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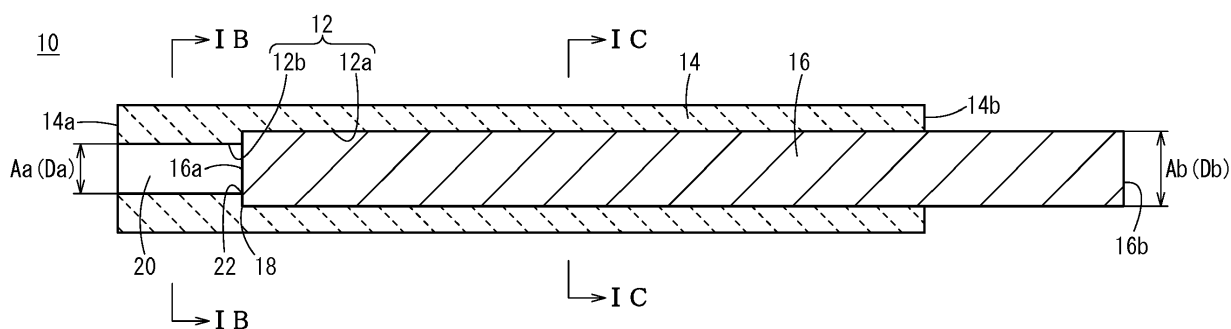
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(54) ELECTRODE AND ELECTRODE STRUCTURAL BODY

(57) The electrode (10) includes an insulator (14) having a hollow portion (12) (first hollow portion (12a) and second hollow portion (12b)) and a conductor (16)

provided in the hollow portion (12) of the insulator (14). An edge portion (18) of one end surface (16a) of at least the conductor (16) is covered with the insulator (14).

FIG. 1A



Description

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2015-005892 filed on January 15, 2015, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention:

[0002] The present invention relates to an electrode structural body containing an insulator and conductive material. For example, the present invention relates to an electrode and an electrode structural body which are suitable for use, e.g., in a dielectric barrier discharge electrode, an ozone generator, or the like.

Description of the Related Art:

[0003] For example, in the ozone generator, ozone is produced by allowing an oxygen-containing gas such as air or oxygen to flow into thermal non-equilibrium plasma exploiting electric discharge by a high voltage power source. As for the apparatus for producing electric discharge, for example, a silent electric discharge scheme is adopted. In the silent electric discharge scheme, high voltage of several to several tens kV is produced by a high voltage alternating power source, and the high voltage is applied to an electric discharge gap between the high voltage electrode and the ground electrode to produce electric discharge which is a set of minute electric discharge columns, and the oxygen-containing gas is decomposed to produce the ozone.

[0004] An example of the shape of an electrode used in such an ozone generator can be seen from an electrode disclosed in Japanese Laid-Open Patent Publication No. 08-185955. The electrode described in Japanese Laid-Open Patent Publication No. 08-185955 is formed by inserting a metallic rod shaped electric conductor into a through hole formed in a thin cylindrical ceramics dielectric body extending in a longitudinal direction, and a lead wire from a high voltage alternating current power source is connected to one end of the rod shaped electric conductor in the same direction. Further, a low temperature plasma generator described in Japanese Laid-Open Patent Publication No. 08-185955 is formed by joining two electrodes by a line contact, and sealing both ends of the dielectric body together with the electric conductor using a ceramics seal body.

SUMMARY OF THE INVENTION

[0005] However, the electrode described in Japanese Laid-Open Patent Publication No. 08-185955 is formed by inserting the metallic rod shaped electric conductor into the through hole of the thin cylindrical ceramics dielectric body extending in the longitudinal direction. In this case, when the metallic rod shaped electric conductor is inserted into the through hole of the thin cylindrical ceramics dielectric body extending in the longitudinal direction, unwanted electric discharge occurs between the end portion at which the electric conductor is inserted and the other electrode positioned at a predetermined distance. Since the unwanted electric discharge occurs over the shortest distance, in the conventional structure, the unwanted electric discharge is concentrated at the edge portion (ridgeline portion) of the electric conductor, and the dielectric body may be damaged at the position adjacent to the edge portion of the electric conductor undesirably.

[0006] The present invention has been made taking such a problem into consideration, and an object of the present invention is to provide an electrode and an electrode structural body in which it is possible to avoid concentration of the unwanted electric discharge at the edge portion (ridgeline portion) of the electric conductor (conductor), and prevent damages of the insulator (dielectric body) to achieve improvement in the reliability.

[1] An electrode according to the first invention includes a cylindrical insulator including a hollow portion, and a conductor provided in the hollow portion of the insulator. An edge portion at one end surface of at least the conductor is covered with the insulator. The edge portion includes a border portion (ridgeline portion) between a side surface and one end surface of the conductor, and includes a chamfered portion (C surface or R surface) if the surface of the conductor is chamfered.

[2] In the first invention, preferably, the one end surface of the conductor is positioned inside the hollow portion in comparison with one end surface of the insulator.

[3] In the first invention, preferably, in the hollow portion, a substance having a dielectric constant which is lower than a dielectric constant of the insulator is present between the one end surface of the conductor and one end surface of the insulator.

[4] In this case, the substance may be an air.

[5] In the first invention, preferably, the hollow portion of the insulator includes a first hollow portion and a second hollow portion connected to the first hollow portion; the conductor is provided in the first hollow portion and the conductor is not present in the second hollow portion; and an opening cross sectional area at a border between the first hollow portion and the second hollow portion is smaller than a cross sectional area of the conductor normal to an axial direction of the conductor.

[6] In this case, the electrode may be configured to satisfy a relationship of:

$$0.10 \leq Aa/Ab \leq 0.90$$

where Aa denotes the opening cross sectional area at the border between the first hollow portion and the second hollow portion, and Ab denotes the cross sectional area of the conductor normal to the axial direction of the conductor.

[7] In the case of [5] or [6], a cross sectional area of the second hollow portion normal to an axial direction of the insulator may be constant toward the border.

[8] In the case of [5] or [6], a cross sectional area of the second hollow portion normal to an axial direction of the insulator may change stepwise toward the border.

[9] In the case of [5] or [6], a cross sectional area of the second hollow portion normal to an axial direction of the insulator changes continuously toward the border.

[10] In the first invention, the insulator and the conductor may be joined together directly and integrally by firing.

[11] An electrode structural body according to the second invention includes a fixing member configured to fix a plurality of electrodes according to the first invention, wherein axial directions of the electrodes are aligned and the electrodes are spaced from one another, wherein the electrodes are fixed to the fixing member, where the one end surface of each of the conductors is fixed to the fixing member alternately.

[0007] In the electrode and electrode structural body according to the present invention, concentration of the unwanted electric discharge at the edge portion of the conductor is avoided. Accordingly, it is possible to prevent damages of the insulator (dielectric body). Thus, improvement in the reliability is achieved.

