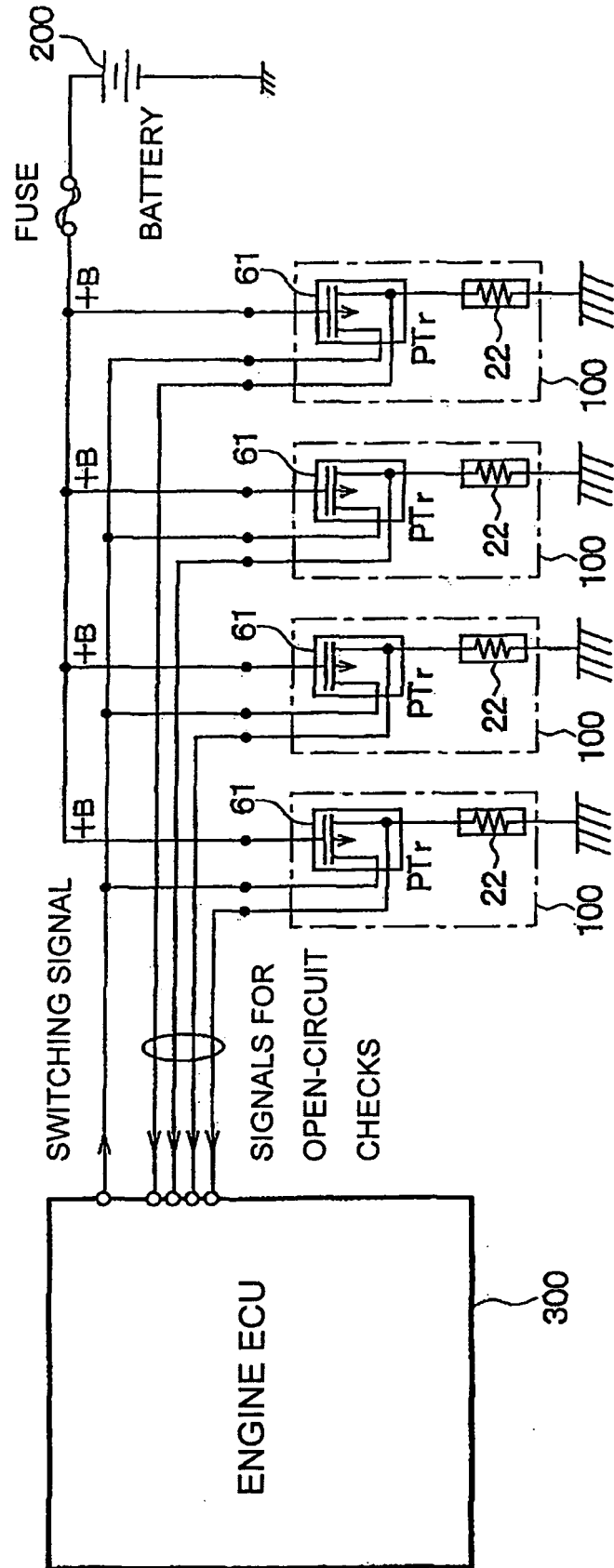


FIG. 4

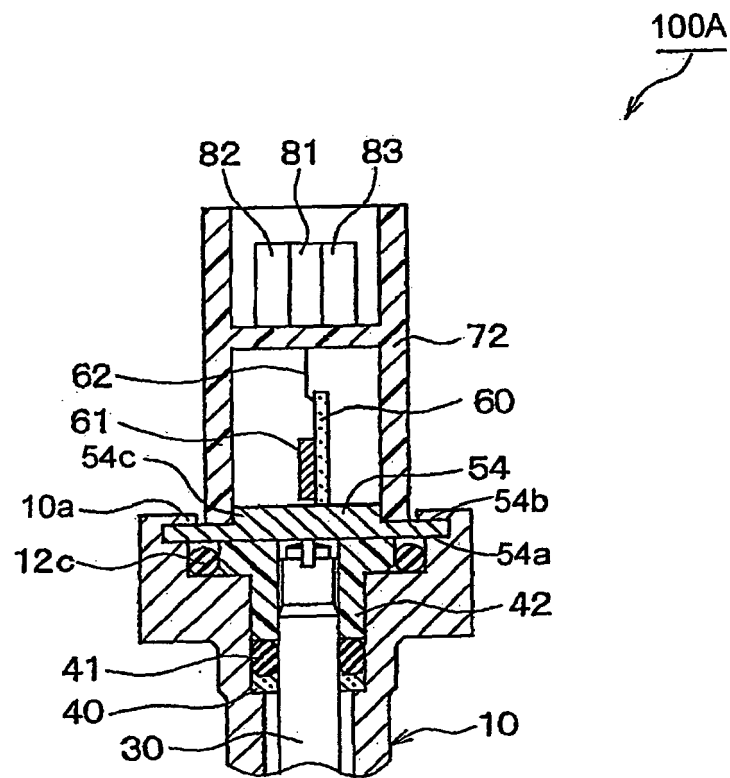


FIG. 5

