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71 Applicant: **ALLIED CORPORATION**
Columbia Road and Park Avenue P.O. Box 2245R (Law
Dept.)
Morristown New Jersey 07960(US)

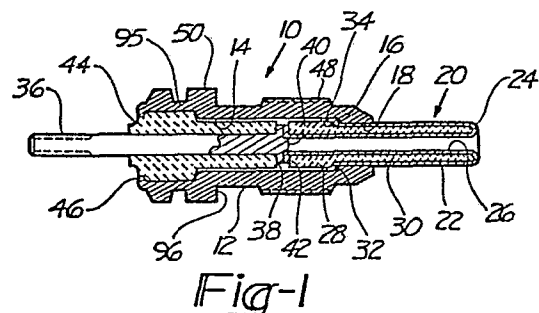
72 Inventor: **Zulauf, Gary Byron**
c/o Allied Corporation P.O. Box 5060
Southfield Michigan 48086(US)

72 Inventor: **Weber, David Charles**
c/o Allied Corporation P.O. Box 5060
Southfield Michigan 48086(US)

74 Representative: **Brullé, Jean et al,**
Service Brevets Bendix 44, rue François 1er
F-75008 Paris(FR)

54 **Glow plug having a metallic silicide resistive film heater.**

57 A glow plug having a heater member (20) formed by depositing a metallic-silicide layer (24) on the internal and external surfaces of a cylindrical ceramic substrate (22). The metallic-silicide layer (24) deposited on the external surface of the substrate (22) is electrically connected to a metal shell (12) which supports one end of the heater member (20). An axial electrode (36) disposed in the shell (12) is electrically connected to the metallic-silicide layer (24) disposed on the internal surface of the substrate (22) and further serves to lock the heater member (20) in the shell (12).



A GLOW PLUG HAVING A METALLIC SILICIDE
RESISTIVE FILM HEATER

Cross Reference

The invention is related to the glow plug described in co-pending, commonly assigned patent application Serial No. 507,254 entitled "An Improved Glow Plug Having a Resistive Film Heater" filed June 23, 1983.

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Background of the Invention

The invention is related to the field of electric heaters for the ignition of hydrocarbon fuels and in particular to a glow plug for internal combustion engines having a metallic silicide resistive film heater.

Prior Art

15 Electrically energized glow plugs are currently used in compression ignited or Diesel type internal combustion engines to assist in the ignition of compressed air/fuel mixtures during cold starts. In particular glow plugs are essential in the Northern states during the winter months when the ambient temperature falls below 10°C.

20 In commonly assigned patent application Serial No. 507,254 entitled "An Improved Glow Plug Having A Resistive Surface Film Heater" filed June 23, 1983, a novel heater configuration was disclosed in which a noble metal resistive film was disposed along the external and internal surfaces of a cylindrical ceramic substrate. Although this type of glow plug has

excellent performance characteristics which are superior to glow plugs currently used in automotive vehicles, difficulties have been experienced in the deposition of satisfactory noble metal resistive films due to
5 micro-irregularities on the surfaces of the ceramic substrate and the thinness of the noble metal films required to achieve the desired resistivity. The object of the invention is the substitution of a
10 metallic-silicide film for the noble metal film which because of the higher resistivity of the metallic silicides permits the use of thicker resistive films which are less sensitive to the micro-irregularities of the ceramic structure, have a higher melting temperature which permits the glow plug to be operated at higher
15 temperatures, and have a larger positive coefficient of resistance potentially making the glow plug self-limiting reducing the requirements of the attendant controller.

The use of metallic-silicides for heater elements is
20 well-known in the art. The Kanthal Corporation of Bethel, Connecticut makes a variety of heater elements using metal silicides as the resistive element. These heater elements take the form of a metallic silicide as were disclosed by Giler in U.S. Patent No. 3,912,905 or
25 a layer of metallic-silicide formed over an insulating or ceramic layer disposed over a metal wire for structural strength as disclosed by Wilson in U.S. Patent No. 3,810,734. Suzuki et al in U.S. Patent No. 4,437,440 discloses a glow plug having a tubular
30 molybdenum disilicide (MoSi_2) element in which electrical contact is made between the shell and an axial electrode contacting the closed end of the tubular heating element.

