(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 400 950 A1**

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: 90305797.4

(51) Int. Cl.5: H01T 21/02, H01T 13/39

(22) Date of filing: 29.05.90

(30) Priority: 29.05.89 JP 132760/89

(43) Date of publication of application: 05.12.90 Bulletin 90/49

(84) Designated Contracting States: DE FR GB

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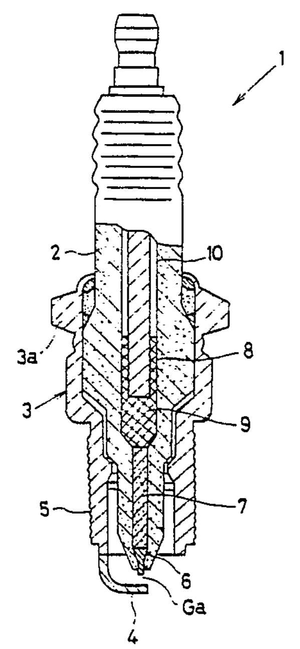
(54) **Spark plug.**

(57) In a spark plug for an internal combustion engine, a center electrode has a firing tip at its front end. The firing tip is made from iridium powder compact which is degreased, and sintered in a condition such as a vacuum, or inert atmosphere, so that the density of the powder compact is more than 90 percent to impart a spark-corrosion resistant property.

Fig. 1



EP 0 400 950 A1

SPARK PLUG

This invention relates to spark plugs, in particular the improvements of their resistance to spark corrosion.

Due to a demand for high power outputs from internal combustion engines, the need has arisen for the spark corrosion resistance of spark plugs to be improved. To meet this demand, firing tips have been manufactured individually from precious metals such as platinum or platinum-iridium based alloys. These firing tips may be columnar or laminar, and respectively bonded to a center electrode and an outer electrode by welding. The columnar tip, however, requires a great amount of precious metal thus raising manufacturing costs. On the other hand, the use of a laminar tip leads to a waste of precious metal because the tip is punched from a sheet of the metal thus reducing the yield by 30 percent. Further, a tip which is made of a Pt-Ir alloy has a melting point of more than 2300 degrees Celsius, so that it is difficult to machine the tip unless it is at an extremely high temperature. The Pt-Ir tip, which is alloyed by means of a metallurgical process, is ductile but fragile, and cracks readily occur on the tip at the time of machining, thus making it very difficult to machine the tip into a complex shape. The tip may also be shaped by means of electric discharge machining, but this takes a long time to finish because of its high melting point.

Therefore, it is an object of the present invention to reduce the above drawbacks, and provide a firing tip structure which has improved spark-corrosion resistance for a long service life at a reduced cost.

According to one aspect of the present invention, there is provided a method of producing a firing tip for a spark plug by making a compact of a substantially metallic powder and sintering the compact.

According to another aspect of the present invention, there is provided a firing tip for a spark plug which is a sintered substantially metallic powder compact.

The firing tip may be made from an iridium powder compact which is compressed by means of metallic die press, thus lending itself to simple mass production, at reduced costs, with minimal waste of precious metal. Further, the use of powder metallurgy makes it possible to form firing tips of complex shapes which metallurgical processes may be unable to achieve.

These and other aspects of the present invention will be more readily understood from the following description, when taken with the attached drawings, which are given by way of example only, and in which:

Fig. 1 is a view of a spark plug according to a first embodiment of the invention, with the lower half of the spark plug in section;

Fig. 2 is an enlarged cross sectional view of the firing tip of Fig. 1;

Fig. 3 is a schematic view showing a dimensional relationship of the firing tip;

Fig. 4 is a view similar to Fig. 1, of a second embodiment of the invention;

Fig. 5 is an enlarged cross sectional view of a firing tip of Fig. 4; and

Fig. 6 is a graph showing the comparison between the corrosion of a sintered compact body and an equivalent conventionally produced iridium tip at different extents of sintering.