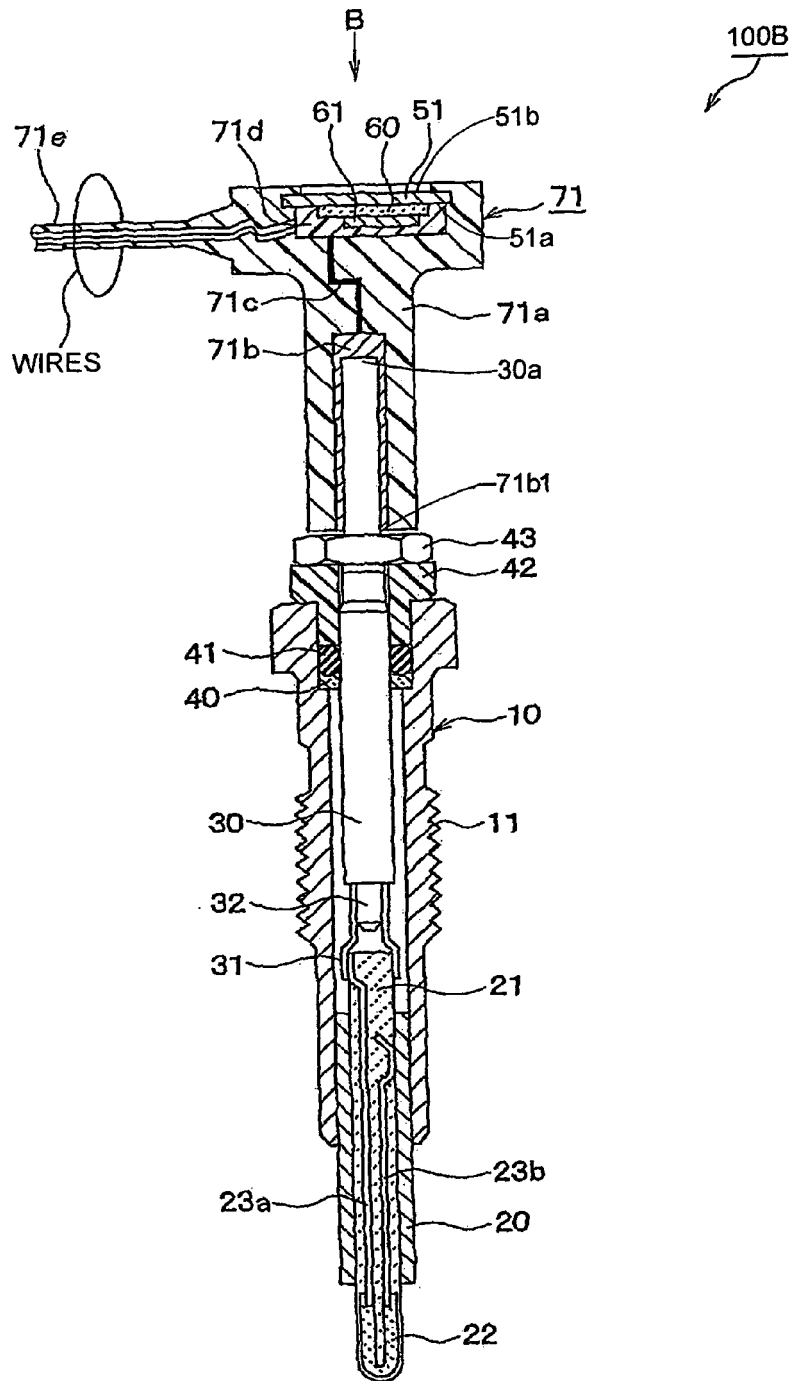


FIG. 6

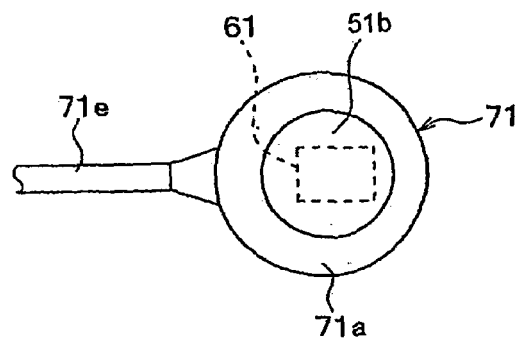


FIG. 7