Summary of the Invention

The invention is a glow plug for internal combustion
5 engines of the type having a metal shell, and an axial
electrode disposed in the metal shell and electrically
insulated therefrom, a heater member electrically
connected between the metal shell and the axial
electrode characterized by a cylindrical substrate and a
10 continuous metallic-silicide resistive layer disposed on
the surfaces of the cylindrical substrate. The
substrate has an internal portion disposed in the shell
and captivated between one end of the shell and the
axial electrode, and an external portion protruding
15 external to the shell. The metallic-silicide resistive
layer is disposed along the internal and external
surfaces of the cylindrical substrate and around the end
of said external portion. The portion of the resistive
layer disposed on the external surface of the substrate
20 being in electrical contact with the metal shell and the
portion of the resistive layer disposed on the internal
surface being in electrical contact with the axial
electrode.

The advantages of the glow plug is that the interior
25 of the cylindrically shaped heater member forms an
extremely hot cul-de-sac which is not cooled by the
impinging air/fuel mixture. Another advantage is that
the metallic-silicide resistive layer is relatively
insensitive to oxidation and the corrosive atmosphere
30 inside the engine. Another advantage is that the low
mass of the heater member permits the glow plug to reach
an operating temperature in less than 5 seconds with an
applied power of less than 60 watts. These and other
advantages of the glow plug will become more apparent
35 from a reading of the specification in
conjunction with the figures.

Brief Description of the Drawings

FIGURE 1 is a cross-sectional view of the glow plug embodying the cylindrical ceramic heater member.

5 FIGURE 2 is a cross-sectional view of a first embodiment of the cylindrical heater member.

FIGURE 3 is a cross-sectional view of a second embodiment of the cylindrical heater member.

10 FIGURE 4 is a cross-sectional view of an embodiment of the heater member having the interior of the ceramic filled with a metallic silicide.

FIGURE 5 is a cross-sectional view of an embodiment of the heater member having the cylindrical substrate formed around the axial electrode.

15 FIGURE 6 is a cross-sectional view of an embodiment of the heater member having the interior of the cylindrical substrate filled with alumina.

Detailed Description of the Invention

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A cross-sectional view of the glow plug is shown in Figure 1. The glow plug comprises a cylindrical metal shell 12 having an internal bore 14. Formed at one end of the shell 12 is a contact seat 16, defining a heater aperture 18. Located in the internal bore 14 is a heater member 20 having a resistive metallic-silicide surface film heater element 24 coated or disposed on at least one surface of a non-conductive cylindrical substrate 22 as shall be described hereinafter. The non-conductive substrate 22 is preferably a high temperature ceramic, such as alumina, but may be quartz, a high temperature glass or a metal sleeve coated with an insulating material. The cylindrical

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substrate 22 has an internal bore 26 passing therethrough, a base or internal portion 28 disposed in shell 12 and a smaller diameter external portion 30 protruding external to the shell 12 through the heater aperture 18. The heater aperture 18 has a diameter smaller than the diameter of the internal portion 28 of the substrate 22 and larger than the diameter of the external portion 30.

An axial electrode 36 having a radial flange 38 and guide finger 40 formed at one end is received in the internal bore 26 of the cylindrical substrate 22 with the radial flange abutting the internal end face of the cylindrical substrate 22. The axial electrode 36 producing a force on the end of the cylindrical substrate 22 sufficient to deform an electrically conductive gasket 32 interposed between shoulder 34 of the cylindrical substrate 22 and the shell contact seat 16. The conductive gasket 32 may be copper, gold or any other maleable metal or alloy.

A cylindrical insulator member 44, similar to the insulator commonly used in spark plugs, is inserted in bore 14 circumscribing axial electrode 36 and abutting the opposite face of radial flange 38. The end of the shell 12 is crimped over to form a peripheral lip 46. The insulator member 44, axial electrode 36 and heater member 20 are then locked tightly inside of shell 12 by a hot press operation which heat then cools the undercut groove 95 while the compressive force is applied between peripheral lip 46 and the opposing end 96 of an external hexagonal portion 50. The shell 12 further includes an externally threaded portion 48 for mounting the glow plug in the engine. The external hexagonal portion 50 facilitates threading the glow plug 10 into an appropriate threaded aperture of the engine.

