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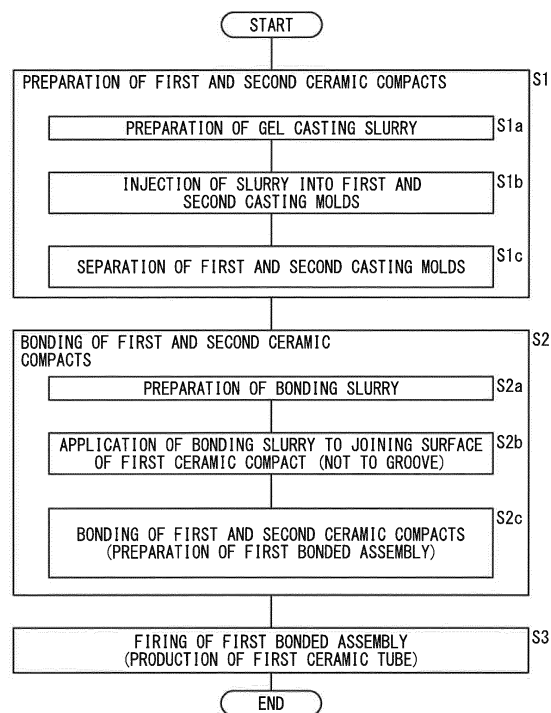
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METHOD FOR PRODUCING CERAMIC TUBE AND CERAMIC TUBE

(57) This method for producing a ceramic tube produces a single ceramic tube for a high-brightness discharge lamp by joining a plurality of ceramic compacts, and has: a compact-producing step (step S1) for producing a plurality of ceramic compacts including at least one ceramic compact having a groove on the joining surface; and a compact-joining step (step S2) for joining the joining surfaces of the plurality of ceramic compacts to each other. The method for producing a ceramic tube produces a ceramic tube having a hole formed by means of the groove.

FIG. 1



Description

Technical Field

5 **[0001]** The present invention relates to a method for producing a ceramic tube usable in a high-intensity discharge lamp such as a high-pressure sodium vapor lamp or a metal halide lamp, and further relates to the ceramic tube.

Background Art

10 **[0002]** In ceramic metal halide lamps, a pair of electrodes are inserted into a ceramic tube for a high-intensity discharge lamp, and a metal halide is ionized by the electrodes to show discharge emission.

15 **[0003]** Such a ceramic tube has a pair of narrow pipes, and the axis lines of the narrow pipes extend toward a light-emitting portion. Each narrow pipe has an electrode insertion hole, into which the electrode is inserted. Various types of the ceramic tubes (such as those produced by assembling a plurality of members, those composed of a single integrally formed member, and those produced by bonding two members) are disclosed in e.g. Japanese Laid-Open Patent Publication Nos. 63-143738, 5-334962, 7-021990, 8-055606, 2010-514125 (PCT), and 2010-514127 (PCT), US Patent Application Publication No. 2006/0001346, and Japanese Laid-Open Patent Publication Nos. 2009-530127 (PCT) and 2008-044344.

20 **[0004]** For example, one electrode is inserted into the electrode insertion hole of one of the two narrow pipes (small holes) in the ceramic tube, the electrode insertion hole is sealed with a fritted glass or the like, a light-emitting material is introduced from the other electrode insertion hole into a light-emitting container, the other electrode is inserted into the other electrode insertion hole, and then the other electrode insertion hole is sealed by the fritted glass or the like, to obtain an arc tube. In another known example, the ceramic tube has a third narrow pipe or small hole in addition to the above two narrow pipes for electrode insertion, and the light-emitting material is introduced through the third narrow

25 pipe or small hole into the light-emitting container after the electrodes are sealed.

30 **[0005]** Specifically, Japanese Laid-Open Patent Publication No. 63-143738 discloses a ceramic discharge lamp containing an arc tube bulb composed of a translucent ceramic and closure members composed of a conductive cermet. The arc tube bulb has openings at either end, and the openings are sealed by solid-phase-bonding, the closure members having electrodes. The arc tube bulb further has a small hole for discharging an exhaust gas from the tube and for supplying an inclusion, and the small hole is closed by welding a ceramic cover.

35 **[0006]** Japanese Laid-Open Patent Publication No. 5-334962 discloses a translucent bulb composed of a polycrystalline alumina. The translucent bulb has cylindrical openings at either end, and closure members are attached to the cylindrical openings. Each closure member has a hole at the center, and an electrode is inserted into the hole. The translucent bulb further has an opening, and a light-emitting material is introduced from the opening into the translucent bulb. The opening is formed in a position eccentrically with respect to the center of one of the closure members.

