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(54) **Glow plug**

(57) [Objective] An object is to effectively prevent evaporation of components of the material of a heating resistor without formation of Al_2O_3 coating, to thereby dramatically prolong the service life of a glow plug.

[Means for Solution] A glow plug 1 includes a cylindrical tube 7 which has a closed front end and which is hermetically sealed, and a heating coil 9 which is disposed in the tube 7 and whose front end is connected to the front end of the tube 7. The heating coil 9 is formed of an alloy containing Ni as a main component and containing W in an amount smaller than that of Ni.

FIG. 1A

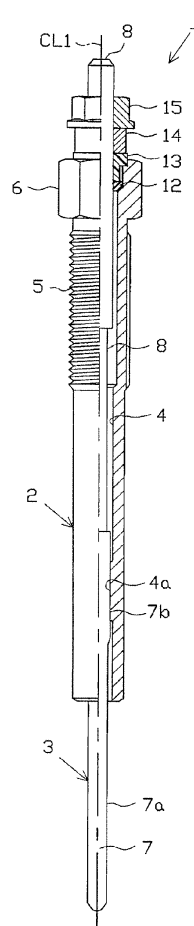
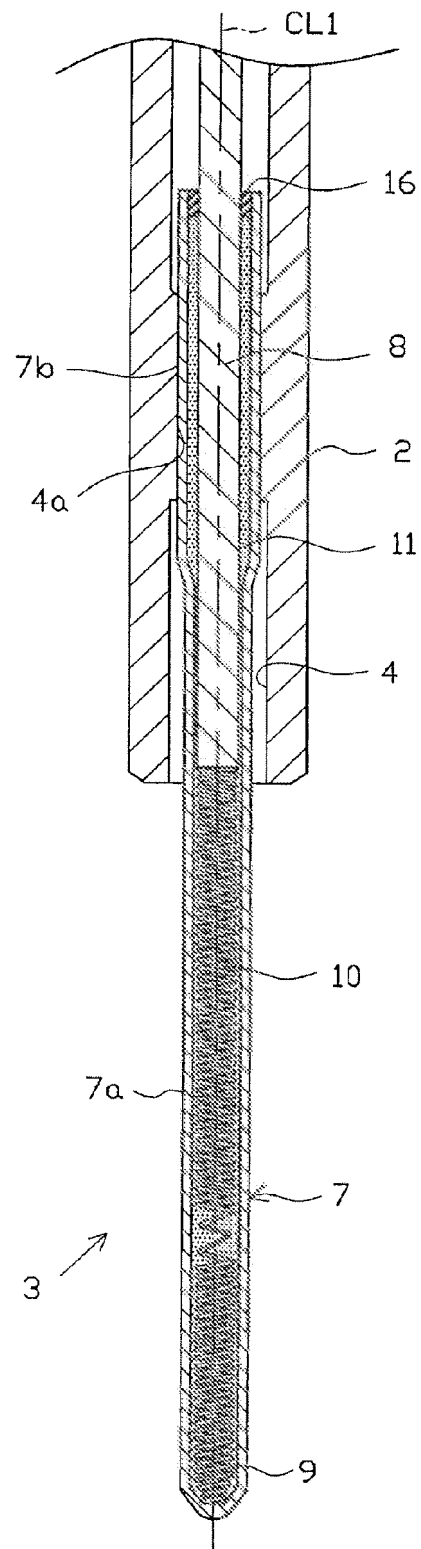


FIG. 1B



Description

[Technical field]

[0001] The present invention relates to a glow plug used for, for example, preliminary heating of a diesel engine.

[Background Art]

[0002] There have been known glow plugs used for, for example, preliminary heating of a diesel engine generally employing a sheath heater formed of a metallic tube which has a closed front end and which includes therein insulating powder (e.g., magnesium oxide) and a heating resistor formed of an alloy containing iron (Fe) as a main component, and chromium (Cr), aluminum (Al), or the like.

[0003] When the heating resistor contains Al, aluminum oxide (Al_2O_3) coating is formed on the surface of the resistor through reaction between Al and oxygen contained in the tube. This Al_2O_3 coating can prevent evaporation of components of the material of the heating resistor.

[0004] The Al_2O_3 coating formed on the surface of the heating resistor may be broken due to thermal shock through repetition of heating and cooling. When a sufficient amount of oxygen is present in the tube, new Al_2O_3 coating is formed on the resistor surface. However, when oxygen contained in the tube is completely consumed through repetition of formation and breakage of Al_2O_3 coating, new Al_2O_3 coating may fail to be formed, since the tube is hermetically sealed. Failure to formation of Al_2O_3 coating may cause a decrease in the volume of the heating resistor, through which electricity flows, due to evaporation of components of the material of the resistor, leading to an increase in resistance and breakage of a heating coil.

[0005] There has been proposed a technique for solving such a problem, in which a metal oxide is incorporated into insulating powder contained in a tube (see, for example, Patent Document 1). According to this technique, even when oxygen contained in the tube is consumed, oxygen is generated therein through reduction of the metal oxide, and thus formation of Al_2O_3 coating may be repeated for a longer period of time.

[Prior Art Documents]

[Patent Documents]

[0006] [Patent Document 1] Japanese Patent No. 4076162

[Summary of the Invention]

[Problems to be Solved by the Invention]

[0007] However, even if a larger amount of a metal oxide is incorporated, oxygen contained in the tube is eventually exhausted. That is, a limitation is imposed on the technique for preventing evaporation of components of the material of a heating resistor through formation of Al_2O_3 coating on the surface of the resistor.

[0008] The present invention has been achieved in view of the above circumstances, and an object of the invention is to provide a glow plug in which evaporation of components of the material of a heating resistor can be effectively prevented without formation of Al_2O_3 coating, and which exhibits dramatically prolonged service life.