One advantage of the glow plug 10 shown in Figure 1 is that the electrical connections between the surface film heater element 24, the shell 12 and the axial electrode 36 are made internal to shell 12 where they are protected from the high temperatures and corrosive atmosphere inside the engine. This configuration eliminates the erosion problems of the electrical connections between the metallic silicide film, the shell 12 and the axial electrode 36.

10 The details of the preferred embodiment of the heater members 20 are illustrated in Figure 2. Referring to Figure 2, the heater member 20, as previously described, has a generally cylindrical ceramic substrate 22 having an axial bore 26, an
15 internal portion 28, a smaller diameter external portion 30 and a sloped shoulder 34 connecting the external surfaces of the internal portion 28 and external portion 30. Radii are provided at the edges at the substrate's end face 52 blending the end face 52 with the contiguous
20 internal surface of bore 26 and the external surface 64 of the substrate or a full radius may be provided as shown. In a similar manner, a radius 54 is provided at the base of the substrate blending the end face 42 with the internal surface of bore 26.

25 A continuous resistive metallic-silicide film 24, such as molybdenum disilicide (MoSi_2), tungsten disilicide (WSi_2) tantalum disilicide (TaSi_2) or titanium disilicide (TiSi_2), is deposited along the sloped shoulder 34 along the length of the external
30 surface 64, around the end 52, then along the internal surface of bore 26 terminating on end face 42 at a point intermediate the internal and external diameters of the substrate. The metallic-silicide layer 24 may also be extended a short distance along the length of the
35 external surface 60 of substrate 22 as shown.

The opposite ends of the metallic-silicide layer 24 are electrically isolated by the uncoated region 56 of the external surface 60 and an uncoated peripheral region 58 of the end face 42. The metallic-silicide coating or film 24 may be applied to the desired surfaces of the substrate 22 by chemical vapor deposition techniques or any other method known in the art. Since the deposition techniques for metallic-silicide films have been extensively developed for low-resistance contacts in the solid state industry, it is not necessary to describe in detail how the metallic-silicide films are deposited for an understanding of the invention.

In practice, the uncoated areas may be protected by mechanical shields during the deposition process. However, the entire substrate may be coated and the metallic-silicide layer removed from the insulator regions 56 and 58 by air abrasion. As shown in Figure 6, the interior of the cylindrical substrate after it has been coated with a metallic silicide may be filled with a dielectric material 65, such as alumina, to increase the structural strength of the ceramic substrate.

In the embodiment shown on Figure 3, highly conductive metal coating 66 and 68 may be applied over metallic silicide layer 24 disposed on the sloped shoulder 34 and the internal end face 42 respectively to assure good electrical contact between the metallic silicide surface layer 24, the heater seat 16, and the axial electrode 26, respectively.

In the embodiment shown on Figure 4, the length of the axial bore 26 is completely filled with metallic-silicide material or other suitable conductive material to form an internal conductor 70 and the

resistive metallic-silicide layer 24 is deposited along the length of the substrates external surfaces 34 and 64 and over the end 52 making electrical contact with the internal conductor 70 filling external bore 26. The
5 internal conductor 70 filling the bore 26 may have a recess 72 formed at the end face 42 of the substrate 22 to receive the guide finger 40 of the axial electrode 36 and may be extended onto the end face 42 to provide a contact region 74 for the axial electrodes radial flange
10 38. Alternatively, the ceramic substrate may be formed directly around the axial electrode 36 and the resistive metallic-silicide film 24 deposited along the external surfaces 34 and 60 of the substrate 22 and over the end surface 74 of the axial electrode 36 as shown in Figure
15 5. In this embodiment, the axial electrode 36 has a protrusion 76 adjacent to the interior portion 28 of the cylindrical substrate 22 to longitudinally lock the substrate 22 to the axial electrode 36 preventing any possible longitudinal shifting of the substrate 22 with
20 respect to the axial electrode which would fracture or cause any electrical discontinuities at the junction between the metallic-silicide film 24 and the end face 78 of the axial electrode 36. A highly conductive metal coating such as coating 66, shown in Figure 3, may be
25 deposited over the sloped shoulder 34 to assure good electrical contact between the shell 12 and the resistive metal-silicide layer 24.

