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(71) Applicants:

- **DENSO CORPORATION**
Kariya-city,
Aichi-pref. 448-8661 (JP)
- **Tanaka Denshi Kogyo K.K.**
Tokyo 100-6422 (JP)

(72) Inventors:

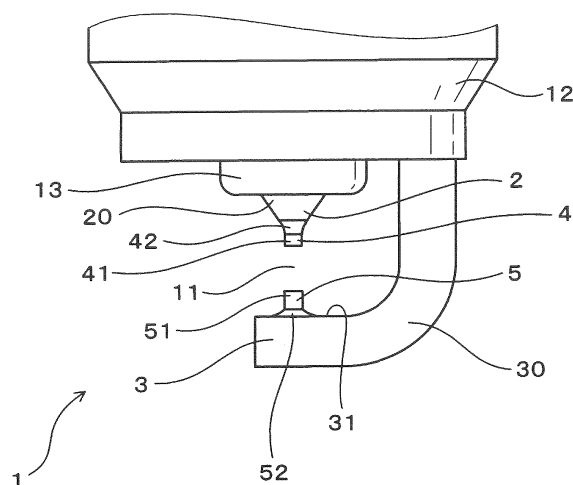
- **MURAYAMA, Yuki**
Kariya-city
Aichi 448-8661 (JP)
- **ABE, Nobuo**
Kariya-city
Aichi 448-8661 (JP)
- **SAKAIRI, Koichi**
Hiratsuka-shi
Kanagawa 254-0076 (JP)
- **TANAKA, Kunihiro**
Hiratsuka-shi
Kanagawa 254-0076 (JP)

(74) Representative: **Kuhnen & Wacker**
Patent- und Rechtsanwaltsbüro
Prinz-Ludwig-Straße 40A
85354 Freising (DE)

(54) METHOD FOR MANUFACTURING SPARK PLUG FOR INTERNAL COMBUSTION ENGINE

(57) A method of manufacturing a spark plug 1 in which at least one of a center electrode 2 and a ground electrode 3 includes a discharge chip 5. In a chip making step, the discharge chip 5 is made by joining a discharge part 51 arranged on a spark discharge gap 11 side and a base member-joining part 52 that is made of a material having a lower melting point than the discharge part 51 and to be joined to an electrode base member 30. In a temporary joining step, the discharge chip 5 is temporarily joined, at the base member-joining part 52, to the electrode base member 30 by resistance welding. In a main joining step, the discharge chip 5 is joined, by laser welding, to the electrode base member 30 so that a side surface 511 of the discharge part 51 and a surface 31 of the electrode base member 30 are smoothly connected by a connecting surface 523 that has no sharp edge.

FIG. 7



Description

[TECHNICAL FIELD]

[0001] The present invention relates to a method of manufacturing a spark plug for an internal combustion engine; in the spark plug, at least one of a center electrode and a ground electrode includes a discharge chip, the center and ground electrodes being opposed to each other with a spark discharge gap formed therebetween.

[BACKGROUND ART]

[0002] As internal combustion engines such as automotive engines, for improving the fuel economy, high-efficiency engines are required which, for example, have low emissions and perform supercharging. In these high-efficiency engines, for improving the ignition performance, high-performance spark plugs are employed which have a discharge chip in at least one of a center electrode and a ground electrode.

[0003] As the discharge chip, for securing the wear resistance, noble metals such as Pt, Ir, Ru, Rh, Pd, Os or the like, or rare metals are used. However, in terms of cost reduction and suppression of the exhaustion of resources, it is requested, as an important issue, to reduce the use of high-melting point metals. As a measure on this issue, there have been proposed spark plugs in which the discharge chip is constituted of a clad material consisting of a base member-joining part joined to an electrode base member and a discharge part facing a spark discharge gap. Moreover, in Patent Document 1, there is disclosed a method of manufacturing a discharge chip that is constituted of a clad material formed by joining a base member-joining part and a discharge part by both resistance welding and diffusion bonding.

[PRIOR ART LITERATURE]

[PATENT LITERATURE]

[0004] [PATENT DOCUMENT 1] WO2013015262A1

[SUMMARY OF THE INVENTION]

[PROBLEMS TO BE SOLVED BY THE INVENTION]

[0005] However, the discharge chip (clad electrode) disclosed in Patent Document 1 involves the following problems. Specifically, since the discharge chip is obtained by joining the discharge part and the base member-joining part, it is easy for a step to be formed therebetween. Accordingly, it is easy for a sharp corner portion of the base member-joining part to appear at a side portion of the discharge chip. Thus, when the discharge chip is used in a ground electrode or a center electrode of a spark plug, the strength of electric field will be high in the vicinity of the sharp corner portion of the base member-

joining part. Consequently, it will be easy for discharge sparks to fly to the sharp corner portion of the base member-joining part at the side portion of the discharge chip; thus it may be difficult to form a normal discharge spark.

[0006] Therefore, it is desirable to eliminate the step between the discharge part and the base member-joining part. However, in the case of using the manufacturing method disclosed in Patent Document 1, it is difficult to obtain a discharge chip without a step. Specifically, in the manufacturing method, a noble metal chip (discharge part) is joined to a tape-shaped base material (base member-joining part) by resistance welding; then an integrated body of the base material and the noble metal chip is blanked out. Consequently, a step is formed between the noble metal chip and the base material. That is, after the blanking process, the diameter of the base material becomes greater than the diameter of the noble metal chip.

[0007] Moreover, if the discharge chip is made by blanking a composite plate that is obtained by bonding the material of the discharge part and the material of the base member-joining part, it is possible to result in the discharge chip having no step between the discharge part and the base member-joining part. However, in recycling the composite plate after the blanking process, it is necessary to separate the two different materials; thus there is a problem that the recycling cost becomes high.