[0008] The above and other objects, features, and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings in which a preferred embodiment of the present invention is shown by way of illustrative example.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

FIG. 1A is a cross sectional view showing an electrode according to an embodiment of the present invention;

FIG. 1B is a cross sectional view taken along a line IB-IB in FIG. 1A;

FIG. 1C is a cross sectional view taken along a line IC-IC in FIG. 1A;

FIGS. 2A to 2C are enlarged cross sectional views each showing an example where an edge portion of a conductor is covered with an insulator;

FIG. 3 is a perspective view showing an electrode according to the embodiment of the present invention;

FIG. 4 is a cross sectional view showing an electrode structural body using the electrode according to the embodiment of the present invention and a creepage path;

FIG. 5 is a cross sectional view showing an electrode structural body using an electrode according to a comparative example and a creepage path;

FIG. 6A is a cross sectional view showing an electrode according to a first modified example with partial omission;

FIG. 6B is a cross sectional view showing an electrode according to a second modified example with partial omission;

FIG. 6C is a cross sectional view showing an electrode according to a third modified example with partial omission;

FIG. 7A is a cross sectional view showing an electrode according to a fourth modified example with partial omission;

FIG. 7B is a cross sectional view showing an electrode according to a fifth modified example with partial omission;

FIG. 7C is a cross sectional view showing an electrode according to a sixth modified example with partial omission;

FIG. 8 is a cross sectional view showing an electrode according to a seventh modified example with partial omission;

FIG. 9 is a cross sectional view showing an example of an electrode structural body according to a modified example;

FIG. 10A is a cross sectional view showing an electrode according to a comparative example 1 with partial omission;

FIG. 10B is a cross sectional view showing an electrode according to a comparative example 2 with partial omission;

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010] Hereinafter, an embodiment of an electrode and an electrode structural body according to the present invention will be described below with reference to FIGS. 1A to 10B. It should be noted that, in this description, a numeric range of "A to B" includes both the numeric values A and B as the lower limit and upper limit values.

[0011] As shown in FIGS. 1A to 1C, an electrode 10 according to the embodiment of the present invention includes a cylindrical insulator 14 having a hollow portion (through hole) 12, and a rod shaped conductor 16 provided in the hollow portion 12 of the insulator 14. At least an edge portion 18 of the conductor 16, i.e., an edge portion 18 of one end surface 16a of the conductor 16 is covered with the insulator 14. It should be noted that the insulator 14 may be referred to as the dielectric body for inducing a charge. As shown in FIG. 2A, the edge portion 18 includes a border portion (ridgeline portion) between a side surface and one end surface 16a of the conductor 16, and as shown in FIGS. 2B and 2C, includes a chamfered portion (R surface or C surface) if the surface of the conductor 16 is chamfered.

[0012] The one end surface 16a of the conductor 16 is positioned inside the hollow portion 12 in comparison with one end surface 14a of the insulator 14. Another end surface 16b of the conductor 16 protrudes from another end surface 14b of the insulator 14. In the hollow portion 12, an air 20 is present between the one end surface 16a of the conductor 16 and the one end surface 14a of the insulator 14. The dielectric constant of the air 20 is lower than the dielectric constant of the insulator 14.

[0013] The hollow portion 12 of the insulator 14 includes a first hollow portion 12a and a second hollow portion 12b connected to the first hollow portion 12a. The conductor 16 is provided in the first hollow portion 12a, and the conductor 16 is not present in the second hollow portion 12b. Specifically, as shown in FIG. 3, a connection hole 22 is formed at the border between the first hollow portion 12a and the second hollow portion 12b. The opening cross sectional area A_a of this connection hole 22 is smaller than the cross sectional area (cross sectional area A_b) of the conductor 16 in a direction normal to an axial direction of the conductor 16. In the embodiment of the present invention, the relationship of $0.10 \leq A_a/A_b \leq 0.90$ is satisfied. Further, in the second hollow portion 12b, the cross sectional area A_c of the second hollow portion 12b in the direction normal to the axial direction of the insulator 14 is constant toward the connection hole 22.

[0014] In the case where the insulator 14 has a cylindrical shape, and the conductor 16 has a columnar shape, it can be said that the diameter D_a of the connection hole 22 is smaller than the diameter D_b of the conductor 16. In this case, the relationship of $0.65 \leq D_a/D_b \leq 0.75$ is satisfied. In this structure, the outer diameter of the insulator 14 is in a range of 0.4 to 5 mm, the length of the insulator 14 in the axial direction is in a range of 5 to 100 mm, and the thickness of the insulator 14 is in a range of 0.1 to 1.5 mm. The outer diameter of the conductor 16 is in a range of 0.2 to 4.8 mm, and the length of the conductor 16 in the axial direction is in a range of 7 to 300 mm.

[0015] The insulator 14 and the conductor 16 are joined together directly and integrally by firing the insulator 14 and the conductor 16. For example, a green body to be processed into the insulator 14 is produced beforehand. Then, after the conductor 16 is inserted into a hollow portion of the green body, the insulator 14 and the conductor 16 are fired to join the insulator 14 and the conductor 16 together directly and integrally. In this manner, the electrode 10 is produced. The green body can be produced, e.g., using a gel cast method. Specifically, raw material slurry containing raw material powder, dispersion medium, and gelling agent is prepared. The prepared raw material slurry is solidified by hardening reaction induced by the gelling agent to form the green body. Using the gel cast method, even if the hollow portion 12 of the insulator 14 has a complicated shape, the green body can be produced easily. After the green body is fired into the insulator 14, the conductor 16 may be inserted into the hollow portion 12 of the insulator 14 to join the insulator 14 and the conductor 16 integrally, as long as the gap between the insulator 14 and the conductor 16 is sufficiently small.

[0016] As shown in FIG. 4, an electrode structural body 50 according to the embodiment of the present invention has a first fixing member 52A and a second fixing member 52B for fixing a plurality of the electrodes 10 such that axial directions of the electrodes 10 are aligned and the electrodes 10 are spaced from each other. In the electrodes 10, one end surface 16a of each of the conductors 16 is fixed to the first fixing member 52A and the second fixing member 52B alternately. In an example of FIG. 4, among the two electrodes 10 (first electrode 10A and second electrode 10B), one end surface 16a of the conductor 16 in the first electrode 10A is oriented to the left side, and one end surface 16a of the conductor 16 in the second electrode 10B is oriented to the right side.

[0017] The first fixing member 52A has a first through hole 56a and a second through hole 56b. One end 54Aa of the first electrode 10A is inserted into the first through hole 56a, and another end 54Bb of the second electrode 10B is inserted into the second through hole 56b. The second fixing member 52B has a third through hole 56c and a fourth through hole 56d. Another end 54Ab of the first electrode 10A is inserted into the third through hole 56c, and one end 54Ba of the second electrode 10B is inserted into the fourth through hole 56d.

[0018] The first electrode 10A and the second electrode 10B are fixed by the first fixing member 52A and the second fixing member 52B such that the axial directions of the first electrode 10A and the second electrode 10B are aligned with a predetermined electrode discharge gap 58 (e.g., 0.3 to 1.0 mm) between the first electrode 10A and the second electrode 10B.

[0019] Another end 60Ab of the conductor 16 in the first electrode 10A and another end 60Bb of the conductor 16 in

the second electrode 10B function as current collecting electrodes connected electrically to a power source (not shown). The area where the conductor 16 in the first electrode 10A and the conductor 16 in the second electrode 10B face each other is an electrode discharge area 62 where electric discharge (silent electric discharge) occurs.

[0020] Each of the conductors 16 in the first electrode 10A and the second electrode 10B is preferably made of a material containing a substance selected from the group consisting of molybdenum, tungsten, silver, copper, nickel, chromium, and alloys containing at least one thereof. Examples of such alloys include invar, kovar, inconel (registered trademark), and incoloy (registered trademark).