Preferably the cold resistance of the resistive metallic-silicide heater element 24 is between 0.2 and
30 0.6 ohms. which permits the heater member 20 to achieve an operating temperature of greater than 900°C with a current flow of less than 5 amperes when using a 12 volt source of electrical power, such as an automotive battery.

The primary advantage of the cylindrical configuration of the heater member 20 shown on Figures 2 and 3 is that the bore 26 forms a high temperature cul-de-sac adjacent to its external end which is
5 isolated from the cooling effects of the swirling air/fuel mixture in the engine's ignition chamber.

Other advantages of the heater member 20 are:

10 1.) The low mass of the cylindrical substrate 22 and the metallic-silicide surface layer 24 permit the glow plug to reach an operation temperature, greater than 800°C, in less than 5 seconds with an applied electrical power of approximately 60 watts.

15 2.) The watt density of the metallic-silicide surface layer exceeds that of the bulk material of the cylindrical substrate reducing the current requirements to approximately 5 amperes.

20 3.) The electrical contacts to the metallic-silicide surface layer are made internal to the shell 12 reducing their exposure to the higher engine temperatures thereby reducing their oxidation and/or corrosion.

25 4.) The positive temperature coefficient of the metallic-silicide surface layer heater element tends to make the glow plug less susceptible to variations in the applied voltage and easier to control.

5.) The metallic-silicide heater element is highly resistive to the corrosive atmosphere inside the engine.

30 6.). The components of the glow plug are applicable to standard spark plug manufacturing processes and therefore are potentially less costly than other types of glow plugs.

It is recognized that the configuration of the various elements of the glow plug may be changed from those shown in the drawings or discussed in the specification without departing from the spirit of the
5 invention as described herein and set forth in the appended claims.

Claims:

1. In a glow plug of the type having a cylindrical metal shell (12), and an axial electrode (36) disposed
5 in said metal shell (12) and electrically insulated therefrom, a heater member (20) electrically connected between the metal shell (12) and the axial electrode (36) characterized by:

10 a generally cylindrical ceramic substrate (22) having internal, external and end surfaces, said substrate (22) having an internal portion (28) disposed in the shell (12) at one end thereof and captivated therein by said axial electrode (36) and an external portion (30) protruding external to the shell; and

15 a continuous metallic-silicide resistive layer (24) disposed along the internal and external surfaces of said cylindrical substrate (22) and around the end of said external portion (30), the portion said resistive layer (24) disposed along the external surface of said
20 substrate (22) being in electrical contact with the metal shell (12) and the portion said resistive layer (24) disposed along the internal surface of said substrate (22) being in electrical contact with the axial electrode (36).

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2. The heater member of Claim 1 wherein the metal shell (12) has a peripheral seat (16) defining a heater aperture (18) at said one end thereof, said internal portion (28) of said cylindrical substrate (22) has a
30 shoulder portion (34) engaging said peripheral seat (16) and said external portion (30) passes through said heater aperture (18) and wherein said resistive layer (24) disposed along said external surface extends along the surface of said shoulder portion (34).

3. The heater member of Claim 2 wherein the axial electrode (36) has a radial flange (38) engaging the end (42) of said internal portion (28) of said cylindrical substrate, said resistive layer disposed along the internal surface of said substrate (22) is extended along the surface of the end (42) of said internal portion (28) to form an electrical contact area having a diameter intermediate the internal and external diameters of said internal end portion, and wherein the radial flange (38) of the axial electrode (36) makes electrical contact with said contact area.

4. The heater member of Claim 3 having a metal film (66, 68) disposed on the surface of said resistive layer (24) on said shoulder (34) and on said contact area to lower the electrical contact resistance between the metal shell (12) and the axial electrode (36) with the resistive layer (24) disposed along the external and internal surfaces of said cylindrical substrate (22).

5. The heater of Claim 4 having an electrically conductive gasket (32) disposed between said shoulder (34) of the cylindrical substrate (22) and said peripheral seat (16).