[Means for Solving the Problems]

[0009] Configurations suited for achieving the aforementioned object will next be described individually. When necessary, actions and effects peculiar to individual configurations will be described additionally.

[0010] Configuration 1. A glow plug comprising:

a cylindrical tube which has a closed front end and which is hermetically sealed; and
a heating resistor which is incorporated in the tube and whose front end is connected to the front end of the tube, characterized in that the heating resistor is formed of an alloy containing nickel (Ni) as a main component and containing tungsten (W) in an amount smaller than that of Ni.

[0011] As used herein, the term "main component" of a material refers to a component whose relative amount (by mass) is the largest of all the components of the material (the same shall apply hereinafter).

[0012] According to the above-described configuration 1, the heating resistor is formed of an alloy containing Ni as a

main component and containing W in an amount smaller than that of Ni (i.e., Ni-W alloy). Since Ni has a vapor pressure lower than that of Fe, even when the glow plug is employed in a high-temperature environment; for example, in a high-temperature environment in which the temperature of a heating coil becomes 1,300°C, Ni (i.e., a component of the material of the heating resistor) is less likely to be evaporated. Even if Ni present in a surface layer of the heating resistor is evaporated at such a high temperature, virtually no evaporation of W, which has a very low vapor pressure, occurs, and W remains in the surface layer of the heating resistor. As a result, a coating of W (W coating) is formed on the surface layer of the heating resistor. Therefore, evaporation of Ni no longer occurs, by virtue of the thus-formed W coating. That is, according to configuration 1, the glow plug exhibits dramatically prolonged service life by a synergistic interaction between Ni, which is less likely to be evaporated than Fe, and W, which forms a coating on the surface layer of the heating resistor.

[0013] The present invention employs an Ni-W alloy (although it is relatively easily oxidized), since the tube is hermetically sealed, and thus invasion of oxygen from the outside into the tube is suppressed to a minimum possible extent. In other words, since the resistor is incorporated in the tube; i.e., the environment in which invasion of oxygen is suppressed, an Ni-W alloy can be employed for forming the heating resistor.

[0014] In another conceivable case, the heating resistor might be formed of an alloy containing Ni and, instead of W, an element having a low vapor pressure (e.g., Mo). However, in such a case, a coating formed on a surface layer of the heating resistor contains Ni and Mo or a like element, and the coating is unstable. Thus, evaporation of components of the material of the heating resistor may fail to be suppressed sufficiently. In contrast, when the heating resistor is formed of an Ni-W alloy, a stable W coating is formed on the surface layer of the heating resistor. Therefore, evaporation of components of the material of the heating resistor can be suppressed very effectively. From this viewpoint, incorporation of W is of significance.

[0015] In the case where a thin heating resistor having, for example, a coil form is produced, when an alloy containing Fe as a main component is processed into such a thin heating resistor, the alloy must be subjected to wiredrawing under heating (hot wiredrawing). In contrast, an alloy containing Ni as a main component can be wiredrawn without requiring heating. That is, an Ni-W alloy is superior, in processability, to an alloy containing Fe as a main component. From this viewpoint, employment of an Ni-W alloy is effective.

[0016] Preferably, the alloy forming the heating resistor contains substantially no phosphorus (P). When P is contained in the alloy forming the heating resistor, a low-melting-point compound may be generated through reaction between Ni and P, resulting in reduction in high-temperature strength. In addition, since P relatively easily segregates in an Ni alloy, and a P-segregated portion becomes fragile, breakage, etc. of the heating resistor may start at the P-segregated portion. Therefore, preferably, the alloy forming the heating resistor does not contain P.

[0017] However, P is inevitably contained in the raw material of the heating resistor, and thus a very costly process (e.g., a highly refining process) is required for completely removing P from the raw material. Therefore, in comprehensive consideration of such a situation and the performance of the glow plug, preferably, the alloy forming the heating resistor contains "substantially no P." As used herein, "substantially no P" refers to the case where the amount of P contained in the material (alloy) is 0.05 mass% or less on the basis of the total amount of the material (mass of the alloy). A smaller amount of P contained in the material is preferred, solely from the viewpoint of the performance of the glow plug. Therefore, more preferably, the amount of P contained in the material is 0.03 mass% or less on the basis of the total amount of the material. Still more preferably, no P is contained in the material.

[0018] Configuration 2. A glow plug according to the present configuration is characterized in that, in the aforementioned configuration 1, a portion which is exposed to a space in the tube contains at least one of chromium (Cr), silicon (Si), and titanium (Ti).

[0019] "Portion which is exposed to a space in the tube" refers to a portion which defines a space in the tube, or a portion which is incorporated in the tube. Examples of such a portion include the tube itself, the heating resistor, insulating powder for insulating the tube from the heating resistor, and a metallic coating formed on, for example, the inner circumferential surface of the tube.

[0020] Cr, Si, and Ti are elements which are relatively easily oxidized. Therefore, according to the above-described configuration 2, when such an element is contained in the portion which is exposed to a space in the tube, the element serves as a so-called oxygen getter element and can capture oxygen in the tube. Thus, oxidation of the heating resistor can be further reliably prevented, resulting in further improvement of durability.

[0021] Configuration 3. A glow plug according to the present configuration is characterized in that, in the aforementioned configuration 1 or 2, the heating resistor contains at least one of Cr in an amount of 5 mol% to 30 mol%, Si in an amount of 1 mol% to 10 mol%, and Ti in an amount of 1 mol% to 5 mol%.