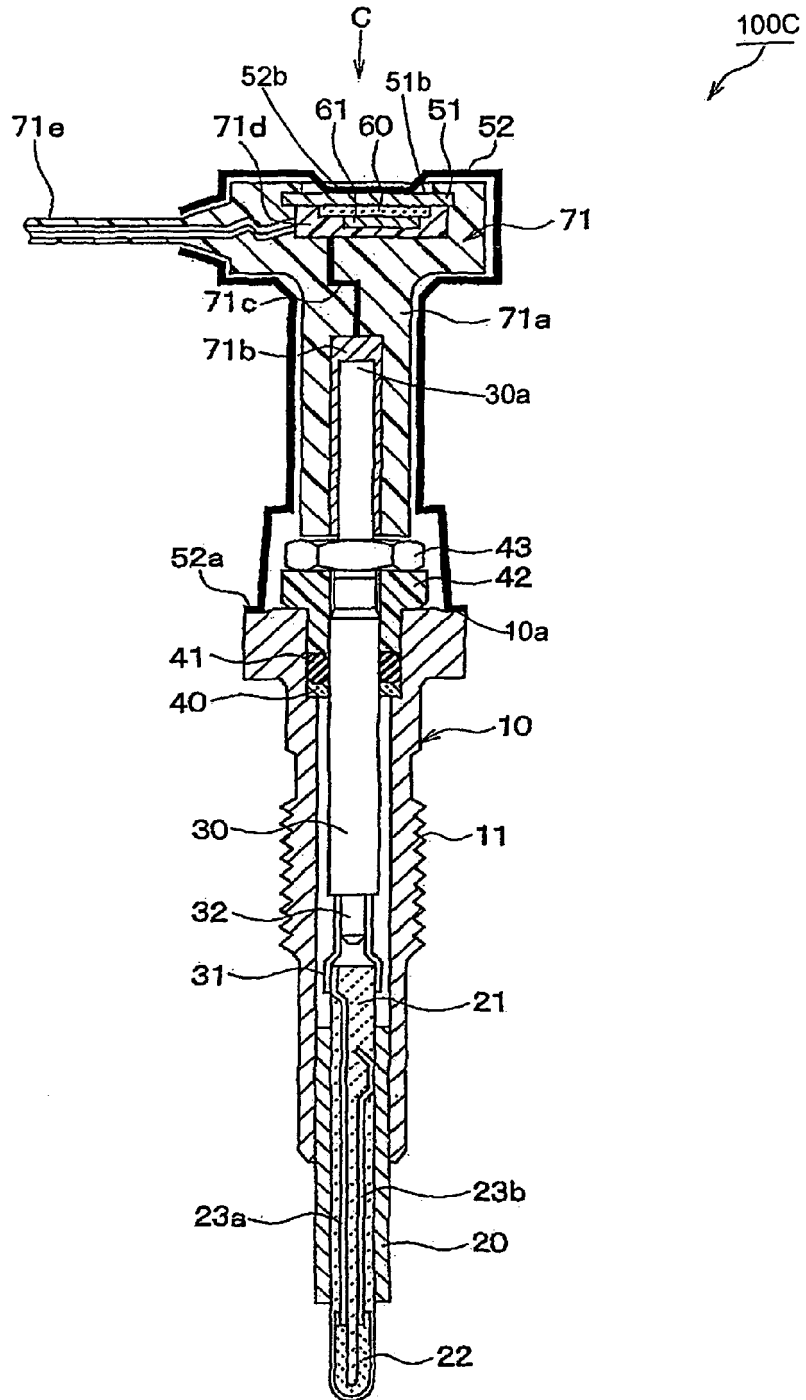


FIG. 8

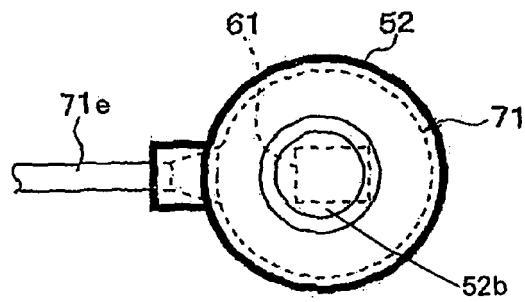