6. The heater member of Claim 1 wherein said metallic-silicide resistive layer (24) is a molybdenum disilicide resistive layer.

7. The heater member of Claim 1 wherein said metallic-silicide resistive layer (24) is a tungsten disilicide resistive layer.

8. The heater member of Claim 1 wherein said metallic-silicide resistive layer (24) is a tantalum disilicide resistive layer.
- 5 9. The heater member of Claim 1 wherein said metallic-silicide resistive layer (24) is a titanium disilicide resistive layer.
- 10 10. The heater member of Claim 1 having a dielectric material (65) filling the interior of the cylindrical substrate (22).

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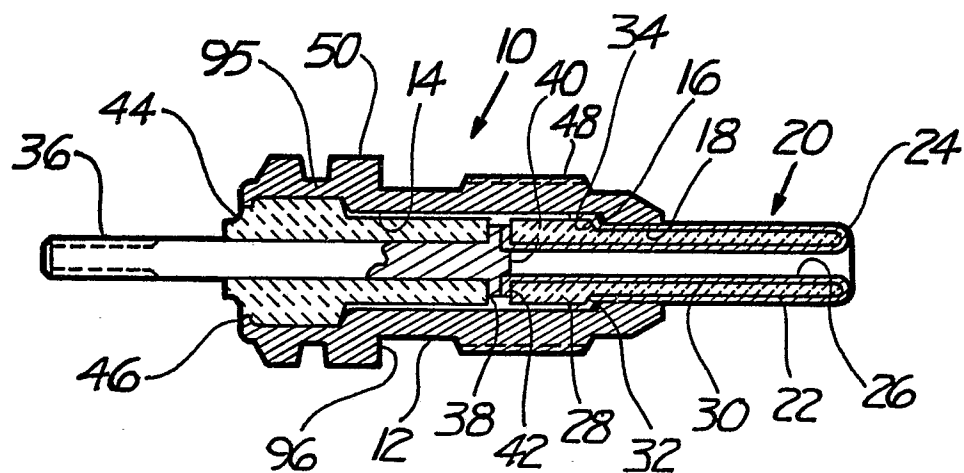