[0021] Further, each of the insulators 14 in the first electrode 10A and the second electrode 10B is preferably made of a ceramic material which can be fired at a temperature lower than the melting point of the conductor 16. Specifically, the material for the insulator 14 preferably includes a single oxide or single nitride material, or a composite oxide or composite nitride material containing one or more substances selected from the group consisting of barium oxide, bismuth oxide, titanium oxide, zinc oxide, neodymium oxide, titanium nitride, aluminum nitride, silicon nitride, alumina, silica, and mullite. Preferably, among these materials, the composite oxide or composite nitride material should be used.

[0022] Next, operations and advantages of the electrode 10 and the electrode structural body 50 will be described by contrast with structure of a comparative example (see FIG. 5).

[0023] As shown in FIG. 5, in electrodes 102 (first electrode 102A and second electrode 102B) of an electrode structural body 100 according to the comparative example, the diameter of the hollow portion 12 of the insulator 14 is constant over the entire insulator 14.

[0024] In the electrode structural body 100 according to the comparative example, silent electric discharge occurs in an area where the conductor 16 in the first electrode 102A and the conductor 16 in the second electrode 102B face each other. Additionally, unwanted electric discharge occurs along a creepage path 104 between the conductor 16 in the first electrode 102A and the conductor 16 in the second electrode 102B. In this case, both ends of each of the creepage paths 104 are a side surface of the conductor 16 in the first electrode 102A, an edge portion 18 of the conductor 16 in the second electrode 102B, and a side surface of the conductor 16 in the second electrode 102B and an edge portion 18 of the conductor 16 in the first electrode 102A. Therefore, when unwanted electric discharge occurs between both ends of each of the creepage paths 104, the unwanted electric discharge tends to be concentrated at the edge portion 18 of the conductor 16, and the insulator 14 may be damaged at a position adjacent to the edge portion 18 of the conductor 16.

[0025] In contrast, in the electrode 10 and the electrode structural body 50 according to the embodiment of the present invention, as shown in FIG. 4, both ends of each of the creepage paths 104 are the side surface of the conductor 16 in the first electrode 10A and the central portion (surface portion) of one end surface 16a of the conductor 16 in the second electrode 10B, and the side surface of the conductor 16 in the second electrode 10B and the central portion (surface portion) of the one end surface 16a of the conductor 16 in the first electrode 10A. Therefore, even if unwanted electric discharge occurs between both ends of each of the creepage paths 104, concentration of the unwanted electric discharge at the edge portion 18 of the conductor 16 is avoided. Accordingly, it is possible to prevent damages of the insulator 14 at the position adjacent to the edge portion 18 of the conductor 16. Thus, improvement in the reliability of the electrode 10 and the electrode structural body 50, and consequently, the reliability of the application (ozone generator, etc.) using the electrode 10 is achieved.

[0026] Next, several modified examples of the electrode 10 according to the embodiment of the present invention will be described with reference to FIG. 6A to FIG. 8.

[0027] Firstly, as shown in FIG. 6A to 6C, an electrode 10a according to a first modified example to an electrode 10c according to a third modified example have the same structure as the structure of the electrode 10 according to the embodiment of the present invention. However, the electrode 10a according to the first modified example to the electrode 10c according to the third modified example are partly different from the electrode 10 according to the above described embodiment of the present invention in respect of the structure of the second hollow portion 12b. Specifically, the cross sectional area (cross sectional area A_x) of the second hollow portion 12b normal to the axial direction of the insulator 14 changes stepwise toward the border (connection hole 22). The electrode 10a according to the first modified example to the electrode 10c according to the third example are merely examples. Various other examples can be envisaged.

[0028] As shown in FIG. 6A, in the electrode 10a according to the first modified example, the cross sectional area A_c of the second hollow portion 12b is decreased stepwise toward the border (connection hole 22). In this case, the cross sectional area A_x of the second hollow portion 12b at one end surface of the insulator 14 may be larger than the cross sectional area A_b of the conductor 16.

[0029] As shown in FIG. 6B, in the electrode 10b according to the second modified example, the cross sectional area A_c of the second hollow portion 12b is increased stepwise toward the border (connection hole 22), and then, decreased stepwise toward the border.

[0030] As shown in FIG. 6C, in the electrode 10c according to the third modified example, the cross sectional area A_c of the second hollow portion 12b is decreased stepwise toward the border (connection hole 22), and then, increased stepwise toward the border, and then, decreased stepwise toward the border.

[0031] In the electrode 10a according to the first modified example to the electrode 10c according to the third modified example, it becomes possible to increase the distance of the creepage path 104. Therefore, occurrence of the unwanted electric discharge can be suppressed. Even if unwanted electric discharge occurs, as described above, it is possible to avoid concentration of unwanted electric discharge at the edge portion 18 of the conductor 16, and prevent damages of the insulator 14 at the position adjacent to the edge portion 18 of the conductor 16. Accordingly, the structure is advantageous in respect of reduction in the electrode damage rate.

[0032] Next, as shown in FIGS. 7A to 7C, an electrode 10d according to a fourth modified example to an electrode 10f according to a sixth modified example have the same structure as the structure of the electrode 10 according to the embodiment of the present invention. However, the electrode 10d according to the fourth modified example to the electrode 10f according to the sixth modified example are partly different from the electrode 10 according to the above described embodiment of the present invention in respect of the structure of the second hollow portion 12b. Specifically, the cross sectional area (cross sectional area A_c) of the second hollow portion 12b normal to the axial direction of the insulator 14 changes continuously toward the border (connection hole 22). The electrode 10d according to the fourth modified example to the electrode 10f according to the sixth modified example are merely examples. Various other examples can be envisaged.

[0033] As shown in FIG. 7A, in the electrode 10d according to the fourth modified example, the cross sectional area A_c of the second hollow portion 12b is decreased continuously toward the border (connection hole 22). Also in this case, the cross sectional area A_x at one end surface of the insulator 14 of the second hollow portion 12b may be larger than the cross sectional area A_b of the conductor 16.

[0034] As shown in FIG. 7B, in the electrode 10e according to the fifth modified example, the cross sectional area A_c of the second hollow portion 12b is increased continuously toward the border (connection hole 22), and then, decreased continuously toward the border.

[0035] As shown in FIG. 7C, in the electrode 10f according to the sixth modified example, the cross sectional area A_c of the second hollow portion 12b is decreased continuously toward the border (connection hole 22), then, increased continuously toward the border, and then, decreased continuously toward the border.

[0036] Also in the electrode 10d according to the fourth modified example to the electrode 10f according to the sixth modified example, it becomes possible to increase the distance of the creepage path 104. Therefore, occurrence of the unwanted electric discharge can be suppressed. Even if unwanted electric discharge occurs, as described above, it is possible to avoid concentration of unwanted electric discharge at the edge portion 18 of the conductor 16, and prevent damages of the insulator 14 at the position adjacent to the edge portion 18 of the conductor 16. Accordingly, the structure is advantageous in respect of reduction in the electrode damage rate.

[0037] As shown in FIG. 8, the electrode 10g according to the seventh modified example has structure formed by combining the first modified example (see FIG. 6A) and the fourth modified example (see FIG. 7A). The cross sectional area A_c of the second hollow portion 12b is constant up to an intermediate position toward the border (connection hole 22), and decreased gradually from the intermediate position. It is a matter of course that the first to third modified examples and the fourth to sixth modified examples can be combined together in various manners.

[0038] In the above example, as the electrode structural body 50, instead of adopting the structure shown in FIG. 4, as shown in FIG. 9, three or more electrodes 10 may be arranged such that the axial directions of the electrodes 10 are aligned, the electrodes 10 are spaced from one another, and one end surface 16a of each of the conductors 16 is arranged alternately. In an example shown in FIG. 9, ten electrodes 10 are fixed such that the axial directions of the electrodes 10 are aligned, and the electrodes 10 are spaced from one another.