[0022] According to the above-described configuration 3, basically, actions and effects similar to those of the above-described configuration 2 can be attained. In addition, according to configuration 3, the heating resistor contains Cr, Si, or Ti. Therefore, an oxide film can be formed on the surface of the heating resistor through reaction between Cr, Si, or Ti and oxygen contained in the tube, and the thus-formed oxide film can prevent invasion of nitrogen or oxygen into the heating resistor. Thus, breakage of the heating resistor, which would otherwise occur due to formation of a nitride or an

oxide in the heating resistor, can be further reliably prevented.

[0023] Also, the aforementioned oxide film can further suppress evaporation of components of the material of the heating resistor. Therefore, the glow plug exhibits further prolonged service life by combination of this effect with the aforementioned effect of preventing formation of, for example, a nitride in the heating resistor.

[0024] When the heating resistor contains Al, potential difference generated in the heating resistor in a high-temperature environment may cause migration (diffusion) of Al from the high potential side to the low potential side, resulting in formation of voids in the heating resistor (occurrence of so-called electromigration). However, according to configuration 3, since the heating resistor contains W, which has a larger atomic weight, migration of Al can be prevented, and formation of voids can be suppressed in the heating resistor. That is, when the heating resistor contains Al, W contained therein avoids disadvantages associated with Al, and causes Al to sufficiently exhibit its actions and effects (e.g., the effect of capturing oxygen contained in the tube).

[0025] When the amount of Cr, Si, or Ti contained in the heating resistor is below the aforementioned lower limit, the above-described actions and effects may fail to be attained sufficiently. In contrast, when the amount of Cr, Si, or Ti exceeds the aforementioned upper limit, which corresponds to its solid solubility limit in an Ni-W alloy, such an element may be precipitated from the alloy. Therefore, preferably, the amount of Cr, Si, or Ti is adjusted to be equal to or less than the aforementioned upper limit for preventing deterioration of processability associated with hardening of the alloy.

[0026] Configuration 4. A glow plug according to the present configuration is characterized in that, in any of the aforementioned configurations 1 to 3, the heating resistor contains at least one of vanadium (V) in an amount of 5 mol% to 10 mol%, molybdenum (Mo) in an amount of 5 mol% to 10 mol%, niobium (Nb) in an amount of 1 mol% to 5 mol%, and tantalum (Ta) in an amount of 1 mol% to 10 mol%.

[0027] According to the above-described configuration 4, the heating resistor contains V, Mo, Nb, or Ta, which realizes an increase in resistance of the heating resistor. Therefore, the resistance of the heating resistor can be sufficiently increased without requiring, for example, excessive thinning of the heating resistor, and thus the heating resistor can exhibit satisfactory heating performance. Since the heating resistor is not required to be excessively thinned; i.e., the resistor can be provided in a relatively thick form, the durability of the heating resistor can be improved.

[0028] When the amount of V, Mo, Nb, or Ta contained in the heating resistor is below the aforementioned lower limit, the above-described actions and effects may fail to be attained sufficiently. In contrast, when the amount of V, Mo, Nb, or Ta exceeds the aforementioned upper limit, processability may be deteriorated.

[0029] Configuration 5. A glow plug according to the present configuration is characterized in that, in any of the aforementioned configurations 1 to 4, the heating resistor contains W in an amount of 0.5 mol% or more.

[0030] According to the above-described configuration 5, the heating resistor contains a relatively large amount of W (i.e., 0.5 mol% or more). Therefore, a W coating can be more reliably formed on a surface layer of the heating resistor, and evaporation of components of the material of the heating resistor can be further effectively suppressed.

[0031] Configuration 6. A glow plug according to the present configuration is characterized in that, in any of the aforementioned configurations 1 to 5, the heating resistor contains W in an amount of 15 mol% or less.

[0032] According to the above-described configuration 6, the amount of W contained in the heating resistor is 15 mol% or less. Therefore, the processability of the alloy forming the heating resistor can be improved, and the heating resistor can be relatively easily formed into a desired shape.

[0033] Configuration 7. A glow plug according to the present configuration is characterized in that, in any of the aforementioned configurations 1 to 6, the heating resistor contains phosphorus (P) in an amount of 0.05 mass% or less.

[0034] According to the above-described configuration 7, the amount of P contained in the heating resistor is 0.05 mass% or less. Therefore, there can be more reliably prevented, for example, reduction in high-temperature strength due to formation of a low-melting-point compound through reaction between Ni and P, or breakage of the heating resistor due to segregation of P. Thus, the heating resistor having a relatively thin form (e.g., ϕ 0.2 mm or less) can be stably produced without causing, for example, breakage. In addition, the above-described effect of improving durability associated with employment of an Ni-W alloy can be further reliably attained.

[Brief Description of the Drawings]

[0035]

[FIG. 1] FIG. 1A is a partially cutaway front view of a glow plug of the present embodiment, and FIG. 1B is a partial expanded cross-sectional view of a front end portion of the glow plug.

[FIG. 2] Graph showing the vapor pressures of Fe, Al, Cr, Ni, and W.

[Modes for Carrying Out the Invention]

[0036] One embodiment will now be described with reference to the drawings. FIG. 1A is a partially cutaway front

view of a glow plug according to the present invention, and FIG. 1B is a partial expanded cross-sectional view of the glow plug (including a sheath heater).

[0037] As shown in FIGs. 1A and 1B, a glow plug 1 includes a tubular metallic shell 2, and a sheath heater 3 attached to the metallic shell 2.

[0038] The metallic shell 2 has an axial hole 4 extending through the metallic shell 2 in the direction of an axis CL1. The metallic shell 2 also has, on its outer circumferential surface, a screw portion 5 for attachment to, for example, a diesel engine, and a tool engagement portion 6 which has a hexagonal cross section, and with which a tool such as a torque wrench is engaged.

[0039] The sheath heater 3 includes a tube 7 and a center rod 8 united together in the direction of the axis CL1.