Fig-1

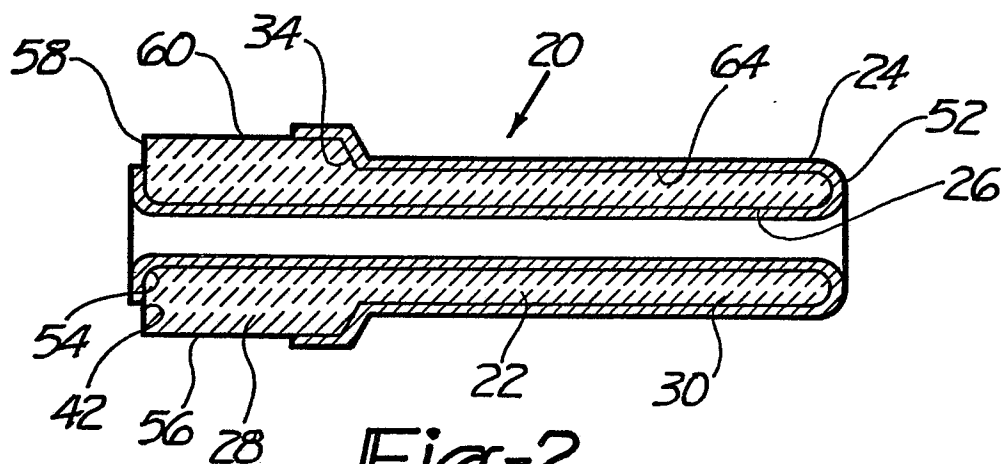


Fig-2

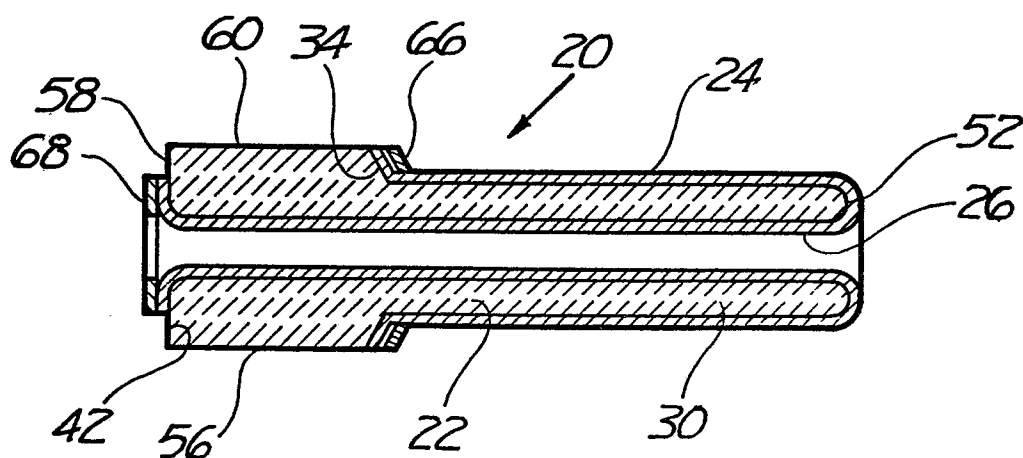


Fig-3

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Fig-4

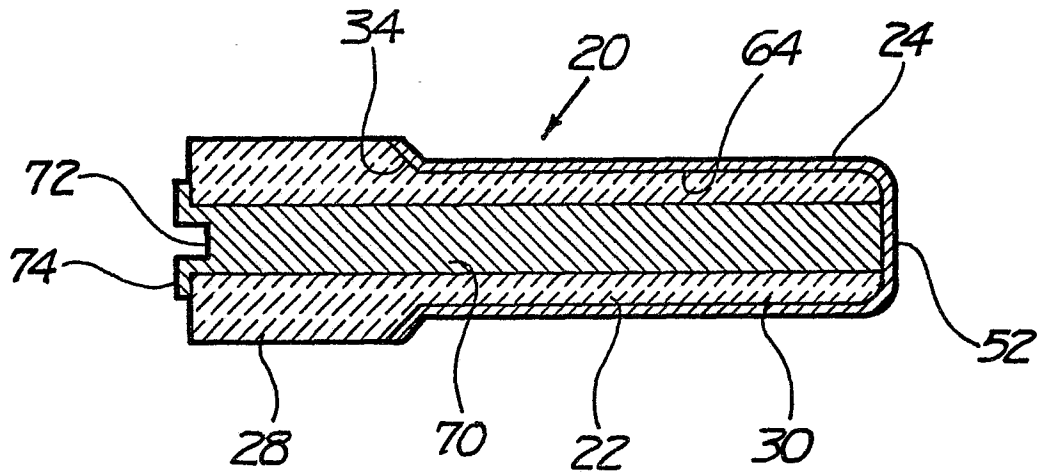


Fig-5

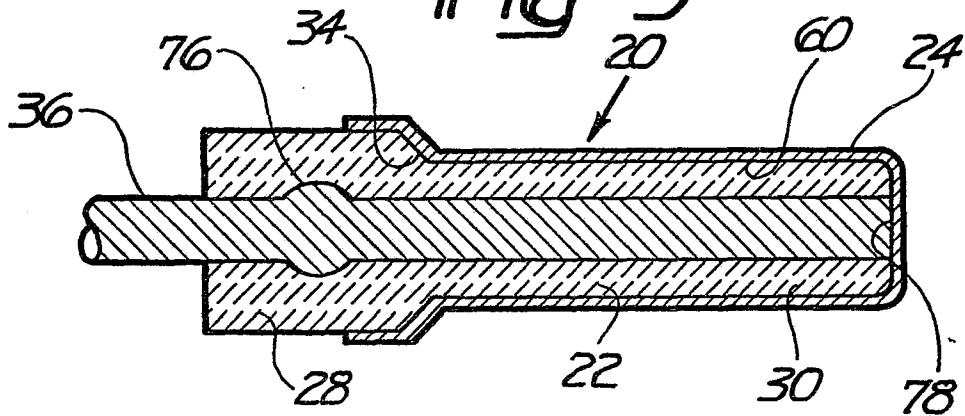


Fig-6