[Embodiment Examples]

[0039] Next, the electrode damage rate of the electrode structural bodies according to the embodiment examples 1 to 3, and the comparative examples 1 and 2 were checked, after a simulation test of applying electric power of 6 W between the electrodes for one hour.

(Embodiment Example 1)

[0040] Ten electrodes 10 (see FIGS. 1A to 1C) according to the embodiment of the present invention were prepared. As shown in FIG. 9, an electrode structural body was produced by arranging the ten electrodes 10 such that the axial directions of the electrodes 10 are aligned, the electrodes 10 are spaced from one another, and one end surface 16a of each of conductors 16 was arranged alternately. Then, a simulation test was conducted for the electrode structural body having these ten electrodes 10. In each of the electrodes 10, the insulator 14 has a cylindrical shape, and the conductor 16 has a columnar shape. The diameter D_a of the connection hole 22 and the diameter D_b of the conductor 16 satisfy the relationship of $D_a/D_b = 0.7$.

(Embodiment Example 2)

[0041] Ten electrodes 10a according to the first modified example (see FIG. 6A) were prepared. The electrode structural body having the ten electrodes 10a was prepared in the same manner as in the case of the embodiment example 1, and a simulation test was conducted for the electrode structural body. In each of the electrodes 10a, the insulator 14 has a cylindrical shape, and the conductor 16 has a columnar shape. The diameter D_a of the connection hole 22 and the diameter D_b of the conductor 16 satisfy the relationship of $D_a/D_b = 0.7$.

(Embodiment Example 3)

[0042] Ten electrodes 10d according to the fourth modified example (see FIG. 7A) were prepared. The electrode structural body having the ten electrodes 10d was prepared in the same manner as in the case of the embodiment example 1, and a simulation test was conducted for the electrode structural body. In each of the electrodes 10d, the insulator 14 has a cylindrical shape, and the conductor 16 has a columnar shape. The diameter D_a of the connection hole 22 and the diameter D_b of the conductor 16 satisfy the relationship of $D_a/D_b = 0.7$.

(Comparative Example 1)

[0043] Ten electrodes 102 according to the comparative example (see FIG. 10A and FIG. 5) were prepared. The electrode structural body having the ten electrodes 102 was prepared in the same manner as in the case of the embodiment example 1, and a simulation test was conducted for the electrode structural body. In each of the electrodes 102, the insulator 14 has a cylindrical shape, and the conductor 16 has a columnar shape. The diameter D_d of the hollow portion 12 and the diameter D_b of the conductor 16 satisfy the relationship of $D_d/D_b = 1.0$.

(Comparative Example 2)

[0044] As shown in FIG. 10B, the hollow portion 12 of an electrode 110 according to a comparative example 2 is not the through hole. One end surface 16a of the conductor 16 is closed by the insulator 14. Ten electrodes 110 of this type were prepared. The electrode structural body having the ten electrodes 110 was produced in the same manner as in the case of the embodiment example 1, and a simulation test was conducted for the electrode structural body. In the electrode 110, the insulator 14 has a cylindrical shape with one closed end, and the conductor 16 has a columnar shape.

(Evaluation results)

[0045] Evaluation results of the embodiment examples 1 to 3 and the comparative examples 1 and 2 are shown in the following table 1.

Table 1

	Electrode Damage Rate (%)
Comparative Example 1	70
Comparative Example 2	50
Embodiment Example 1	10
Embodiment Example 2	0
Embodiment Example 3	0

[0046] In the comparative example 1, it was confirmed that seven electrodes 102 among the ten electrodes 102 were damaged. Therefore, the electrode damage rate is 70 %. In the comparative example 2, five electrodes 110 among the ten electrodes 110 were damaged. Therefore, the electrode damage rate is 50 %.

[0047] In contrast, in the embodiment example 1, it was confirmed that one electrode 10 among the ten electrodes 10 was damaged. Therefore, the electrode damage rate in the embodiment example 1 is 10 %, and practically, there was no problem. In both of the embodiment example 2 and the embodiment example 3, no damage in the electrodes was confirmed. Therefore, the electrode damage rate in the embodiment example 2 and the embodiment example 3 is 0 %.

Claims

1. An electrode comprising:

a cylindrical insulator (14) including a hollow portion (12); and
a conductor (16) provided in the hollow portion (12) of the insulator (14),
wherein an edge portion (18) at one end surface (16a) of at least the conductor (16) is covered with the insulator (14).

2. The electrode according to claim 1, wherein the one end surface (16a) of the conductor (16) is positioned inside the hollow portion (12) in comparison with one end surface (14a) of the insulator (14).

3. The electrode according to claim 1 or 2, wherein, in the hollow portion (12), a substance having a dielectric constant which is lower than a dielectric constant of the insulator (14) is present between the one end surface (16a) of the conductor (16) and one end surface (14a) of the insulator (14).

4. The electrode according to claim 3, wherein the substance is an air (20).

5. The electrode according to any one of claims 1 to 4, wherein the hollow portion (12) of the insulator (14) includes a first hollow portion (12a) and a second hollow portion (12b) connected to the first hollow portion (12a); the conductor (16) is provided in the first hollow portion (12a) and the conductor (16) is not present in the second hollow portion (12b); and an opening cross sectional area at a border between the first hollow portion (12a) and the second hollow portion (12b) is smaller than a cross sectional area of the conductor (16) normal to an axial direction of the conductor (16).

6. The electrode according to claim 5, wherein the electrode is configured to satisfy a relationship of:

$$0.10 \leq Aa/Ab \leq 0.90$$

where Aa denotes the opening cross sectional area at the border between the first hollow portion (12a) and the second hollow portion (12b), and Ab denotes the cross sectional area of the conductor (16) normal to the axial direction of the conductor (16).

7. The electrode according to claim 5 or 6, wherein a cross sectional area (Ac) of the second hollow portion (12b) normal to an axial direction of the insulator (14) is constant toward the border.

8. The electrode according to claim 5 or 6, wherein a cross sectional area (Ac) of the second hollow portion (12b) normal to an axial direction of the insulator (14) changes stepwise toward the border.

9. The electrode according to claim 5 or 6, wherein a cross sectional area (Ac) of the second hollow portion (12b) normal to an axial direction of the insulator (14) changes continuously toward the border.

10. The electrode according to any one of claims 1 to 9, wherein the insulator (14) and the conductor (16) are joined together directly and integrally by firing.

11. An electrode structural body comprising a fixing member (52A, 52B) configured to fix a plurality of electrodes (10) according to claims 1 to 10,

wherein axial directions of the electrodes (10) are aligned and the electrodes (10) are spaced from one another, wherein the electrodes (10) are fixed to the fixing member (52A, 52B), where the one end surface (16a) of each of the conductors (16) is fixed to the fixing member (52A, 52B) alternately.