[0040] The tube 7 is a cylindrical tube which has a closed front end and which is formed of a metallic material containing, as a main component, iron (Fe) or nickel (Ni) (e.g., inconel alloy or stainless steel alloy). The tube 7 includes therein a heating coil 9 which serves as a heating resistor and which is connected to the front end of the tube 7; a control coil 10 which is connected in series to the rear end of the heating coil 9; and insulating powder 11 such as magnesium oxide powder. The front end of the heating coil 9 is electrically connected to the tube 7, but the outer circumferential surfaces of the heating coil 9 and the control coil 10 are insulated from the inner circumferential surface of the tube 7 via the insulating powder 11.

[0041] The rear end of the tube 7 is sealed up by an annular rubber member 16 disposed between the rear end of the tube 7 and the center rod 8. That is, the tube 7 is hermetically sealed.

[0042] The heating coil 9 is formed from a heating resistance wire made of a specific alloy (the composition of the alloy will be described in detail hereinbelow).

[0043] The control coil 10 is formed from a heating resistance wire made of a material having a temperature coefficient of electrical resistivity higher than that of the material of the heating coil 9; for example, the control coil 10 is formed from a material containing cobalt (Co) or Ni as a main component, such as a Co-Ni-Fe alloy. Thus, the electrical resistance of the control coil 10 is increased by heat generated from itself and heat generated from the heating coil 9, whereby the control coil 10 controls the amount of power supplied to the heating coil 9. Therefore, at an initial stage of electricity supply, a relatively large amount of power is supplied to the heating coil 9, and the temperature of the heating coil 9 is rapidly elevated. The control coil 10 is heated by the thus-generated heat, and the electrical resistance of the control coil 10 is increased, whereby the amount of power supplied to the heating coil 9 is reduced. Thus, the sheath heater 3 exhibits a temperature elevation profile including rapid temperature elevation at an initial stage of electricity supply, and subsequent temperature saturation through suppression of power supply by the action of the control coil 10. That is, by virtue of the presence of the control coil 10, the temperature of the sheath heater 3 can be rapidly elevated, and excessive elevation of the temperature (overshoot) of the heating coil 9 can be suppressed.

[0044] The amount of heat generated from the heating coil 9 may be controlled by regulating the amount of power supplied to the heating coil 9 by means of a specific external controller provided outside thereof. Upon breakdown of the external controller, the amount of power supplied to the heating coil 9 may fail to be regulated, resulting in a concern about excessive elevation of the temperature of the heating coil 9. However, in such a case, excessive elevation of the temperature of the heating coil 9 may be prevented by reducing the amount of power supplied to the heating coil 9 by means of the control coil 10. Thus, the control coil 10 can be employed for intentionally regulating the amount of power supplied to the heating coil 9, or for preventing supply of an excessively large current to the heating coil 9.

[0045] Through swaging or a similar process, a small diameter portion 7a for accommodating the heating coil 9, etc. is formed at a front end portion of the tube 7, and a large diameter portion 7b, which is larger in diameter than the small diameter portion 7a, is formed rearward of the small diameter portion 7a. The large diameter portion 7b is press-fitted into a small diameter portion 4a of the axial hole 4 of the metallic shell 2, whereby the tube 7 is held in a state in which the tube 7 projects from the front end of the metallic shell 2.

[0046] The center rod 8 extends through the axial hole 4 of the metallic shell 2. The front end of the center rod 8 is inserted into the tube 7 and is electrically connected to the rear end of the control coil 10. The rear end of the center rod 8 projects from the rear end of the metallic shell 2. At a rear end portion of the metallic shell 2, an O-ring 12 formed of rubber or the like, an insulating bush 13 formed of resin or the like, a holding ring 14 for preventing falling of the insulating bush 13, and a nut 15 for connecting an electricity supply cable are fitted onto the center rod 8 in this order.

[0047] The heating coil 9 is formed of an alloy containing Ni as a main component and containing W in an amount smaller than that of Ni (i.e., 0.5 mol% to 15 mol% in the present embodiment). That is, the heating coil 9 is formed of an alloy containing Ni and W, each of which has a vapor pressure lower than that of each of metal elements forming a conventionally used Fe-Cr-Al alloy as shown in FIG. 2.

[0048] The portion which is exposed to a space in the tube 7 contains at least one of Cr in an amount of 5 mol% to 30 mol%, Si in an amount of 1 mol% to 10 mol%, and Ti in an amount of 1 mol% to 5 mol%. In the present embodiment, the alloy forming the heating coil 9 disposed in a space in the tube 7 contains such an element.

[0049] The alloy forming the heating coil 9 may contain, in addition to or in place of such an element, at least one of V in an amount of 5 mol% to 10 mol%, Mo in an amount of 5 mol% to 10 mol%, Nb in an amount of 1 mol% to 5 mol%,

and Ta in an amount of 1 mol% to 10 mol%.

[0050] The alloy forming the heating coil 9 may contain an inevitable impurity (e.g., C, Mn, S, O, or N) in a total amount of 0.5 mass% or less. When the amount of such an inevitable impurity contained in the alloy is 0.5 mass% or less, deterioration of processability or durability can be more reliably prevented.

[0051] In the present embodiment, the alloy forming the heating coil 9 contains phosphorus (P) in an amount of 0.05 mass% or less. As compared with the aforementioned inevitable impurity, P is likely to affect processability or durability even when the P content of the alloy is low. Therefore, the amount of P contained in the alloy is adjusted to a sufficiently low level (i.e., 0.05 mass% or less). From the viewpoints of processability and durability, preferably, a smaller amount of P is contained in the alloy, more preferably, the amount of P contained in the alloy is 0.03 mass% or less, still more preferably, no P is contained in the material forming the alloy.