[0008] In contrast, in the case of bonding the discharge part and the base member-joining part after blanking, to keep the joining area between the two parts constant, it is necessary to set the diameter of the base member-joining part to be greater than the diameter of the discharge part. Consequently, a step will be formed between the base member-joining part and the discharge part; thus a sharp corner portion of the base member-joining part will be formed at a side portion of the discharge chip.

[0009] The present invention has been made in view of the above circumstances, and aims to provide a method of manufacturing a spark plug for an internal combustion engine by which it is possible to suppress flying sparks to a base member-joining part.

[MEANS FOR SOLVING THE PROBLEMS]

[0010] The present invention provides a method of manufacturing a spark plug for an internal combustion engine. In the spark plug, a center electrode and a ground electrode are opposed to each other with a spark discharge gap formed therebetween, and at least one of the center and ground electrodes has a discharge chip joined to an electrode base member so as to protrude toward the spark discharge gap. The method is characterized by comprising: a chip making step of making the discharge chip by joining a discharge part and a base member-joining part to each other, the discharge part being arranged on the spark discharge gap side, the base member-joining part being made of a material having a lower melting point than the discharge part and to be joined to the electrode base member; a temporary joining step of

temporarily joining the discharge chip, at the base member-joining part, to the electrode base member by resistance welding; and a main joining step of joining, by laser welding, the discharge chip to the electrode base member so that a side surface of the discharge part and a surface of the electrode base member are smoothly connected by a connecting surface that has no sharp edge.

[ADVANTAGEOUS EFFECTS OF THE INVENTION]

[0011] With the above method, in the obtained spark plug, no sharp corner portion of the base member-joining part appears at a side portion of the discharge chip. That is, it is possible to prevent a locally high-electric field strength portion from being formed in the base member-joining part. As a result, it is possible to suppress flying sparks to the base member-joining part.

[0012] Moreover, since the discharge chip is joined, by laser welding, to the electrode base member by melting and solidifying part of the base member-joining part and part of the electrode base member, it is particularly easy to have the outline of the base member-joining part shaped along the side surface of the discharge part and the surface of the electrode base member. Therefore, it is possible to easily join the discharge chip to the electrode base member so that the side surface of the discharge part and the surface of the electrode base member are smoothly connected.

[0013] As above, according to the present invention, it is possible to provide a method of manufacturing a spark plug for an internal combustion engine by which it is possible to suppress flying sparks to a base member-joining part.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0014]

FIG. 1 is a side view of a distal part of a spark plug in Example 1.

FIG. 2 (a) is a front view and FIG. 2(b) is a plan view of a discharge chip obtained by a chip making step in Example 1.

FIG. 3 is a front view showing a state where the discharge chip has been temporarily joined to an electrode base member by a temporary joining step in Example 1.

FIG. 4 is a front view showing a state where the discharge chip has been welded to the electrode base member by a main joining step in Example 1.

FIG. 5 is a schematic cross-sectional view illustrating how laser welding is performed in Example 1.

FIG. 6 is a schematic cross-sectional view showing the state where the discharge chip has been welded to the electrode base member by the main joining step in Example 1.

FIG. 7 is a side view of a distal part of a spark plug in Example 2.

FIG. 8 is a schematic cross-sectional view illustrating how laser welding is performed in Example 2.

FIG. 9 is a schematic cross-sectional view showing a state where a discharge chip has been welded to an electrode base member by a main joining step in Example 2.

[EMBODIMENTS FOR CARRYING OUT THE INVENTION]

[0015] In the above-described spark plug for an internal combustion engine, the discharge chip may be included in the center electrode, in the ground electrode or in each of the center and ground electrodes.

[0016] The spark plug may be used, for example, as an ignition means in a combustion chamber of an internal combustion engine such as an automotive engine.

[0017] Moreover, in the discharge chip obtained in the chip making step, the diameter of the base member-joining part may be greater than the diameter of the discharge part. In this case, it is easy to stably perform the joining of the discharge part and the base member-joining part in the chip making step. However, in this case of the diameter of the base member-joining part being greater than the diameter of the discharge part, a step is formed between the two parts and a sharp corner portion of the base member-joining part appears. If the discharge chip was joined to the electrode base member so that the sharp corner portion remained appearing, it would be easy for discharge sparks of the spark plug to fly to the base member-joining part. Therefore, as described above, in the main joining step, by joining the discharge chip to the electrode base member so that the side surface of the discharge part and the surface of the electrode base member are smoothly connected by the connecting surface that has no sharp edge, the sharp corner portion of the base member-joining part can be eliminated. Consequently, it is possible to effectively suppress flying sparks to the base member-joining part.

[Examples]

(Example 1)

[0018] An example of the above method of manufacturing a spark plug for an internal combustion engine will be described with reference to FIGS. 1-6.

[0019] In a spark plug 1 obtained by the manufacturing method of the present example, as shown in FIG. 1, a center electrode 2 and a ground electrode 3 are opposed to each other with a spark discharge gap 11 formed therebetween. The center and ground electrodes 2 and 3 respectively have discharge chips 4 and 5 joined to electrode base members 20 and 30 so as to protrude toward the spark discharge gap 11.

[0020] In the present example, the discharge chip 5 in the ground electrode 3 is formed by joining a discharge part 51 arranged on the spark discharge gap 11 side and

a base member-joining part 52 that is made of a material having a lower melting point than the discharge part 51 and joined to the electrode base member 30. On the other hand, the discharge chip 4 in the center electrode 2 is not a composite member.

[0021] The manufacturing method of the spark plug 1 of the present example includes a chip making step, a temporary joining step and a main joining step which will be described hereinafter. That is, via the following steps, the discharge chip 5 is joined to the electrode base member 30 to form the ground electrode 3.