FIG. 1A

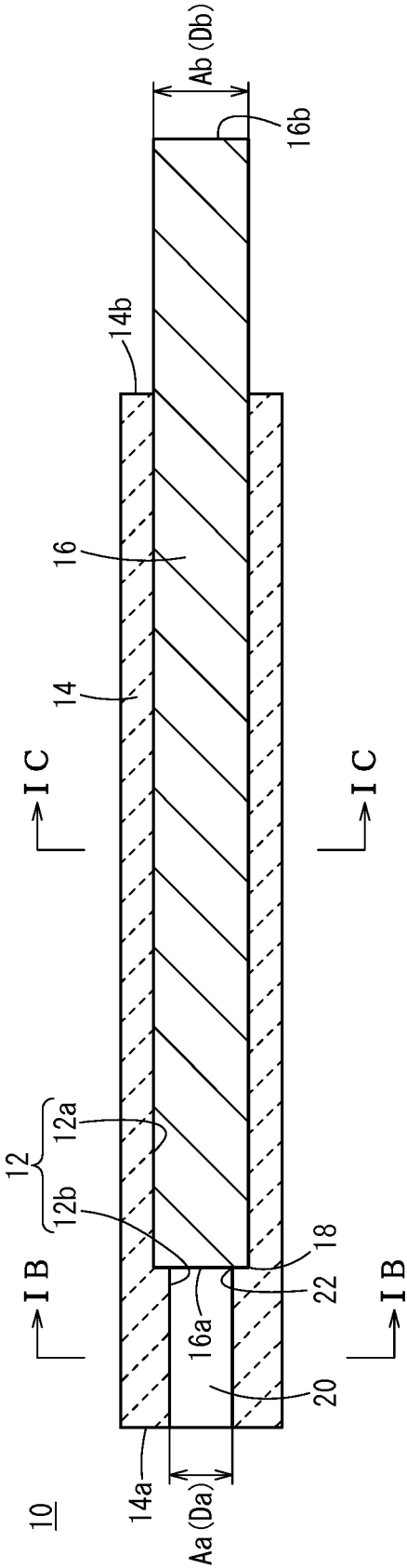


FIG. 1B

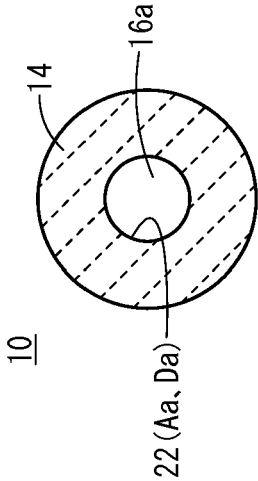


FIG. 1C

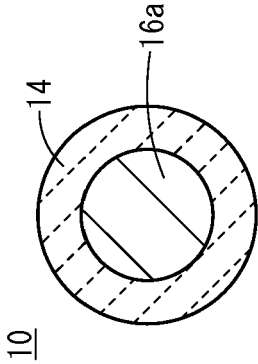


FIG. 2A

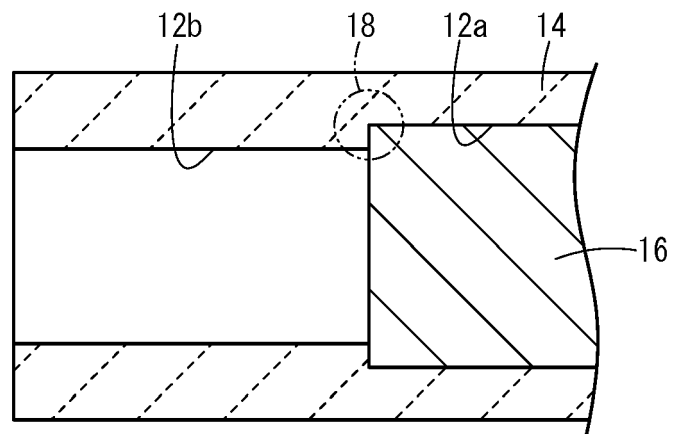


FIG. 2B

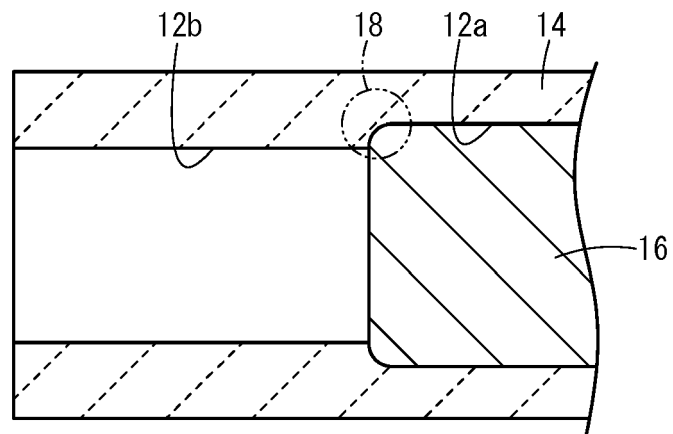


FIG. 2C

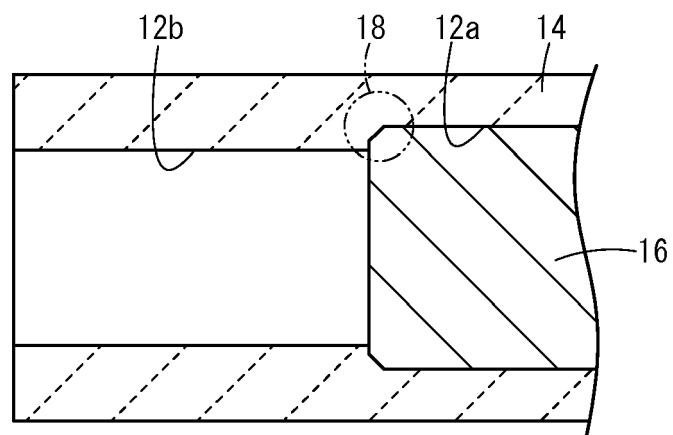