[0052] As described above in detail, according to the present embodiment, the heating coil 9 is formed of an alloy containing Ni as a main component and containing W in an amount smaller than that of Ni. As described above, Ni (i.e., a component of the material of the heating coil 9) has a vapor pressure lower than that of Fe or the like, and thus the component is less likely to be evaporated even at a high temperature. Even if Ni present in a surface layer of the heating coil 9 is evaporated at a high temperature, W, which has a very low vapor pressure, does not evaporate and remains in the surface layer of the heating coil 9. As a result, a coating of W (W coating) is formed on the surface layer of the heating coil 9. Therefore, evaporation of Ni no longer occurs, by virtue of the thus-formed W coating. That is, according to the present embodiment, the glow plug exhibits dramatically prolonged service life by a synergistic interaction between Ni, which is less likely to be evaporated than Fe, and W, which forms a coating on the surface layer of the heating coil 9.

[0053] The present invention employs an Ni-W alloy (although it is relatively easily oxidized), since the tube 7 is hermetically sealed, and thus invasion of oxygen from the outside into the tube 7 is suppressed to a minimum possible extent. In other words, since the heating coil 9 is disposed in the tube 7; i.e., the environment in which invasion of oxygen is suppressed, an Ni-W alloy can be employed for forming the heating coil 9.

[0054] When an alloy containing Fe as a main component is formed into a coil, the alloy must be subjected to wire-drawing under heating (hot wiredrawing). In contrast, an alloy containing Ni as a main component can be formed into a coil without requiring heating. That is, an Ni-W alloy is superior, in processability, to an alloy containing Fe as a main component. From this viewpoint, employment of an Ni-W alloy is effective.

[0055] The portion which is exposed to a space in the tube 7 contains at least one of Cr, Si, and Ti in a specific amount. Such an element serves as a so-called oxygen getter element and can capture oxygen in the tube 7. Therefore, oxidation of the heating coil 9, which is relatively easily oxidized, can be further reliably prevented, resulting in further improvement of durability.

[0056] Particularly in the present embodiment, since the heating coil 9 contains Cr, Si or Ti, an oxide film can be formed on the surface of the heating coil 9 through reaction between Cr, Si, or Ti and oxygen contained in the tube 7. Therefore, the thus-formed oxide film can prevent invasion of nitrogen or oxygen into the heating coil 9, and thus formation of a nitride or an oxide can be prevented in the heating coil 9.

[0057] When at least one of V, Mo, Nb, and Ta is also incorporated into the heating coil 9 in a specific amount, the electrical resistivity of the heating coil 9 can be increased. In such a case, the heating coil 9 is not required to be excessively thinned so as to attain a resistance of interest, and thus the durability of the heating coil 9 can be further improved.

[0058] In the present embodiment, the amount of P contained in the alloy forming the heating coil 9 is 0.05 mass% or less. Therefore, there can be more reliably prevented, for example, reduction in high-temperature strength due to formation of a low-melting-point compound through reaction between Ni and P, or breakage of the heating resistor due to segregation of P. Thus, deterioration of processability can be prevented, and the above-described effect of improving durability associated with employment of an Ni-W alloy can be further reliably attained.

[0059] In order to investigate actions and effects attained by the above-described embodiment, there were produced a glow plug sample having a heating coil formed from an Fe-Al-Cr alloy (this sample corresponds to Comparative Example), and glow plug samples each having a heating coil formed from an alloy containing Ni as a main component and containing W in an amount smaller than that of Ni (these samples correspond to Examples). Each of the thus-produced samples was subjected to a durability evaluation test.

[0060] The durability evaluation test was carried out as follows. Specifically, each glow plug sample was subjected to thermal cycles, each cycle consisting of supply of electricity to the sample for elevating the temperature of the surface of a portion of the tube (measurement portion) located 2 mm away from the front end of the tube to 1,100°C, supply of electricity to the sample for maintaining the temperature for 360 seconds, and subsequent cooling for 120 seconds. The number of thermal cycles until breakage occurred in the sample (i.e., number of breakage cycles) was measured. Table 1 shows the composition of the alloy forming the heating coil of each sample, and the number of breakage cycles of the sample. The temperature was measured by means of a thermocouple attached to the aforementioned measurement portion. The wire diameter of the heating coil of each sample was regulated so that all the samples exhibited the same resistance. In Table 1, the alloy composition is shown in two ways; i.e., the amount of an element (e.g., W, Mo, or Al)

is represented by mol%, and the amount of such an element is represented by mass%.

[0061]

[Table 1]

Composition (mol%)	Composition (mass%)	Number of breakage cycles	Evaluation
Fe-13.2Al-25.5Cr	Fe-7Al-26Cr	8000	X
Ni-0.5W	Ni-1.5W	8500	○
Ni-0.7W	Ni-2.2W	9000	○
Ni-5W	Ni-14.7W	10000	○
Ni-9W	Ni-23.7W	13000	○
Ni-14.5W	Ni-34.7W	16000	○
Ni-0.7W-5Mo	Ni-2.1W-7.8Mo	12000	○
Ni-0.7W-5Al	Ni-2.2W-2.3Al	10000	○
Ni-0.7W-30Cr	Ni-2.2W-27.1Cr	10000	○
Ni-5W-5Mo	Ni-13.8W-7.2Mo	12000	○
Ni-9W-5Mo	Ni-23.0W-6.7Mo	16000	○
Ni-5W-5Ta	Ni-12.9W-12.7Ta	12000	○
Ni-5W-5Nb	Ni-13.8W-7.0Nb	11000	○
Ni-9W-3Ti	Ni-23.8W-2.1Ti	14000	○
Ni-9W-5Si	Ni-24.2W-2.1Si	13000	○
Ni-14W-2V	Ni-33.8W-1.3V	16000	○

[0062] As shown in Table 1, samples of Examples, each having a heating coil formed of an alloy containing Ni as a main component and containing W, exhibited excellent durability (i.e., the number of breakage cycles: more than 8,000). This is considered to be attributed to the fact that, after evaporation of Ni in a surface layer of the heating coil, a coating of W (i.e., an element having very low vapor pressure) is formed on the surface layer of the heating coil, and thus evaporation of Ni is effectively suppressed.