Referring to Fig. 1, there is shown a spark plug 1 which is to be incorporated into an internal combustion engine. The spark plug 1 has a cylindrical metallic shell 3 having a nut portion 3a and a thread portion 5 at its outer surface. Within the metallic shell 3, a tubular insulator 2 is concentrically enclosed which is made of alumina and nitride based ceramics such as aluminum nitride (AlN) and silicon nitride (Si_3N_4). The interior of the insulator 2 has as an axial bore 8 into which a terminal electrode 10 and a center electrode 7 are concentrically enclosed. These electrodes 10, 7 are linearly aligned by way of an electrically conductive glass sealant 9 which is encapsulated into the axial bore 8. The center electrode 7 is made of a metallic material, but may be made of an electrically conductive ceramic powder or a metal-coated ceramic body.

A front end of the center electrode 7 is terminated somewhat short of the front end of the insulator 2. Into the front end of the insulator 2, a firing tip 6 is inserted and sintered simultaneously at the insulator, and metallurgically bonded to the front end of the insulator 2 by means of an electrical resistant welding (Wd) as shown in Fig. 2.

In this instance, a front end of the firing tip 6 extends somewhat beyond the front end of the insulator 2 so as to provide a spark gap (Ga) between the tip 6 and an outer electrode 4 mounted on the metallic shell 5. The firing tip 6 is made from an iridium powder compact body by means of a metallic die press, C.I.P., extrusion or injection. Then, the compact body is degreased, and primarily sintered at a temperature of more than 2000 degrees Celsius in a vacuum, or an inert reductive atmosphere, so that the density of the powder compact is more than 90 percent, thus improving the spark-corrosion resistance. The firing tip 6 has a frusto-conically shaped stem 11 at a side in which the tip 6 is metallurgically bonded to the insulator 2. As shown in Fig. 3, the firing tip 6 measures 2.0 mm in length (C), and measures 0.8 mm, and 1.2 mm at its diameters (a), (b) at its stem 11. The stem 11 measures 0.5 mm in height (d) with a 45 degree taper of its stem 11. Now, Table 1 shows a relationship between relative press forming density, sintering atmosphere, sintering conditions and density of a sintered compact body. If the sintered compact body is placed in air at the time of sintering the iridium of the compact body is oxidized to produce a black iridium oxide leading to volatilization. In order to protect the compact body against over-volatilization, it is necessary to sinter the compact body in a vacuum, or an inert atmosphere.

The compact body is then sintered at a temperature ranging from 1700 to 2200 degrees Celsius, and preferably sintered at more than 2000 degrees Celsius.

When the density of the sintered compact body is low, the number pores in the compact body is high, which causes a temperature rise, quickly corroding the firing tip due to the high energy released when a spark discharge occurs. In order to reduce corrosion, it is necessary to ensure that the density of the sintered compact body is more than 90 percent, as shown in Fig. 6 which is a graph showing the comparative erosion between a sintered compact body and a metallurgically processed iridium tip at different densities of sintered compact. The value 100 is taken to be the erosion of metallurgically processed iridium tip. As shown in Fig. 5, the comparative erosion of the firing tip decreases with the increase of the density of the sintered compact body.

In the meantime, it is desirable to sinter the compact body a second time to increase its density again as shown at Table 2.

A spark erosion experiment is carried out with the sample (K) at Table 2 employed. The sample is an iridium powder compact which is compressed by means of a die press, so that the press forming density ratio is 66.3 percent.

Then, the compact body, thus compressed, is primarily sintered at 2200 degrees Celsius in a hydrogen atmosphere for 60 minutes, so that the density of the compact body is 92.5 percent. The compact body is secondarily sintered at 1400 degrees Celsius in an argon atmosphere for 60 minutes, and shaped as shown in Fig. 3 by means of a hot isostatic hydraulic press.

The result shows that the corrosion of sample (K) is substantially identical to that of a Pt-Ir tip which is metallurgically processed to impart an increased erosion-resistant property.