40 **[0007]** Japanese Laid-Open Patent Publication No. 7-021990 discloses a discharge tube, wherein pin-like current conductors having a diameter of 300 μm are inserted into the ends of the discharge tube, and plugs are directly bonded to the ends by sintering. Especially, as shown in FIGS. 3 and 4 of this patent document, a filling hole having a diameter of 1 mm or more may be formed, for introducing a light-emitting material into the discharge tube, in a wall of the discharge tube around the second end or in the second plug.

45 **[0008]** Japanese Laid-Open Patent Publication No. 8-055606 discloses an arc tube having an infundibular portion, which is formed integrally with a small-diameter tube having a closed lower end. The small-diameter tube extends downward from the center of the infundibular portion, and a liquid metal halide is stored in a lower portion (coldest portion, which is coldest during lighting) of the small-diameter tube. The liquid metal halide is not vaporized and remains in the arc tube. In particular, this patent document describes that one opening formed on a flange-like intermediate portion may be used as an inlet for the metal halide and mercury, and the small-diameter tube may be used as an inlet tube.

50 **[0009]** Japanese Laid-Open Patent Publication No. 2010-514125 (PCT) discloses a ceramic burner containing a discharge vessel. One end of the discharge vessel is formed integrally with a wall of the tube, and the other end of the discharge vessel is sealed with a ceramic plug. Particularly, in an example of this patent document, a tube extends outward from a ceramic wall of the discharge vessel, and is used for introducing an ionizing filler into the discharge vessel in the manufacture of the ceramic burner. Incidentally, the tube is air-tightly sealed.

55 **[0010]** Japanese Laid-Open Patent Publication 2010-514127 (PCT) discloses a discharge vessel having a substantially spherical or oval shape containing two independent portions (separated by a dashed line in FIG. 2A of this patent document). A tube is formed only on the first portion of the discharge vessel, extends outward from a ceramic wall of the discharge vessel, and is used for introducing an ionizing filler into the discharge vessel in the manufacture of a ceramic burner. Incidentally, the tube is air-tightly sealed.

[0011] US Patent Application Publication No. 2006/0001346 discloses a structure containing a tube portion and end members bonded to either end of the tube portion. An electrode is disposed at the center of each end member, and

extends toward the inside of the tube portion. Particularly one end member has an inlet hole, which extends from the outer surface of the member to the inner surface (the surface facing the tube portion). A metal halide or the like is introduced from the inlet hole into the tube portion, and then the inlet hole is sealed with a plug member.

[0012] Furthermore, a production method containing preparing a plurality of inorganic powder compacts, applying a slurry to the joining surfaces of the compacts, and integrating and sintering the compacts to obtain a strongly-bonded sintered body is known from e.g. Japanese Laid-Open Patent Publication No. 2009-530127 (PCT), and a bonded assembly of inorganic powder compacts that can be produced while preventing or avoiding the deformation of the joining portion and the increase of surface roughness is known from e.g. Japanese Laid-Open Patent Publication No. 2008-044344.

[0013] Specifically, Japanese Laid-Open Patent Publication No. 2009-530127 (PCT) discloses a method for producing a sintered body suitable for use in an arc tube of a discharge lamp. The method uses an inorganic powder, an organic dispersion medium having a reactive functional group, and a gelling agent, and contains the steps of performing a chemical solidification reaction between the organic dispersion medium and the gelling agent to obtain first and second inorganic powder compacts, applying a slurry containing a powder and an organic dispersion medium to the joining surface of the first inorganic powder compact, bringing the inorganic powder compacts into contact with each other with the slurry applied therebetween to obtain an integrated bonded assembly, and sintering the bonded assembly to produce the sintered body.

[0014] Japanese Laid-Open Patent Publication No. 2008-044344 discloses a sintered body suitable for use in an arc tube of a discharge lamp. The sintered body is derived from a bonded assembly of two or more inorganic powder compacts, and has a first portion corresponding to the two or more inorganic powder compacts in the bonded assembly and a second portion corresponding to a joining portion in the bonded assembly. The sintered body has one or both of the following properties (a) and (b).

(a) The surface roughness of the second portion is lower than that of the first portion.

(b) The translucency of the second portion is higher than that of the first portion in the vicinity of the width-direction center.