[0022] In the chip making step, as shown in FIG. 2, the discharge chip 5 is made by joining the discharge part 51 and the base member-joining part 52 to each other. In the temporary joining step, as shown in FIG. 3, the discharge chip 5 is temporarily joined, at the base member-joining part 52, to the electrode base member 30 by resistance welding. In the main joining step, as shown in FIG. 4, the discharge chip 5 is joined, by laser welding, to the electrode base member 30 by melting and solidifying part of the base member-joining part 52 and part of the electrode base member 30, so that a side surface 511 of the discharge part 51 and a surface of the electrode base member 30 are smoothly connected by a connecting surface 523 that has no sharp edge.

[0023] As shown in FIG. 1, the electrode base member 30 of the ground electrode 3 extends distalward (i.e., downward in FIG. 1) from a distal end of a housing 12 of the spark plug 1 and is bent to a central axis side. The electrode base member 20 of the center electrode 2 is held inside an insulator 13 that is held inside the housing 12. Each of the housing 12 and the electrode base member 30 of the ground electrode 3 is made of a nickel alloy. Moreover, the electrode base member 20 of the center electrode 2 is also made of a nickel alloy.

[0024] Moreover, the electrode base member 30 of the ground electrode 3 has an opposing surface 31 that opposes the center electrode 2 in an axial direction of the spark plug 1 (to be simply referred to as "plug axial direction" hereinafter). To the opposing surface 31, there is joined the discharge chip 5. Moreover, to the distal end of the electrode base member 20 of the center electrode 2 which opposes the opposing surface 31 in the plug axial direction, there is joined the discharge chip 4. In the present example, the discharge chip 4 of the center electrode 2 is constituted, not of a composite member, but of, for example, a noble metal chip of an iridium alloy or the like. That is, the discharge chip 4 constituted of a noble metal chip is joined, for example by welding, to the distal end of the electrode base member 20 of the center electrode 2.

[0025] On the other hand, as described above, the discharge chip 5 of the ground electrode 3 is constituted of a composite member that is obtained by joining the discharge part 51 and the base member-joining part 52 to each other. In forming the ground electrode 3 that includes the discharge chip 5 constituted of the composite member, the above-described chip making step, the tem-

porary joining step and the main joining step are performed. An example of each step will be described in detail hereinafter.

[0026] In the chip making step, first, the discharge part 51 made of a material having a relatively high melting point (e.g., the melting point being higher than or equal to 1700°C) and the base member-joining part 52 made of a material having a lower melting point than the discharge part 51 are prepared. As the material of the discharge part 51, it is possible to use, for example, Pt (Platinum), Ir (Iridium), Ru (Ruthenium), Rh (Rhodium), Pd (Palladium), Os (Osmium) or the like. Moreover, as the material of the base member-joining part 52, it is possible to use, for example, a Ni (Nickel) alloy. In addition, as the Ni alloy, it is possible to use one which has a melting point of, for example, 1400-1450°C.

[0027] Those metal members are processed, for example by blanking, to respectively form the cylindrical discharge part 51 and base member-joining part 52. Moreover, the diameter of the base member-joining part 52 is greater than the diameter of the discharge part 51.

[0028] The cylindrical discharge part 51 and base member-joining part 52 formed in the above manner are axially superposed with the central axes of the two parts coinciding with each other, as shown in FIG. 2. Then, in a state of the two parts being pressed against each other, a heat treatment is performed to join the discharge part 51 and the base member-joining part 52 by diffusion bonding. Consequently, the discharge chip 5 is obtained as a composite member. Therefore, in the vicinity of the interface between the discharge part 51 and the base member-joining part 52 in the discharge chip 5, there is formed a diffusion layer (not shown) in which atoms of the materials of the discharge part 51 and the base member-joining part 52 are diffused to each other.

[0029] In the discharge chip 5 obtained in the chip making step, the diameter of the base member-joining part 52 is greater than the diameter of the discharge part 51. Therefore, in this stage, there is formed a step between the base member-joining part 52 and the discharge part 51; at the step, there exists a sharp corner portion 521 of the base member-joining part 52.

[0030] In the temporary joining step, as shown in FIG. 3, the discharge chip 5 obtained in the chip making step is temporarily joined to the opposing surface 31 of the electrode base member 30. The temporary joining is performed by resistance welding. Specifically, the discharge chip 5 is made to abut, on its base member-joining part 52-side surface, a predetermined position on the opposing surface 31 of the electrode base member 30. Then, with the discharge chip 5 and the electrode base member 30 sandwiched between a pair of resistance welding electrodes, electric current is supplied to flow between the discharge chip 5 and the electrode base member 30. Consequently, by the Joule heat, the discharge chip 5 is welded and thus temporarily joined to the electrode base member 30.

[0031] Next, in the main joining step, as shown in FIG.

4, the discharge chip 5 is joined to the electrode base member 30 by laser welding. Specifically, as shown in FIG. 5, a laser beam L is irradiated to the discharge chip 5 temporarily joined to the electrode base member 30 from the vicinity of the joining portion. Here, the laser beam L is irradiated from a plurality of locations over the entire circumference of the joining portion with respect to the electrode base member 30. Moreover, the laser welding is performed at a temperature lower than the melting point of the discharge part 51. That is, in the main joining step, part of the base member-joining part 52 and part of the electrode base member 30 are melted without melting the discharge part 51. Consequently, as shown in FIG. 6, on an outer periphery of the base member-joining part 52, there is formed an annular melt zone 522 where the base member-joining part 52 and the electrode base member 30 are melted together and solidified.

[0032] Moreover, by the laser welding, as shown in FIGS. 4 and 6, the sharp corner portion 521 (see FIGS. 3 and 5) of the base member-joining part 52 is eliminated in shape, and there is formed the connecting surface 523 that smoothly connects the side surface 511 of the discharge part 51 and the surface (i.e., the opposing surface 31) of the electrode base member 30. The connecting surface 523 has, on a cross section taken along a plane passing through the central axis of the discharge chip 5, such a shape as to smoothly connect a curve and a straight line and have no sharp edge.

[0033] Next, advantageous effects of the present example will be described.