[0063] Particularly, a sample having a heating coil formed of an alloy containing Ni and W (W content: 5 mol% or more) was found to exhibit very excellent durability (i.e., the number of breakage cycles: 10,000 or more).

[0064] A sample having a heating coil formed of an Ni-W alloy containing an element such as Mo, Cr, Ta, Nb, Ti, Si, or V was found to exhibit very excellent durability, even in the case of relatively low W content. This improvement of durability is considered to be attained by the below-described function of such an element. Conceivably, when an element such as Cr, Si, or Ti is incorporated, the element serves as an oxygen getter element and can capture oxygen in the tube, and thus oxidation of the heating coil can be prevented. Also, conceivably, when V, Mo, Nb, or Ta is incorporated, the electrical resistivity of the alloy forming the heating coil can be increased, and the wire diameter of the heating coil can be relatively increased.

[0065] In comprehensive consideration of the aforementioned results of the evaluation test, preferably, a heating coil is formed from an alloy containing Ni as a main component and containing W in an amount smaller than that of Ni, from the viewpoint of improvement of durability. Particularly preferably, the amount of W contained in the alloy is adjusted to a relatively high level (i.e., 5 mol% or more), or an additional element such as Mo or Cr is incorporated into the alloy, from the viewpoint of further improvement of durability.

[0066] Next, cylindrical alloys (ϕ 12 mm) containing Ni as a main component and containing W in different amounts were provided, and each cylindrical alloy was thinned to thereby form a wire material of ϕ 1 mm. The processability of each alloy depending on the W content thereof was evaluated by determining whether or not breakage occurred in a wire material formed from the alloy. For evaluation of the processability of each cylindrical alloy, the alloy was thinned in a stepwise manner, and the alloy was subjected to thermal treatment at the time when the diameter of the alloy became ϕ 10 mm, ϕ 8 mm, ϕ 6 mm, ϕ 4 mm, ϕ 3 mm, ϕ 2.3 mm, and ϕ 1.8 mm for wire drawing.

[0067] When a wire material of ϕ 1 mm having no breakage was obtained, the wire material was formed into a heating coil, and a glow plug sample was produced by use of the heating coil. The durability of the thus-produced sample was

evaluated by the following test. Specifically, the sample was subjected to thermal cycles, each cycle consisting of supply of electricity to the sample for elevating the temperature of the surface of a portion of the tube (measurement portion) located 2 mm away from the front end of the tube to 1,130°C, supply of electricity to the sample for maintaining the temperature for 120 seconds, and cooling by air blowing at ambient temperature for 120 seconds after termination of electricity supply. The number of thermal cycles until breakage occurred in the heating coil (i.e., number of breakage cycles) was measured. Table 2 shows the presence or absence of breakage in each sample upon production thereof, as well as the number of breakage cycles of the sample. Table 2 also shows the alloy composition wherein the W content is represented by mass%.

[0068]

[Table 2]

Composition (mol%)	Composition (mass%)	Presence/absence of breakage	Number of breakage cycles
Ni-0.3W	Ni-0.9W	Absence	8500
Ni-0.5W	Ni-1.5W	Absence	10000
Ni-6W	Ni-16.7W	Absence	14000
Ni-10W	Ni-25.8W	Absence	16000
Ni-13W	Ni-31.9W	Absence	17000
Ni-15W	Ni-35.6W	Absence	17000
Ni-16W	Ni-37.4W	Presence	-
Ni-18W	Ni-40.7W	Presence	-
Ni-19W	Ni-42.4W	Presence	-
Ni-22W	Ni-46.9W	Presence	-

[0069] As shown in Table 2, the number of breakage cycles increased as W content increased. However, breakage occurred in a sample when produced from an alloy having a W content of more than 15 mol%, and the alloy was evaluated to have poor processability in terms of the aforementioned wiredrawing.

[0070] The above-described test data suggest that the W content of an alloy employed is preferably adjusted to 15 mol% or less for preventing deterioration of processability and durability.

[0071] Next, cylindrical alloys (ϕ 12 mm) containing Ni as a main component, containing W in an amount of 12 mol% (29.9 mass%), and having different P contents (mass%) were provided, and each cylindrical alloy was thinned in a manner similar to that described above, to thereby form a wire material of ϕ 1 mm. The processability and durability of each alloy depending on the P content thereof was evaluated by determining whether or not breakage occurred in a wire material formed from the alloy. When a wire material of ϕ 1 mm having no breakage was obtained, the wire material was formed into a heating coil, and a glow plug sample was produced by use of the heating coil. The durability of the thus-produced sample was evaluated by the aforementioned test. Specifically, the sample was subjected to thermal cycles, each cycle consisting of supply of electricity to the sample for elevating the temperature of the surface of a portion of the tube (measurement portion) located 2 mm away from the front end of the tube to 1,130°C, supply of electricity to the sample for maintaining the temperature for 360 seconds, and subsequent cooling for 120 seconds. The number of thermal cycles until breakage occurred in the heating coil (i.e., number of breakage cycles) was measured. Table 3 shows the presence or absence of breakage in each sample upon production thereof, as well as the number of breakage cycles of the sample.