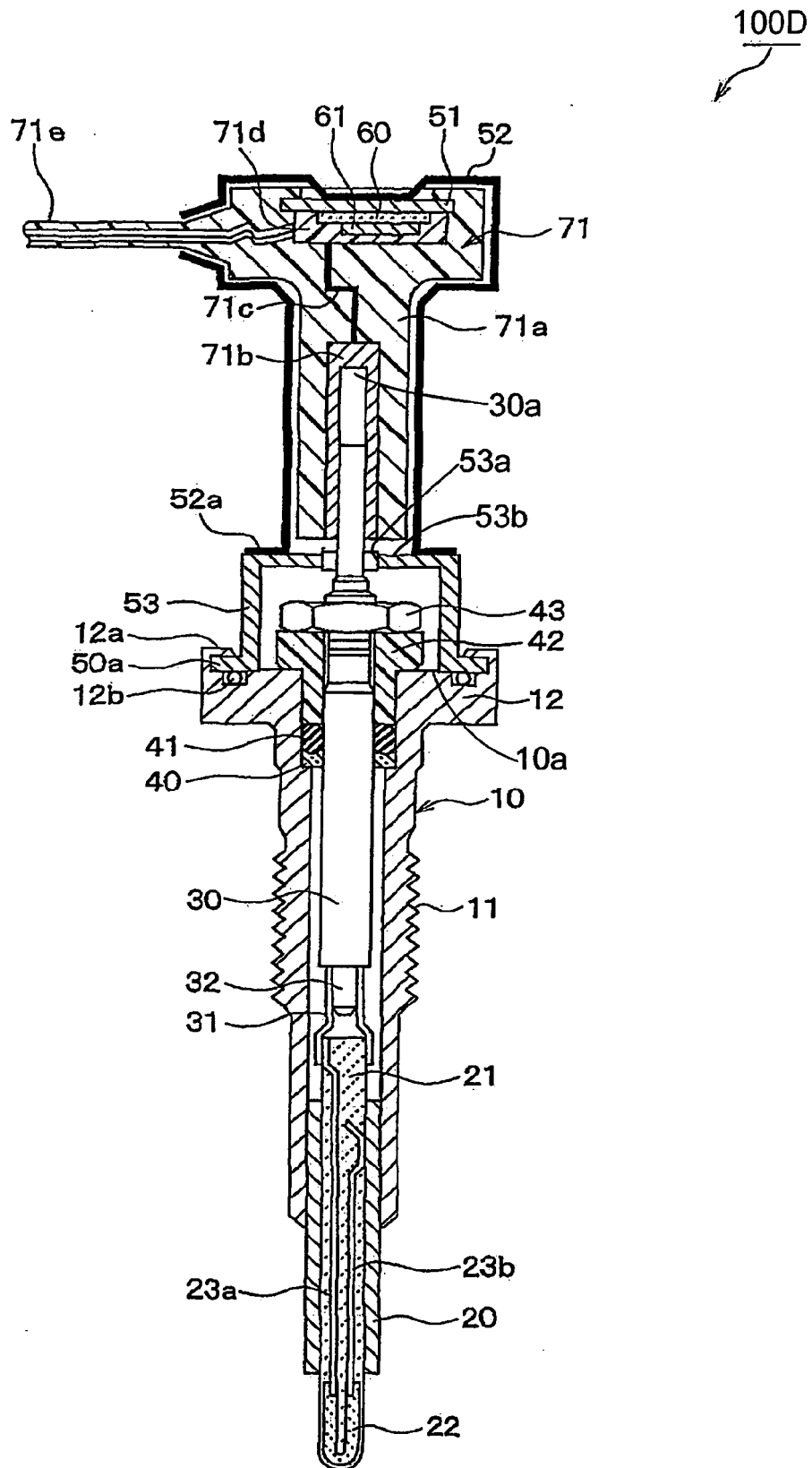


FIG. 9





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