[0034] In the above main joining step, the discharge chip 5 is joined, by laser welding, to the electrode base member 30 by melting and solidifying part of the base member-joining part 52 and part of the electrode base member 30. Consequently, the discharge chip 5 is joined to the electrode base member 30 so that the side surface 511 of the discharge part 51 and the opposing surface 31 of the electrode base member 30 are connected by the connecting surface 523 that has no sharp edge. Therefore, in the obtained spark plug 1, no sharp corner portion 521 (see FIG. 3) of the base member-joining part 52 exists at a side portion of the discharge chip 5; thus it is possible to prevent a locally high-electric field strength portion from being formed in the base member-joining part 52. As a result, it is possible to suppress flying sparks to the base member-joining part 52.

[0035] Moreover, as described above, since the discharge chip 5 is joined, by laser welding, to the electrode base member 30 by melting and solidifying part of the base member-joining part 52 and part of the electrode base member 30, it is particularly easy to have the outline of the base member-joining part 52 shaped along the side surface 511 of the discharge part 51 and the opposing surface 31 of the electrode base member 30, as shown in FIG. 4. Therefore, it is possible to easily join the discharge chip 5 to the electrode base member 30 so that the side surface 511 of the discharge part 51 and the opposing surface 31 of the electrode base member

30 are connected by the connecting surface 523 that has no sharp edge.

[0036] Moreover, in the discharge chip 5 (see FIG. 2) obtained in the chip making step, the diameter of the base member-joining part 52 is greater than the diameter of the discharge part 51. Consequently, it is easy to stably perform the joining of the discharge part 51 and the base member-joining part 52. That is, it is possible to easily have the whole of an end surface of the discharge part 51 abutting the base member-joining part 52; thus it is easy to make the joining area of the discharge part 51 to the base member-joining part 52 constant, thereby obtaining stable joining strength therebetween. However, in this case of the diameter of the base member-joining part 52 being greater than the diameter of the discharge part 51, a step is formed between the two parts and the sharp corner portion 521 of the base member-joining part 52 appears. If the discharge chip 5 was joined to the electrode base member 30 so that the sharp corner portion 521 remained appearing, it would be easy for discharge sparks of the spark plug 1 to fly to the base member-joining part 52. Therefore, as described above, in the main joining step, as shown in FIG. 4, the sharp corner portion 521 of the base member-joining part 52 is eliminated by joining the discharge chip 5 to the electrode base member 30 so that the side surface 511 of the discharge part 51 and the opposing surface 31 of the electrode base member 30 are connected by the connecting surface 523 that has no sharp edge. Consequently, it becomes possible to smoothly connect, by the connecting surface 523 that has no sharp edge, the side surface of the discharge chip 5 from the side surface 511 of the discharge part 51 to a surface (i.e., the opposing surface 31) of the electrode base member 30. As a result, it becomes possible to effectively suppress flying sparks to the base member-joining part 52.

[0037] Moreover, in the main joining step, the laser welding is performed at a temperature lower than the melting point of the discharge part 51. Consequently, it is possible to sufficiently secure the volume and shape of the discharge part 51 that is made of a high-melting point material, thereby securing the wear resistance of the spark plug 1.

[0038] As above, according to the present example, it is possible to provide a method of manufacturing a spark plug for an internal combustion engine by which it is possible to suppress flying sparks to a base member-joining part.

(Example 2)

[0039] In this example, as shown in FIGS. 7-9, the discharge chip 4 of the center electrode 2 is also constituted of a composite member; the composite member is obtained by joining a discharge part 41 arranged on the spark discharge gap 11 side and a base member-joining part 42 that is made of a material having a lower melting point than the discharge part 41 and joined to the elec-

trode base member 20.

[0040] Moreover, in forming the center electrode 2, a chip making step, a temporary joining step and a main joining step are performed as described in Example 1.

[0041] In the chip making step, as in the chip making step of Example 1, the discharge chip 4 is obtained by diffusion-bonding the discharge part 41 and the base member-joining part 42. Next, in the temporary joining step, as shown in FIG. 8, the discharge chip 4 is temporarily joined, by resistance welding, to a distal end surface 21 of the electrode base member 20 of the center electrode 2. Specifically, a distal part of the electrode base member 20 of the center electrode 2 before joining the discharge chip 4 is substantially cone-shaped and has, at its distal end, a flat surface perpendicular to the axial direction. To this flat surface which constitutes the distal end surface 21, the discharge chip 4 is temporarily joined with the base member-joining part 42 abutting the distal end surface 21.

[0042] Next, in the main joining step, the discharge chip 4 is joined to the electrode base member 20 by laser welding. At this time, an annular melt zone 422 is formed between the base member-joining part 42 of the discharge chip 4 and the electrode base member 20. Moreover, as shown in FIG. 9, a sharp corner portion 421 (see FIG. 8) of the base member-joining part 42 is eliminated in shape, and there is formed a connecting surface 423 that smoothly connects a side surface 411 of the discharge part 41 and a surface (i.e., a side surface 22 of the substantially cone-shaped part) of the electrode base member 20. The connecting surface 423 has, on a cross section taken along a plane passing through the central axis of the discharge chip 5, such a shape as to smoothly connect a curve and a straight line and have no sharp edge.

[0043] The others are the same as in Example 1. In addition, unless particularly specified, of the reference signs used in the present example and the drawings relating to the present example, those which are the same as the reference signs used in Example 1 designate the same components as in Example 1.

[0044] In the present example, in the center electrode 2 as well, it is possible to suppress discharge sparks from flying to the electrode base member 20. As a result, it is possible to more reliably generate normal discharge sparks between the discharge part 41 of the center electrode 2 and the discharge part 51 of the ground electrode 3.

[0045] In addition, the present example has the same advantageous effects as Example 1.

[0046] In addition, besides the above-described examples, it is also possible to, for example, constitute the discharge chip of the ground electrode with a metal chip that is not a composite member or provide no discharge chip in the ground electrode while configuring the center electrode in the same manner as in Example 2.