[0072]

[Table 3]

	P content (mass%)	Presence/absence of breakage	Number of breakage cycles
1	0.002	Absence	14000
2	0.005	Absence	14000
3	0.01	Absence	13000
4	0.03	Absence	12000
5	0.05	Absence	10000
6	0.12	Presence	-

[0073] As shown in Table 3, breakage did not occur in samples (samples 1 to 5) when produced from an alloy having a P content of 0.05 mass% or less, and the alloy was found to have excellent processability and durability. It was also found that the number of breakage cycles increases as P content decreases.

[0074] The above-described test data suggest that the P content of an alloy employed is preferably adjusted to 0.05 mass% or less for reliably preventing deterioration of processability and durability. From the viewpoint of improvement of durability, the P content is preferably adjusted to a lower level (more preferably, 0.03 mass% or less).

[0075] Notably, the present invention is not limited to the details of the above-described embodiment, and may be practiced as follows. Needless to say, other application examples and modifications not illustrated below are also possible.

[0076]

(a) In the above-described embodiment, the alloy forming the heating coil 9 contains Cr, Si, or Ti. However, the insulating powder 11 or the alloy forming the tube 7 may contain Cr, Si, or Ti, or a metal coating containing Cr, Si, or Ti may be formed on the inner circumferential surface of the tube 7. Also in such a case, Cr, Si, or Ti serves as an oxygen getter and can capture oxygen in the tube 7. Therefore, similar to the case where Cr, Si, or Ti is incorporated into the heating coil 9, the service life of the glow plug can be further prolonged. When Cr, Si, or Ti is incorporated into the insulating powder 11, preferably, the amount of Cr, Si, or Ti is adjusted so that the insulating powder 11 does not lose its insulating property.

[0077]

(b) In the above-described embodiment, the alloy forming the heating coil 9 contains an additional element (i.e., Cr, Si, or Ti). However, the heating coil 9 may be formed from an Ni-W alloy without incorporation of such an additional element.

[0078]

(c) In the above-described embodiment, the tube 7 is formed of a metallic material, for example, an alloy containing Fe or Ni as a main component. The metallic material forming the tube 7 is not limited to such an example. However, the metallic material forming the tube 7 must be a material which can prevent invasion of oxygen into the tube 7.

[0079]

(d) The shape, etc. of the glow plug 1 are not limited to those described above in the embodiment. For example, the tube 7 may be formed such that it has generally constant outer diameter in an axial direction with omitting the large diameter portion 7b. Alternatively, the axial hole 4 of the metallic shell 2 may be formed such that it has constant diameter in an axial direction with omitting the small diameter portion 4a, and the tube 7 may be press-fitted into the axial hole 4.

[0080]

(e) In the above-described embodiment, the glow plug 1 includes the control coil 10. However, the control coil 10

may be omitted, and the rear end of the heating coil 9 may be connected directly to the center rod 8.

[0081]

(f) In the above-described embodiment, wiredrawing was carried out for evaluating the processability of the alloy forming the heating resistor of the present invention. However, the method for processing the alloy is not limited to the aforementioned wiredrawing process. Therefore, wiredrawing of an alloy having relatively poor processability may be carried out through increased thinning steps.

[Description of Reference Numerals]

[0082]

1: glow plug
7: tube
9: heating coil (heating resistor)

Claims

1. A glow plug comprising:

a cylindrical tube which has a closed front end and which is hermetically sealed; and
a heating resistor which is disposed in the tube and whose front end is connected to the front end of the tube,
characterized in that the heating resistor is formed of an alloy containing nickel as a main component and containing tungsten in an amount smaller than that of nickel.

2. A glow plug according to claim 1, which includes a portion exposed to a space in the tube and containing at least one of chromium, silicon, and titanium.

3. A glow plug according to claim 1 or 2, wherein the heating resistor contains at least one of chromium in an amount of 5 mol% to 30 mol%, silicon in an amount of 1 mol% to 10 mol%, and titanium in an amount of 1 mol% to 5 mol%.

4. A glow plug according to any one of claims 1 to 3, wherein the heating resistor contains at least one of vanadium in an amount of 5 mol% to 10 mol%, molybdenum in an amount of 5 mol% to 10 mol%, niobium in an amount of 1 mol% to 5 mol%, and tantalum in an amount of 1 mol% to 10 mol%.

5. A glow plug according to any one of claims 1 to 4, wherein the heating resistor contains tungsten in an amount of 0.5 mol% or more.

6. A glow plug according to any one of claims 1 to 5, wherein the heating resistor contains tungsten in an amount of 15 mol% or less.

7. A glow plug according to any one of claims 1 to 6, wherein the heating resistor contains phosphorus in an amount of 0.05 mass% or less.