TABLE 1

sample	press forming density ratio (%)	primary sintering atmosphere	sintering condition °C×min.	density of compact body (%)
A	66.4	vacuum	1300× 30	75.6
B	66.4	ditto	1700× 60	86.7
C	67.3	hydrogen	1700× 60	87.7
D	66.4	ditto	1800× 60	87.9
E	66.4	ditto	1900× 60	89.0
F	66.4	ditto	2000× 60	92.1
G	66.3	ditto	2000× 60	92.5

TABLE 2

sample	secondary sintering	sintering condition °C×min.	density of compact body (%)
H	corresponding to sample D	vacuum 1700 × 60	91.6
I	corresponding to sample E	ditto	91.8
J	corresponding to sample F	argon 1400× 60 under hot isostatic hydraulic press	94.4
K	corresponding to sample G	ditto	95.6

Referring to Fig. 4 which shows a spark plug (1A) according to a second embodiment of the invention, the firing tip 6a is formed into a columnar shape, and measures 0.5 mm in diameter (e), and 1.5 mm in length (f).

In this embodiment, like reference numerals in Fig. 1 are identical to those in Fig. 4. A center electrode 12 is made of a copper core clad by a nickel alloy. The center electrode 12 is encapsulated in the axial bore 8 with the glass sealant 9, and has a flanged head 14 at its upper end to engage against a stepped portion 2a of the inner wall of the insulator 2. The front end face of the center electrode 12 has a recess 13 into which the firing tip 6a is fitted, and securely attached at the center electrode 12 by means of a metallurgical bond (L) such as an electron beam welding or a laser welding. It is noted that the firing tip 6a may also be used in igniter plugs in general.

Various other modifications and changes may be also made without departing from the spirit and the scope of the appended claims.

Claims

1. A method of producing a firing tip for a spark plug by making a compact of a substantially metallic powder and sintering the compact.

2. A method of producing a firing tip for a spark plug comprising:
pressing a substantially metallic powder into a compact (of a predetermined shape);
de-greasing the compact;
sintering the compact in a vacuum or inert atmosphere, until the void ratio in the firing tip is below 10%.

3. A method of producing a firing tip according to claim 1 or 2 wherein the compact is sintered into two stages.

4. A method of producing a firing tip according to claim 1, 2 or 3, wherein the compact is mounted in an insulator for a spark plug, and the firing tip and insulator are sintered simultaneously.

5. A firing tip for a spark plug made by the method of any preceding claim.

6. A firing tip for a spark plug which is a sintered substantially metallic powder compact.

7. A spark plug having a firing tip according to claim 5 or 6.

8. A spark plug according to claim 7 wherein the tip is bonded to an electrode extending through the plug.

9. A spark plug according to claim 8 in which a front end face of the center electrode has a recess into which the firing tip is to be fitted, and secured to the center electrode by means of metallurgical bond such as electron beam welding or laser welding.