[DESCRIPTION OF REFERENCE SIGNS]

[0047]

- 1: spark plug
- 11: spark discharge gap
- 2: center electrode
- 20: electrode base member (of the center electrode)
- 3: ground electrode
- 30: electrode base member (of the ground electrode)
- 4: discharge chip (of the center electrode)
- 41: discharge part (of the center electrode)
- 42: base member-joining part (of the center electrode)
- 5: discharge chip (of the ground electrode)
- 51: discharge part (of the ground electrode)
- 52: base member-joining part (of the ground electrode)

Claims

1. A method of manufacturing a spark plug (1) for an internal combustion engine, wherein in the spark plug (1), a center electrode (2) and a ground electrode (3) are opposed to each other with a spark discharge gap (11) formed therebetween, and at least one of the center and ground electrodes (2, 3) has a discharge chip (4, 5) joined to an electrode base member (20, 30) so as to protrude toward the spark discharge gap (11), the method being **characterized by** comprising:

a chip making step of making the discharge chip (4, 5) by joining a discharge part (41, 51) and a base member-joining part (42, 52) to each other, the discharge part (41, 51) being arranged on the spark discharge gap (11) side, the base member-joining part (42, 52) being made of a material having a lower melting point than the discharge part (41, 51) and to be joined to the electrode base member (20, 30);

a temporary joining step of temporarily joining the discharge chip (4, 5), at the base member-joining part (42, 52), to the electrode base member (20, 30) by resistance welding; and

a main joining step of joining, by laser welding, the discharge chip (4, 5) to the electrode base member (20, 30) so that a side surface (411, 511) of the discharge part (41, 51) and a surface (22, 31) of the electrode base member (20, 30) are smoothly connected by a connecting surface (423, 523) that has no sharp edge.

2. The method of manufacturing the spark plug (1) for an internal combustion engine as set forth in Claim 1, further **characterized in that** in the discharge chip (4, 5) obtained in the chip making step, a diameter

of the base member-joining part (42, 52) is greater than a diameter of the discharge part (41, 51).

3. The method of manufacturing the spark plug (1) for an internal combustion engine as set forth in Claim 1 or 2, further characterized that in the main joining step, the laser welding is performed at a temperature lower than the melting point of the discharge part (41, 51).