FIG. 3

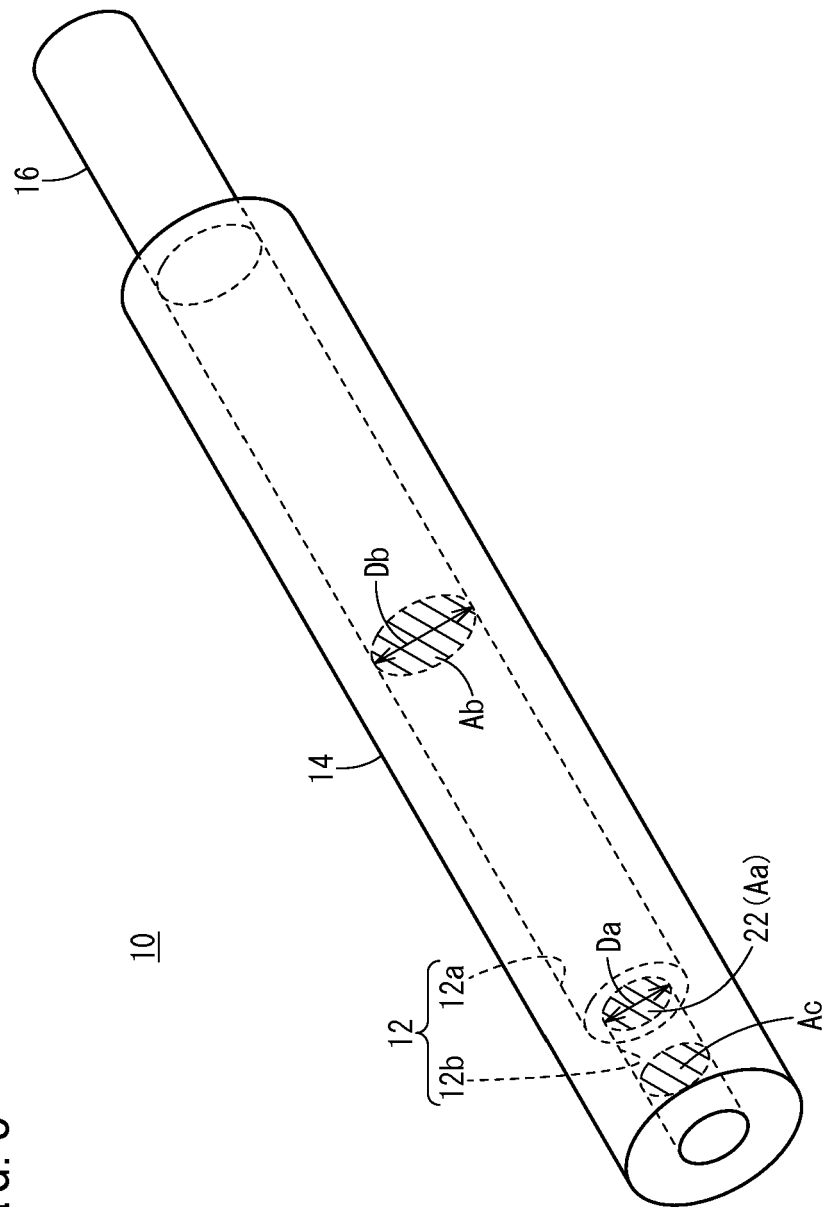


FIG. 4

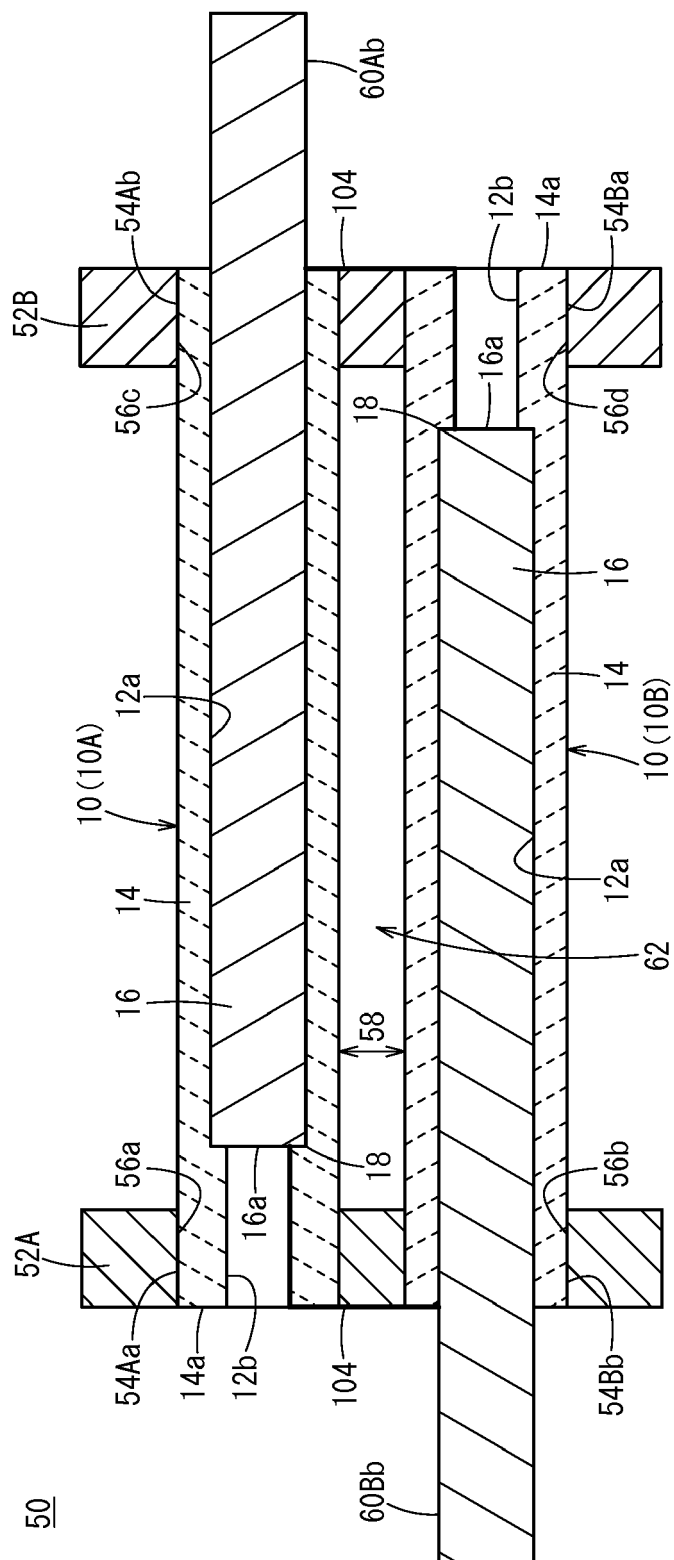


FIG. 5

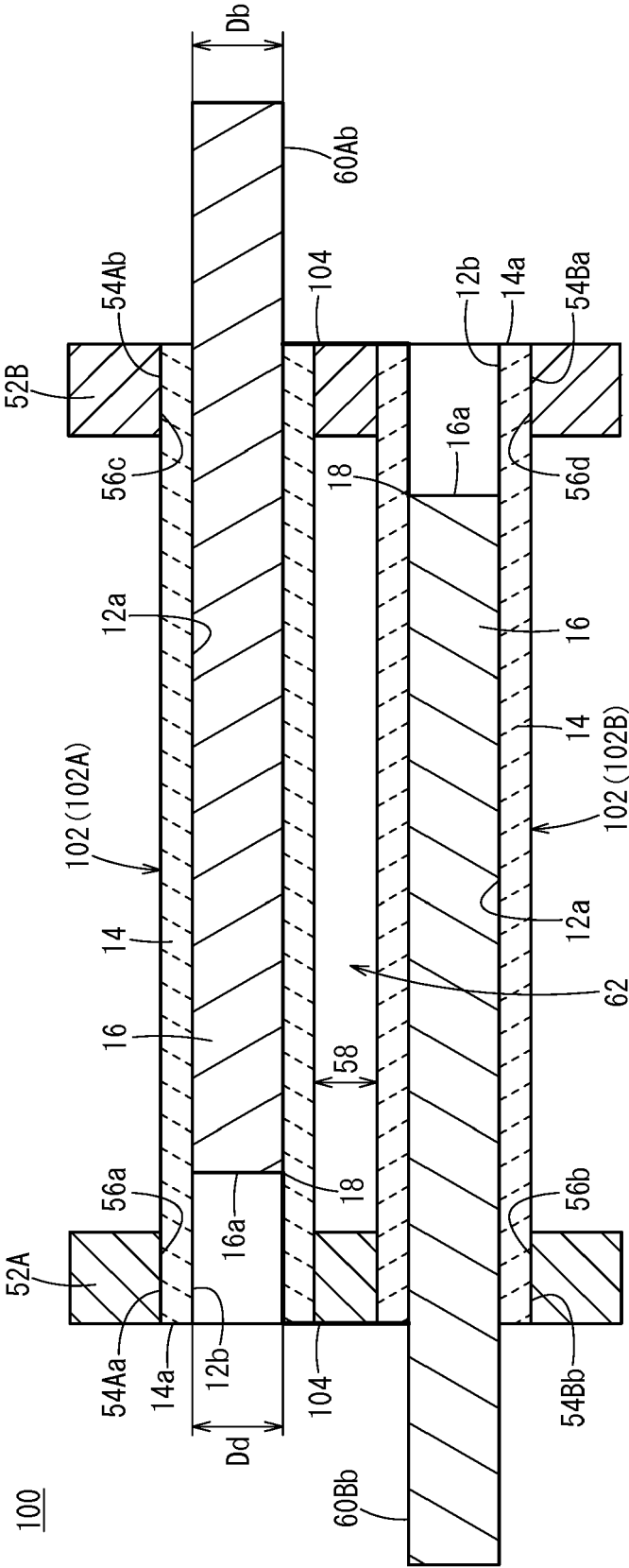


FIG. 6A

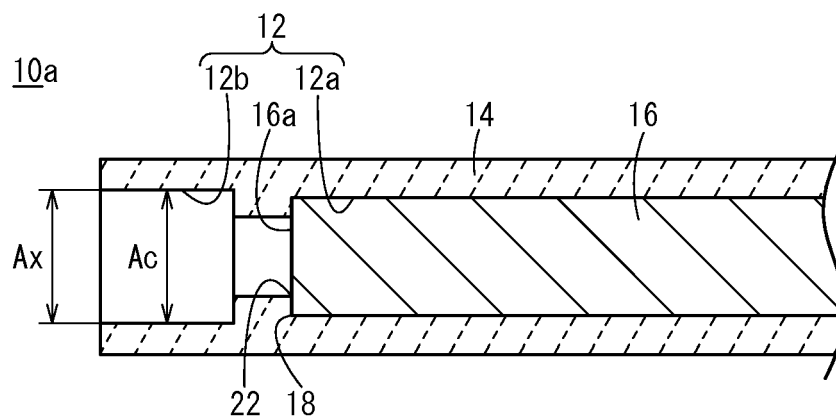


FIG. 6B

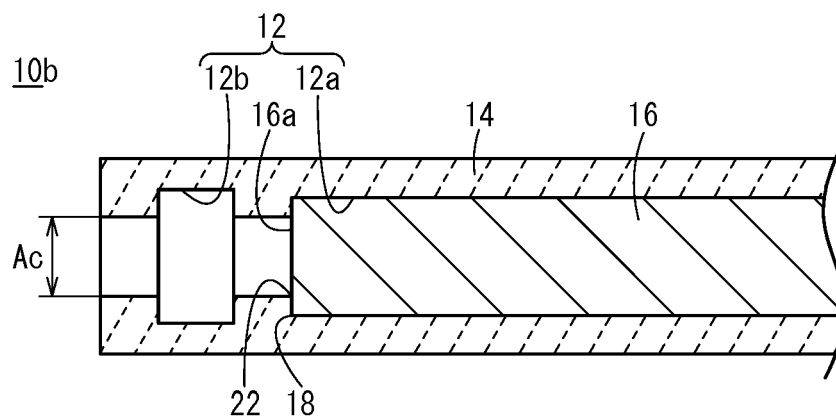


FIG. 6C

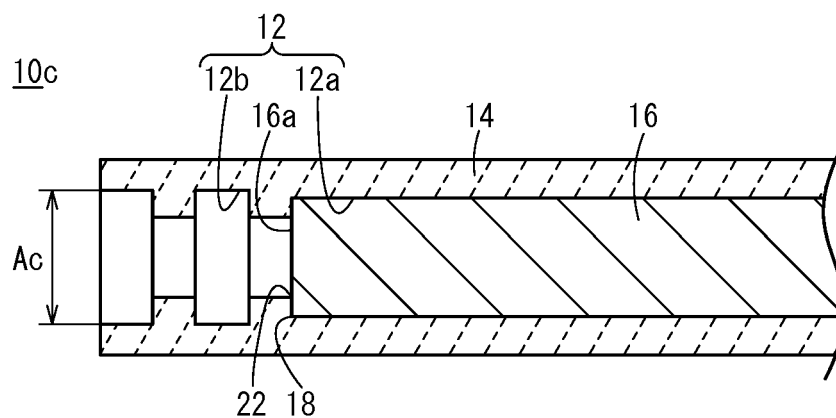