10. A method, firing tip or spark plug according to any preceding claim wherein the metallic powder is iridium.

Fig. 1

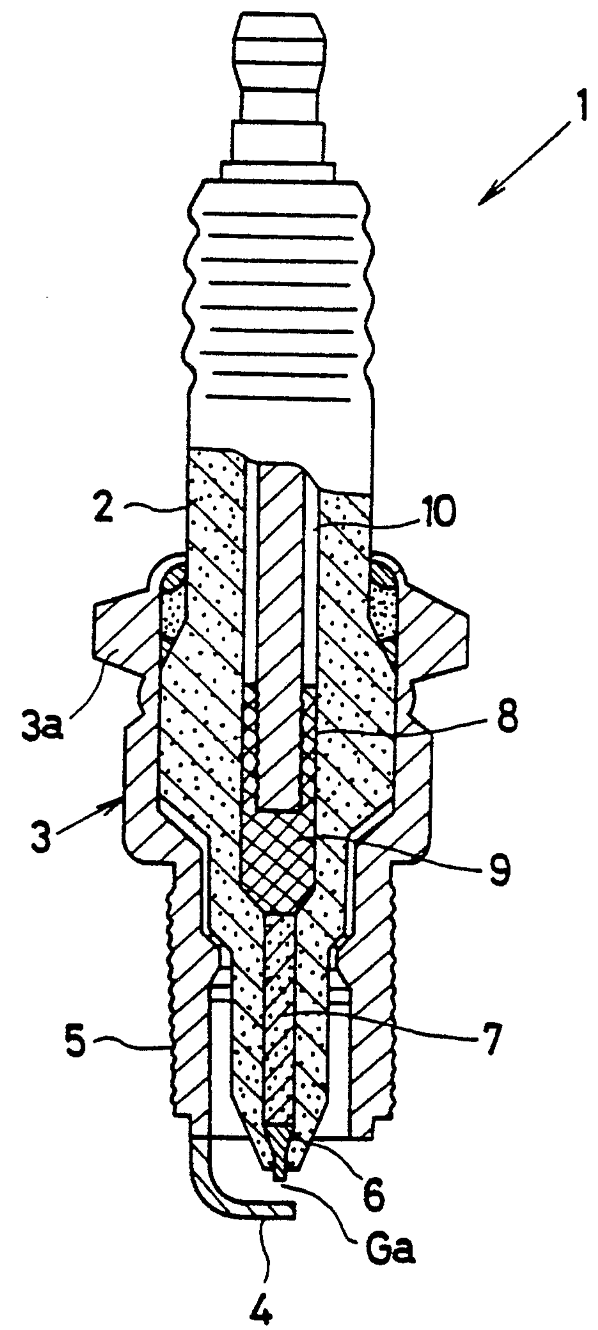


Fig. 2

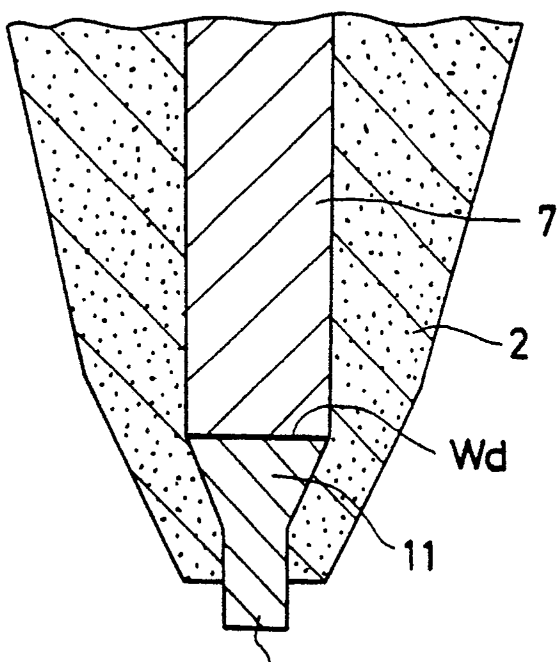


Fig. 3

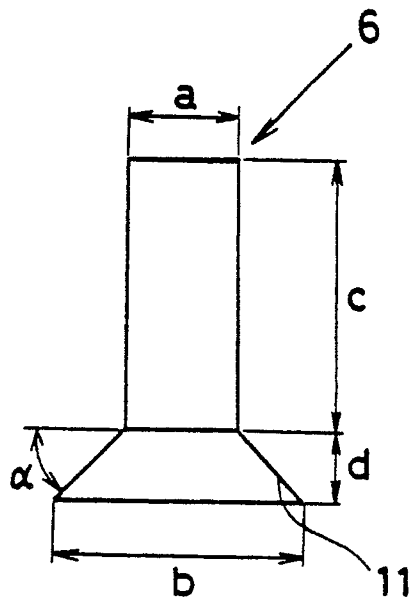


Fig. 5

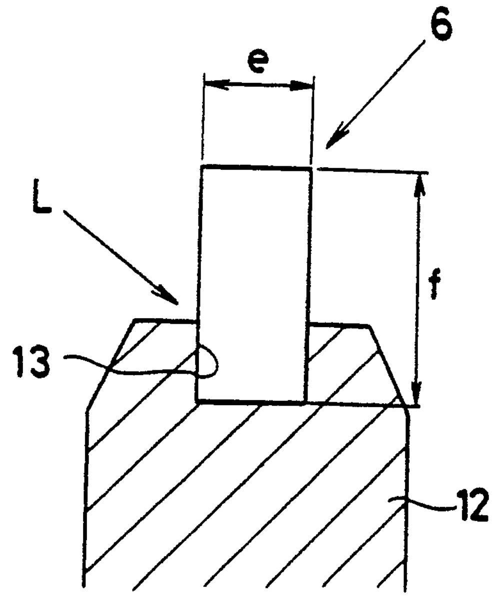


Fig.4

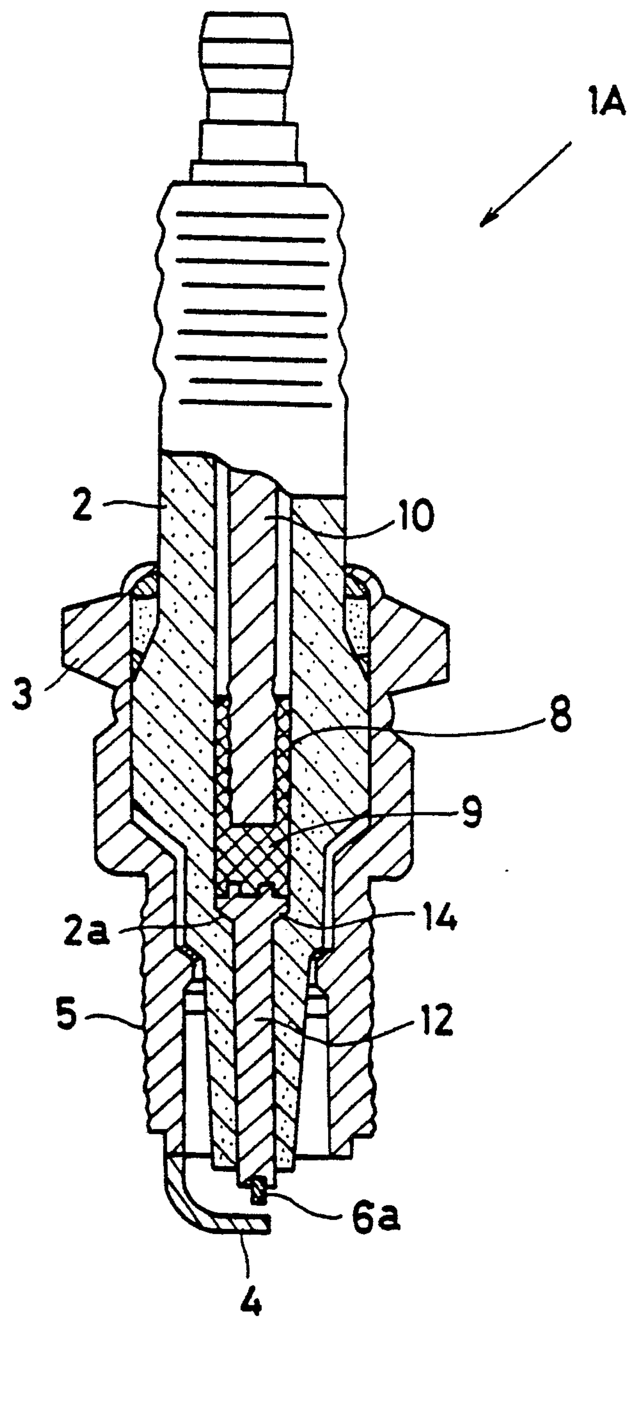
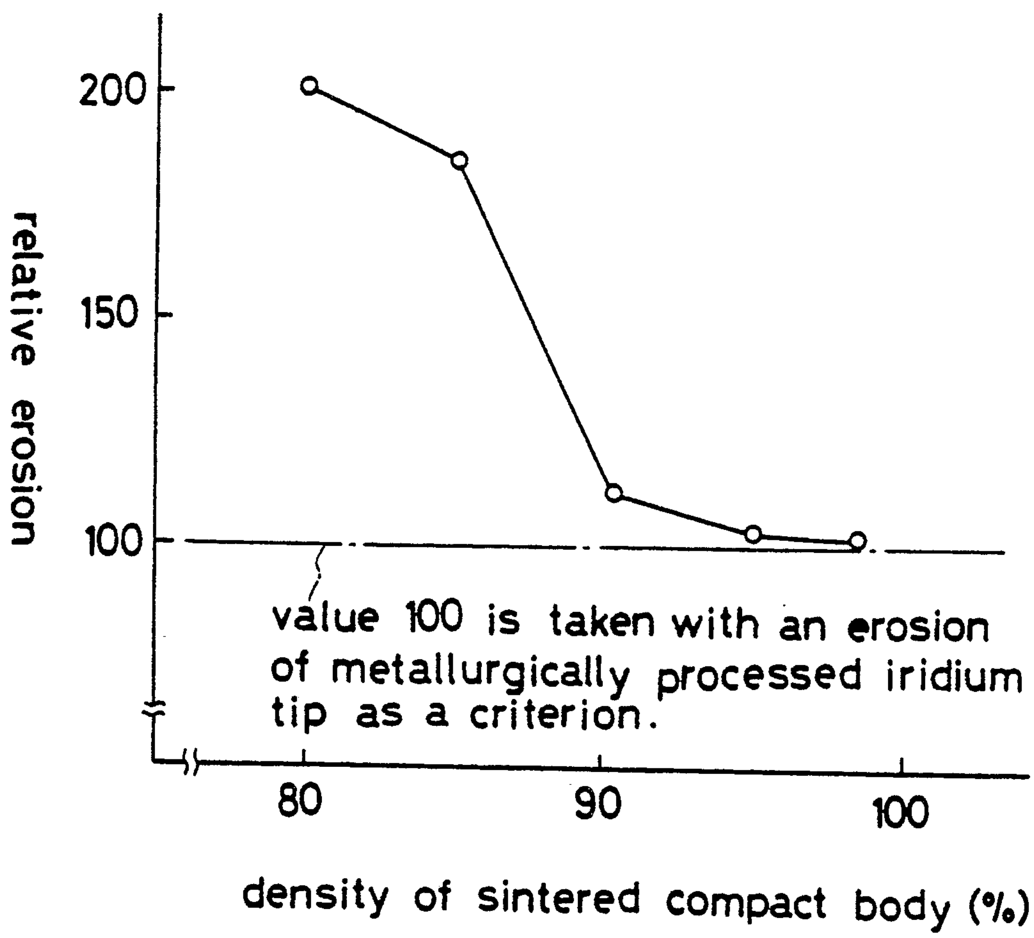


Fig. 6


200
150
100
relative erosion
value 100 is taken with an erosion of metallurgically processed iridium tip as a criterion.
80
90
100
density of sintered compact body (%)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 30 5797

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	DE-A-3038649 (NGK SPARK PLUG CO) * page 10, line 17 - page 12, line 12; figure 1 *	1, 4-8.	H01T21/02 H01T13/39
A	FR-A-1490828 (JOHNSON, MATTHEY & CO) * page 1, right-hand column, lines 5 - 22 *	1, 3.	
A	DE-A-1941979 (CHAMPION SPARK PLUG CIE) * page 8, line 20 - page 9, line 4 * * page 12, lines 3 - 12 *	1, 6, 9, 10.	
A	US-A-3466158 (THE INTERNATIONAL NICKEL CIE)		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

H01T

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 AUGUST 1990	BIJN E.A.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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