Summary of the Invention

[0015] In Japanese Laid-Open Patent Publication Nos. 63-143738, 5-334962, 7-021990, 8-055606, 2010-514125 (PCT), and 2010-514127 (PCT) and US Patent Application Publication No. 2006/0001346, in the case of forming the narrow pipe or small hole for introducing the light-emitting material, the small hole is formed by processing a side surface of a molded ceramic tube or a sealing plug disposed at an end of the ceramic tube, and the narrow pipe is assembled to the small hole. In this case, a large number of complicated procedures are disadvantageously required for the hole processing or the assembling.

[0016] It is to be understood that the ceramic tube and the narrow pipe can be simultaneously formed by cast molding, injection molding, gel casting, or the like. However, since the molded compact does not have a simple axisymmetric shape, a mold having a complicated structure is required for the molding, resulting in a high production cost.

[0017] In the structure described in Japanese Laid-Open Patent Publication Nos. 5-334962 and 7-021990, the small hole is positioned in the coldest portion of the arc tube or in the vicinity thereof. When the arc tube is turned on, the metal halide is not entirely vaporized, and is partially stored in the liquid state in the coldest portion. Therefore, the sealing portion (sealant) of the small hole may be corroded.

[0018] In the case of forming the narrow pipe on the ceramic tube, particularly when the axis direction of the narrow pipe is perpendicular to a tangent line on the outer periphery of the ceramic tube, the narrow pipe is easily broken because of its remarkably small thickness, and is easily corroded as the coldest portion formed away from the light-emitting portion.

[0019] In view of the above problems, an object of the present invention is to provide a method for producing a ceramic tube for a high-intensity discharge lamp, which is capable of easily forming a small hole or a narrow pipe on the ceramic tube at low production cost and high productivity without additional hole or tube formation processing.

[0020] Another object of the present invention is to provide a ceramic tube for a high-intensity discharge lamp, which is capable of preventing breakage of a narrow pipe, locating the narrow pipe in a position away from a coldest point, and exhibiting improved yield and reliability.

[0021] [1] A method according to a first aspect of the present invention, for bonding a plurality of ceramic compacts to produce one ceramic tube for a high-intensity discharge lamp, comprising a compact preparation step of preparing a plurality of ceramic compacts, which include at least one ceramic compact having a groove in the joining surface, and a compact bonding step of bonding the joining surfaces of the ceramic compacts to each other, to produce a ceramic tube having a through-hole corresponding to the groove.

[0022] [2] The method according to the first aspect, wherein in the compact preparation step, one first ceramic compact

having the groove in the joining surface and one second ceramic compact not having the groove in the joining surface are prepared, and in the compact bonding step, the one first ceramic compact and the one second ceramic compact are bonded to each other.

[0023] [3] The method according to the first aspect, wherein in the compact preparation step, two first ceramic compacts having the grooves in the joining surfaces are prepared, and in the compact bonding step, the two first ceramic compacts are bonded to each other such that the grooves in the joining surfaces are aligned with each other.

[0024] [4] A method according to a second aspect of the present invention, for bonding a plurality of ceramic compacts to produce one ceramic tube for a high-intensity discharge lamp, comprising a compact preparation step of preparing a plurality of ceramic compacts, which includes at least one ceramic compact having a first projection in the joining surface, a continuous groove extending from the end of the first projection to the inside continuously in the joining surface, and a compact bonding step of bonding the joining surfaces of the ceramic compacts to each other, to produce a ceramic tube having a through-hole formed of the continuous groove.

[0025] [5] The method according to the second aspect, wherein in the compact preparation step, at least one third ceramic compact having the first projection and one fourth ceramic compact having a second projection in the joining surface are prepared, the continuous groove being not formed in the second projection, and in the compact bonding step, the joining surfaces of the third and fourth ceramic compacts are bonded to each other such that the first and second projections are aligned with each other.

[0026] [6] The method according to the second aspect, wherein in the compact preparation step, at least two third ceramic compacts having the first projections are prepared, and in the compact bonding step, the joining surfaces of the third ceramic compacts are bonded to each other such that the first projections are aligned with each other.

[0027] [7] The method according to the second aspect, wherein the first projection has a base point, which is an intersection between the outer periphery of the joining surface having the first projection and the axis line of the continuous groove in the first projection, and the tangent line at the base point on the outer periphery of the joining surface and the axis line of the continuous groove form an angle of 30° to 60° .

[0028] [8] The method according to the second aspect, wherein the joining surfaces of the ceramic compacts are parallel to a plane perpendicular to the axis direction.