FIG. 7A

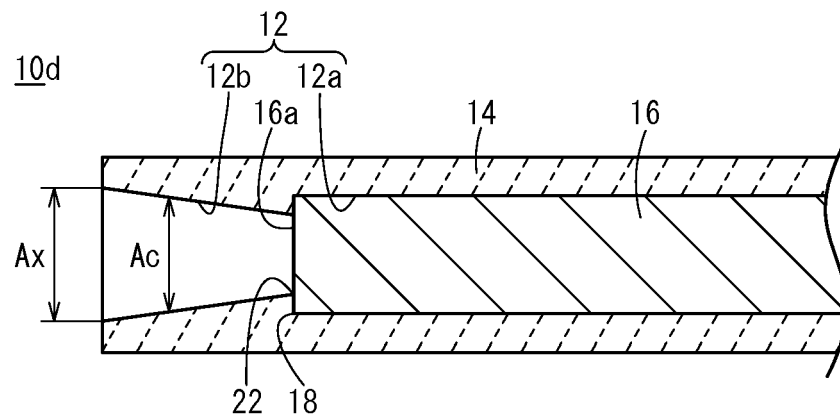


FIG. 7B

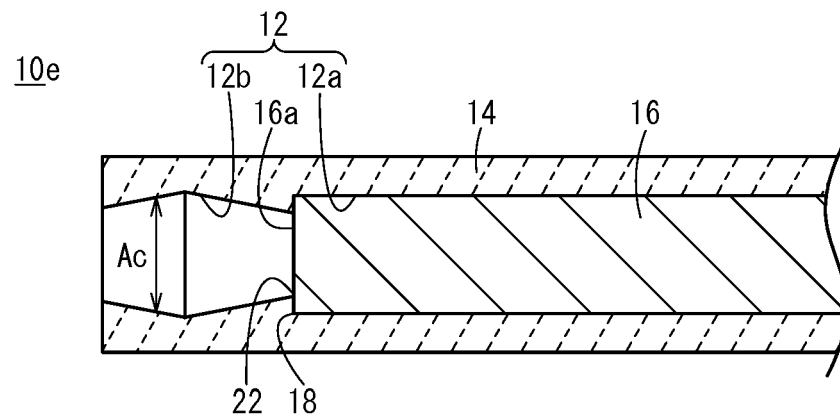


FIG. 7C

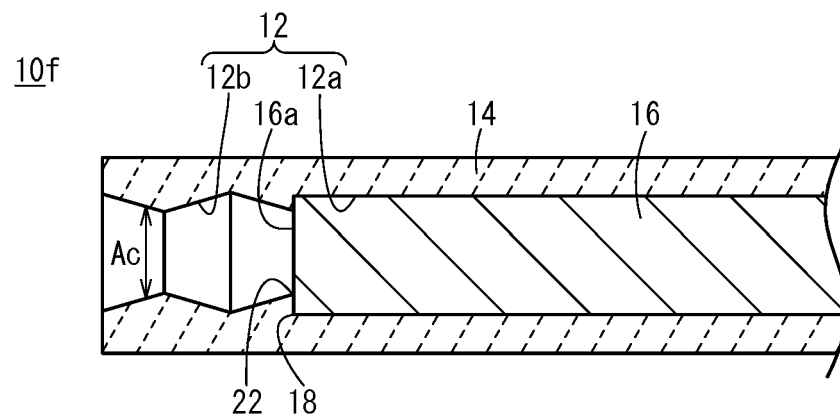


FIG. 8

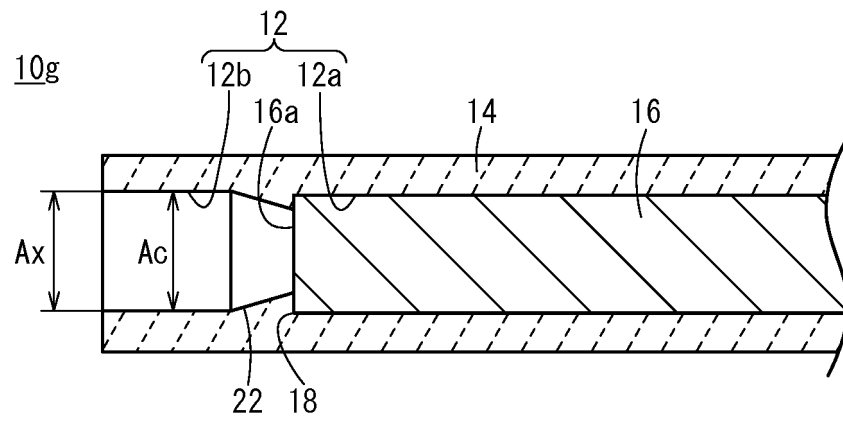


FIG. 9

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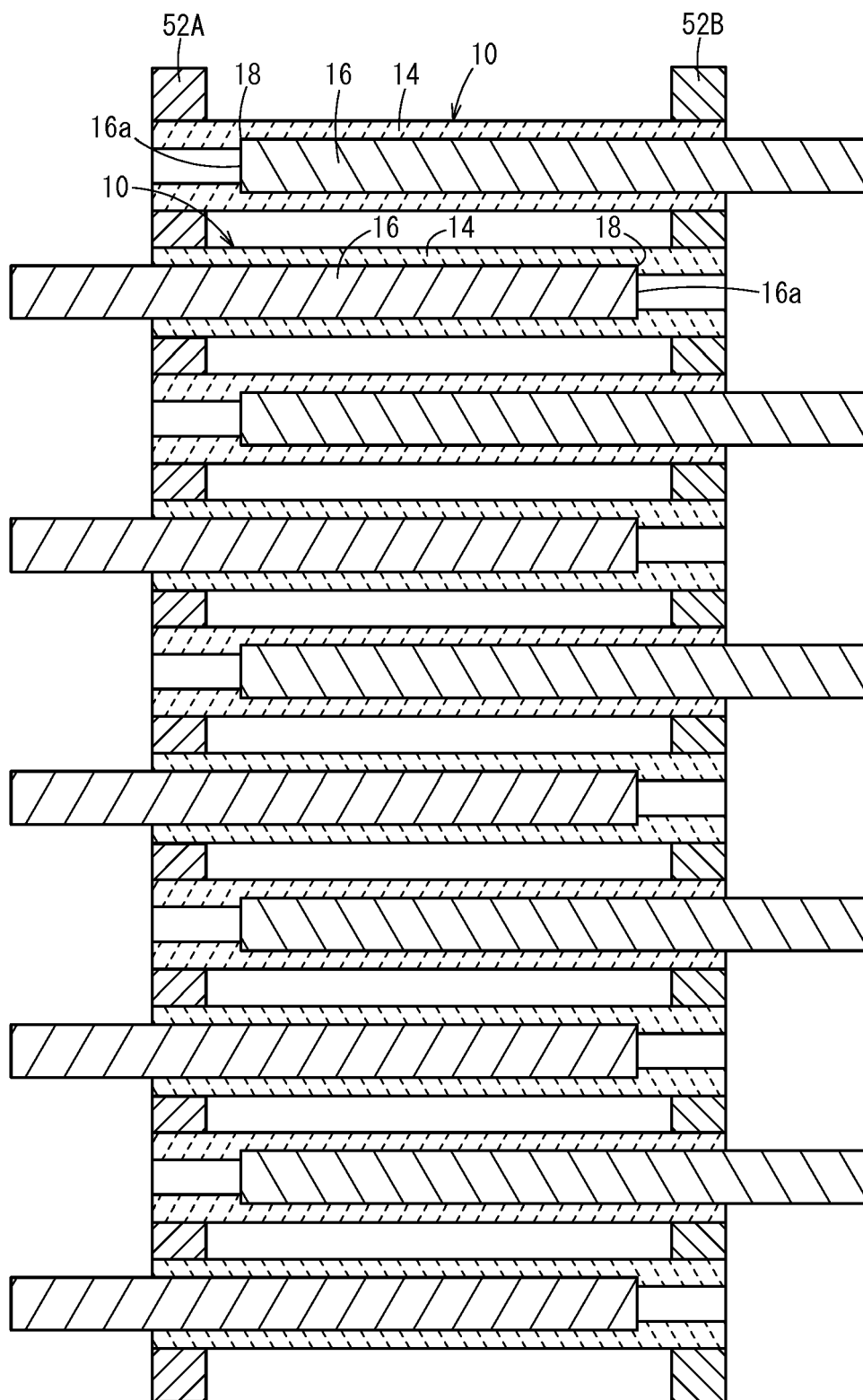