FIG. 1A

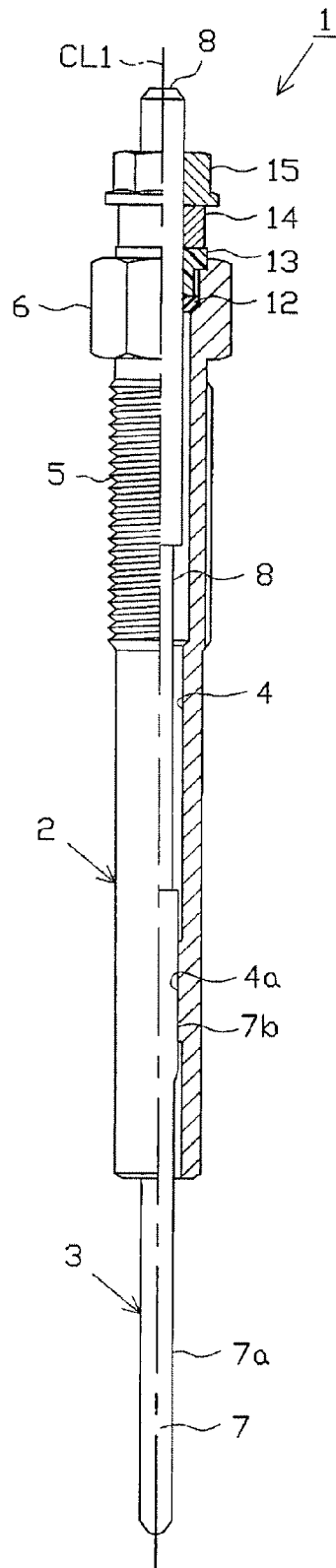


FIG. 1B

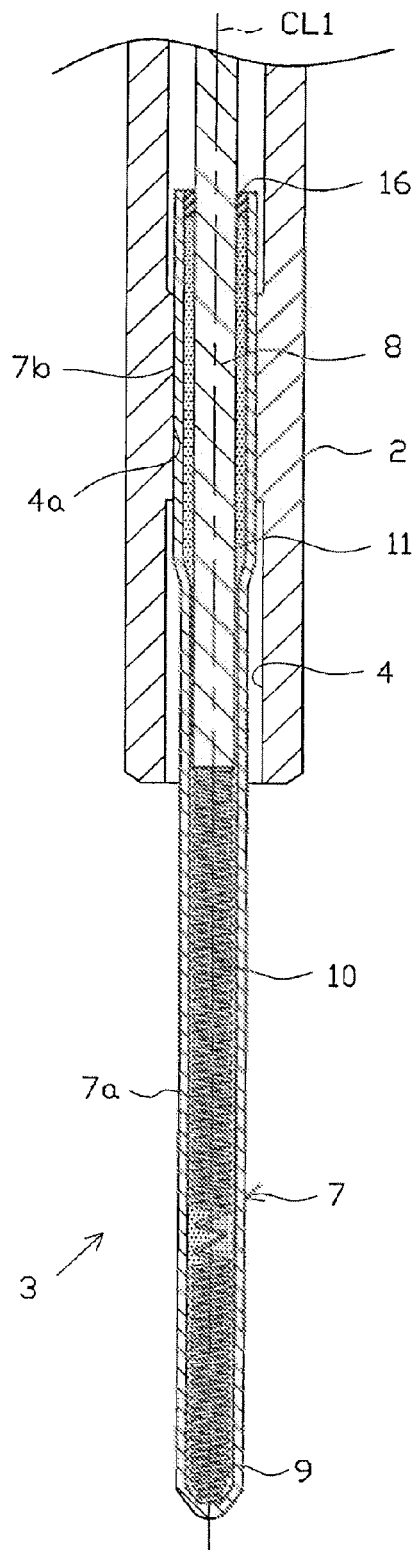
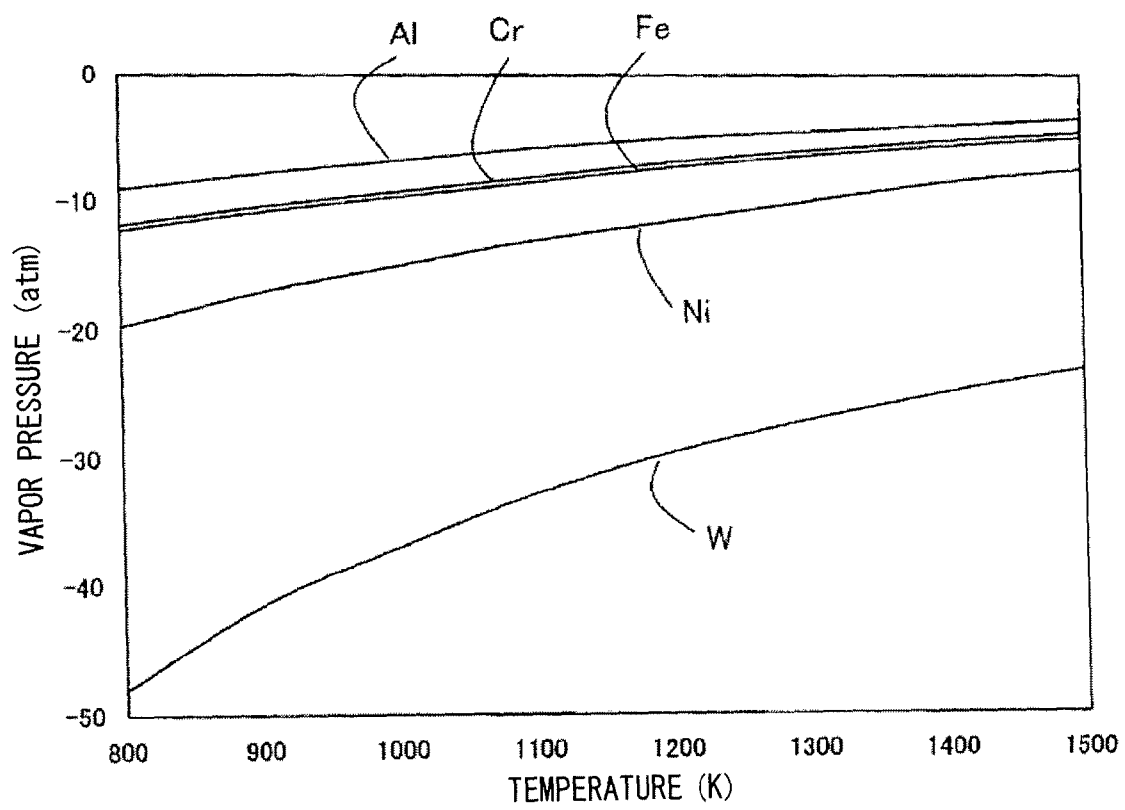


FIG. 2





EUROPEAN SEARCH REPORT

 Application Number
EP 10 18 6701

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