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FIG.1

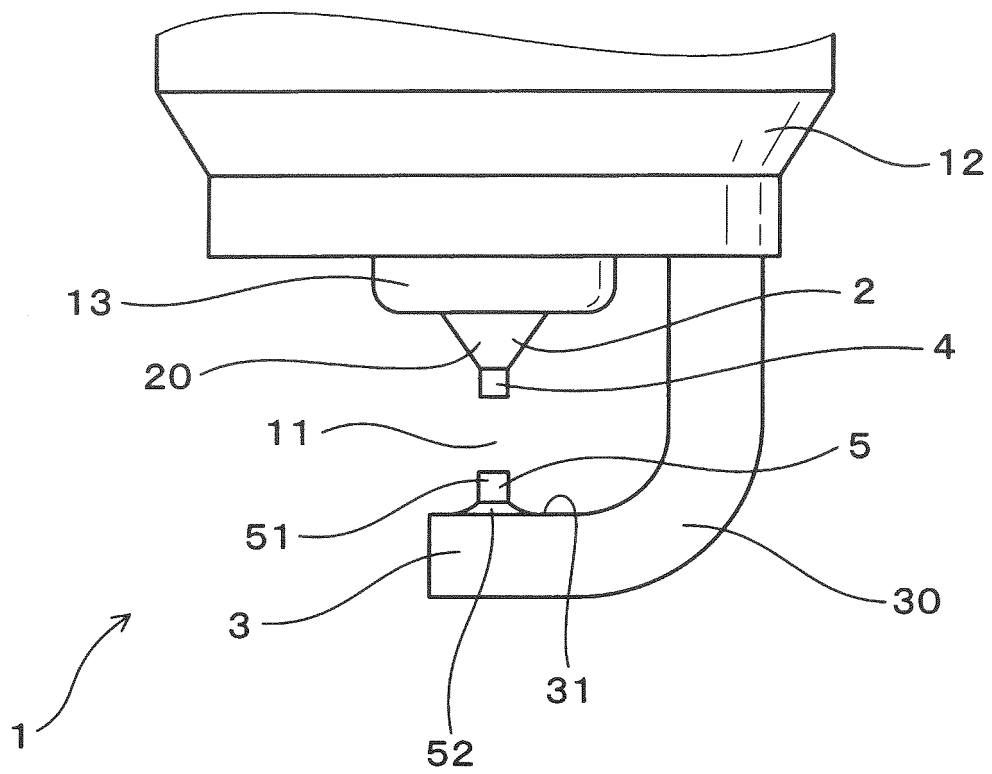


FIG.2

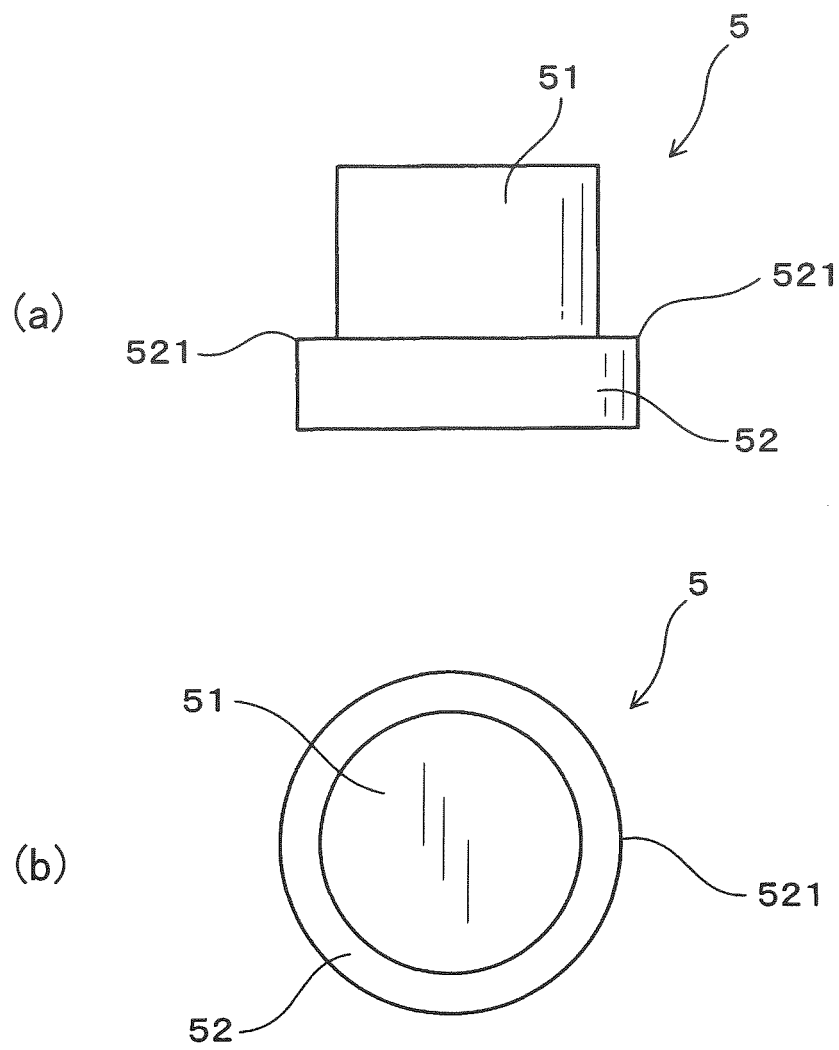


FIG.3

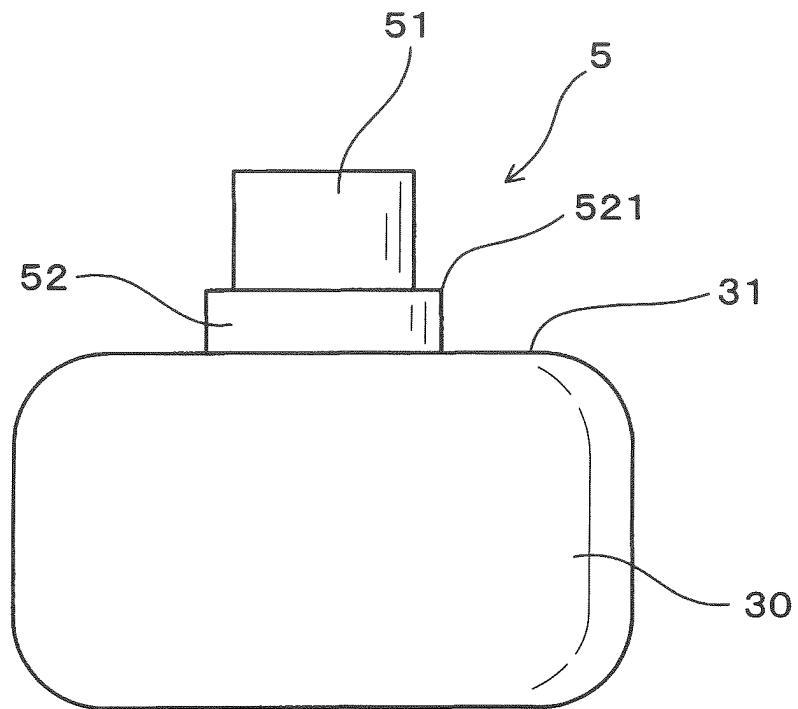


FIG.4

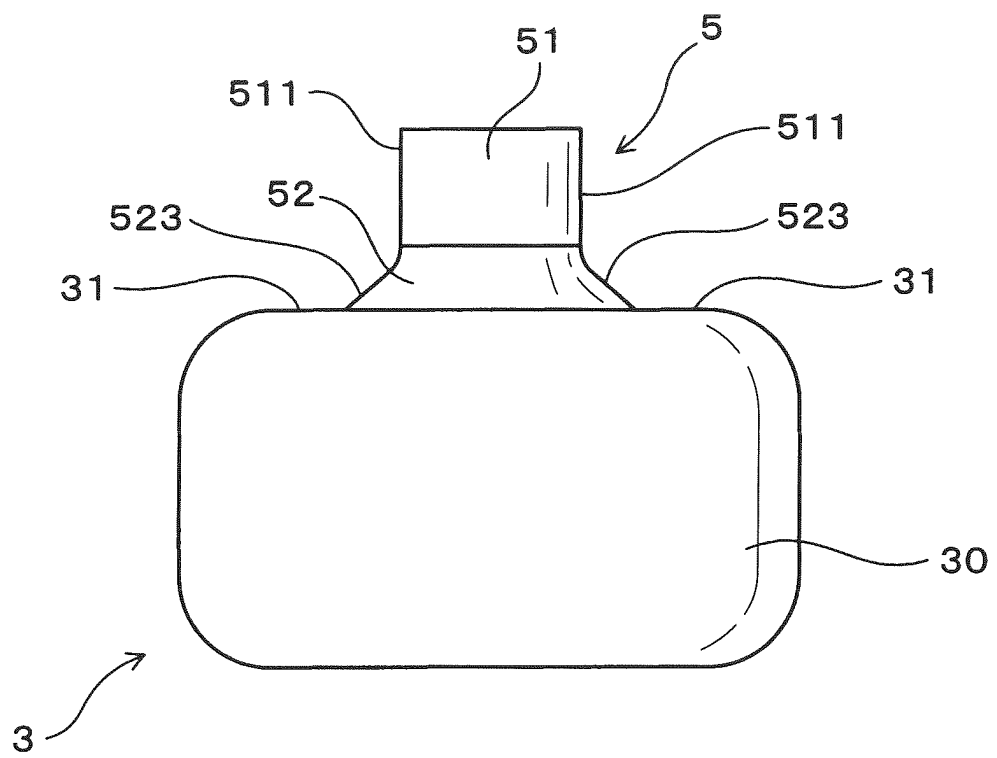


FIG.5

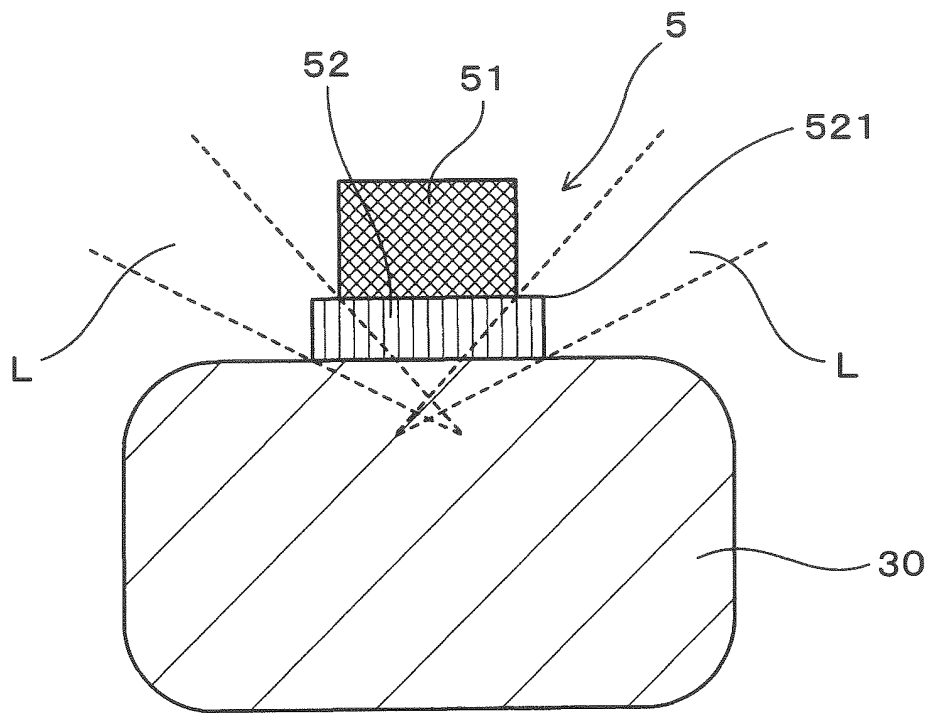


FIG.6

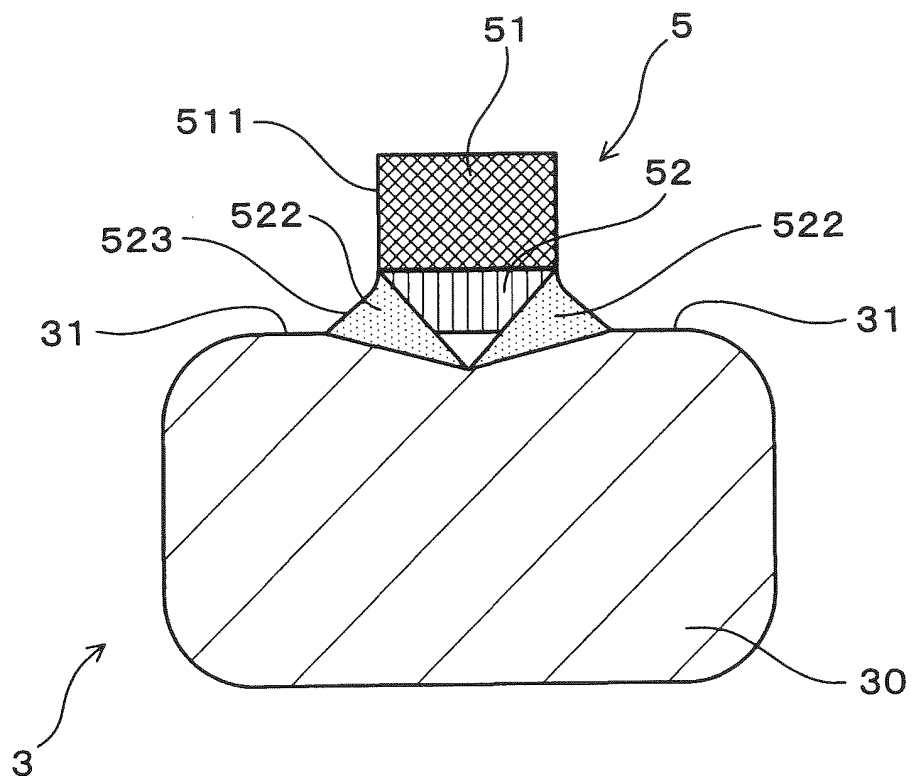


FIG.7

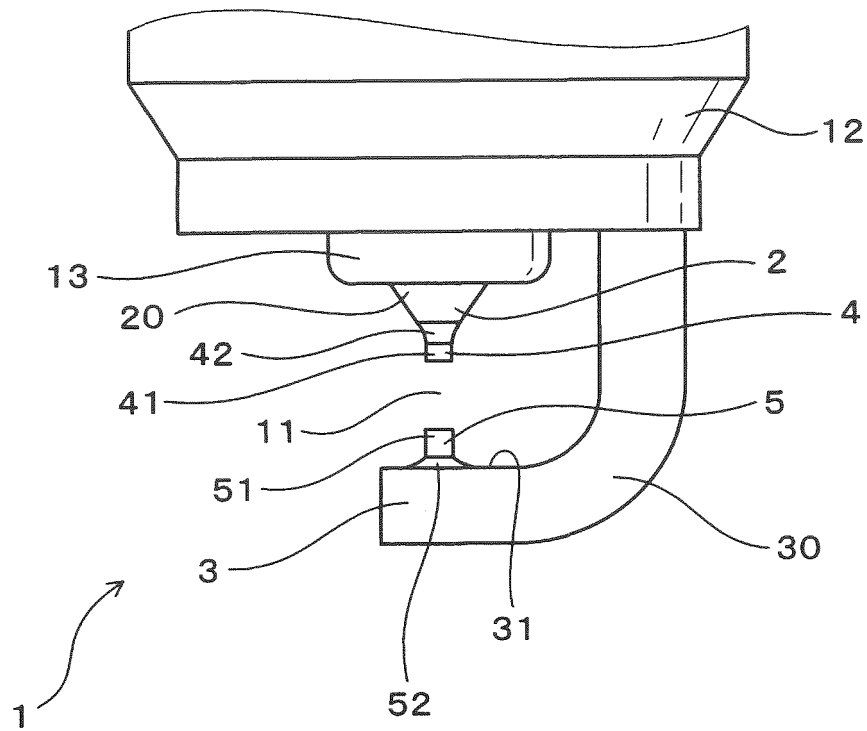


FIG.8

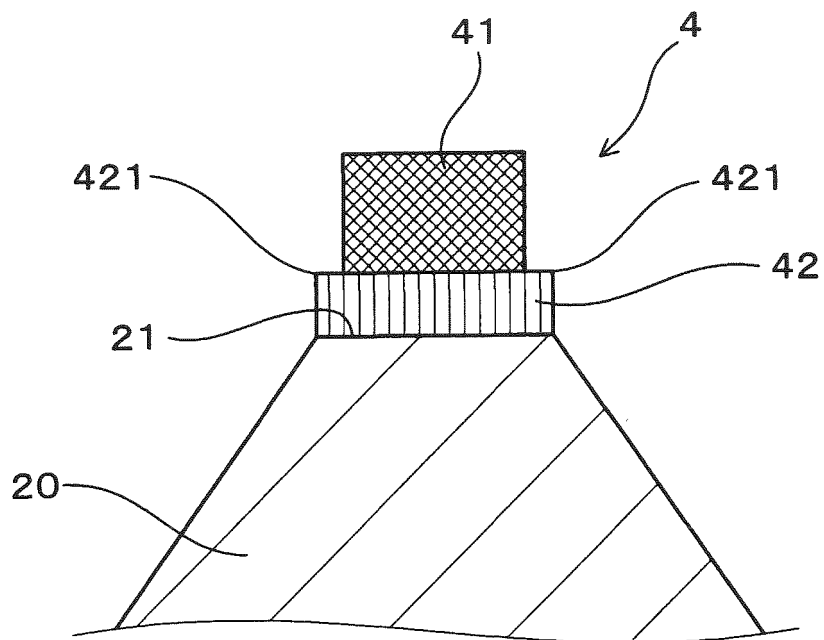
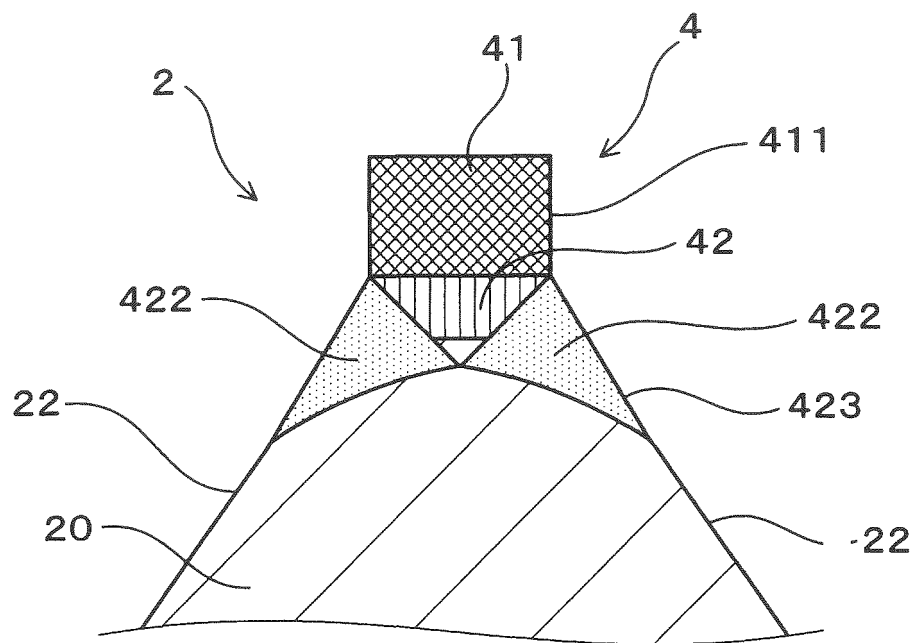


FIG.9



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/063507

A. CLASSIFICATION OF SUBJECT MATTER

H01T13/20(2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01T13/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2014
 Kokai Jitsuyo Shinan Koho 1971-2014 Toroku Jitsuyo Shinan Koho 1994-2014

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2008-77838 A (Denso Corp.), 03 April 2008 (03.04.2008), paragraphs [0127] to [0130]; fig. 1, 23, 24 & US 2008/0074025 A1 & DE 102007000740 A1	1, 2 3
Y	JP 2009-533803 A (Federal-Mogul Corp.), 17 September 2009 (17.09.2009), paragraphs [0027] to [0030]; fig. 6 & US 2007/0236123 A1 & EP 2013953 A2 & WO 2007/118190 A2 & CN 101461106 A & KR 10-2009-0003304 A	3

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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Date of the actual completion of the international search

11 July, 2014 (11.07.14)

Date of mailing of the international search report

22 July, 2014 (22.07.14)

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Patent documents cited in the description

- WO 2013015262 A1 [0004]