FIG. 10A

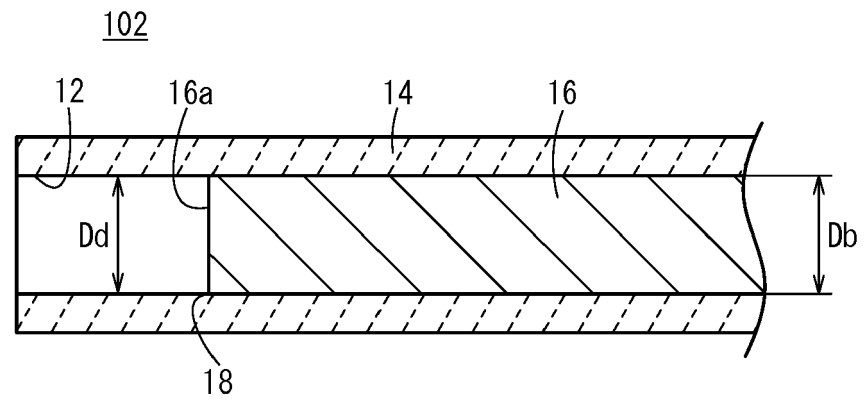
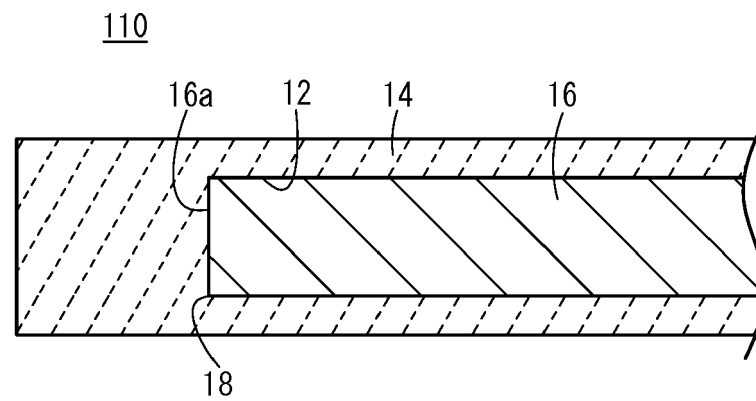


FIG. 10B





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Place of search The Hague		Date of completion of the search 20 April 2016	Examiner de Ruijter-Noordman
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