[0029] [9] A ceramic tube for a high-intensity discharge lamp according to a third aspect of the present invention, obtained by bonding a plurality of ceramic compacts, comprising a light-emitting portion and electrode containers formed integrally, wherein the light-emitting portion is provided for emitting a light inside the ceramic tube, the electrode containers are disposed on either side of the light-emitting portion, electrodes being introduced and sealed therein, the light-emitting portion has a projection with a through-hole independent from the electrode containers, a light-emitting material being introduced from the through-hole into the light-emitting portion, the axis line of the projection extends toward the axis line of the ceramic tube, the axis lines of the projection and the ceramic tube form an angle of 90° , and the projection amount of the projection is within a range of $1/20$ to $10/20$ of the maximum diameter of the light-emitting portion.

[0030] [10] A ceramic tube for a high-intensity discharge lamp according to a fourth aspect of the present invention, obtained by bonding a plurality of ceramic compacts, wherein the ceramic tube comprises a light-emitting portion and electrode containers formed integrally, the light-emitting portion is for emitting a light inside the ceramic tube, the electrode containers are disposed on either side of the light-emitting portion, electrodes being inserted therein, the light-emitting portion has a projection with a through-hole independent from the electrode containers, a light-emitting material being introduced from the through-hole into the light-emitting portion, the outer surface of the light-emitting portion has a cross-sectional outline in a plane containing the axis line of the projection, and the axis line and a tangent line at an intersection between the outline and the axis line form an angle of 30° to 60° .

[0031] In the above ceramic tube production method of the present invention, a small hole or a narrow pipe can be easily formed on the ceramic tube at low production cost and high productivity without additional hole or tube formation processing.

[0032] Furthermore, the ceramic tube of the present invention is capable of preventing breakage of a narrow pipe, locating the narrow pipe in a position away from a coldest point, and exhibiting improved yield and reliability.

Brief Description of the Drawings

[0033]

FIG. 1 is a block flow diagram of a first production method;

FIG. 2 is an exploded perspective view of a combination example of first and second ceramic compacts;

FIG. 3A is a partial cross-sectional view of a first casting mold, and FIG. 3B is a partial cross-sectional view of a second casting mold;

FIG. 4A is a cross-sectional view of a first bonded assembly, and FIG. 4B is a perspective view of a first ceramic tube;

FIG. 5 is a block flow diagram of a conventional production method for producing a ceramic tube having a through-hole;

FIG. 6A is a cross-sectional view of another first bonded assembly, and FIG. 6B is a perspective view of another first ceramic tube;

FIG. 7 is a block flow diagram of a second production method;

FIG. 8 is an exploded perspective view of a combination example of a pair of first ceramic compacts;

FIG. 9A is a cross-sectional view of a second bonded assembly, and FIG. 9B is a perspective view of a second ceramic tube;

FIG. 10 is a block flow diagram of a third production method;

FIG. 11 is an exploded perspective view of a combination example of third and fourth ceramic compacts;

FIG. 12A is a partial cross-sectional view of a third casting mold, and FIG. 12B is a partial cross-sectional view of a fourth casting mold;

FIG. 13 is an exploded perspective view of another combination example of third and fourth ceramic compacts;

FIG. 14 is a view for illustrating a direction of first and second projections in the combination example of FIG. 13;

FIG. 15A is a cross-sectional view of a third bonded assembly, and FIG. 15B is a perspective view of a third ceramic tube derived from the combination example of FIG. 11;

FIG. 16A is a perspective view of a third ceramic tube derived from the combination example of FIG. 13, and FIG. 16B is a view for illustrating the direction of the cylindrical projection;

FIG. 17 is a block flow diagram of a conventional production method for producing a ceramic tube having a cylindrical projection;

FIG. 18A is a view for illustrating a projection amount of a cylindrical projection in the third ceramic tube of FIG. 15B, and FIG. 18B is a view for illustrating a projection amount of a cylindrical projection in the third ceramic tube of FIG. 16A;

FIG. 19 is a block flow diagram of a fourth production method;

FIG. 20 is an exploded perspective view of a combination example of two third ceramic compacts;

FIG. 21 is an exploded perspective view of another combination example of two third ceramic compacts;

FIG. 22A is a cross-sectional view of a fourth bonded assembly, and FIG. 22B is a perspective view of a third ceramic tube derived from the combination example of FIG. 20;

FIG. 23 is a perspective view of a third ceramic tube derived from the combination example of FIG. 21;

FIG. 24 is a view of a pattern of a screen plate used in Example 1; and

FIG. 25 is a view of a pattern of a screen plate used in Example 2.

Description of Embodiments

[0034] Several embodiment examples of the ceramic tube production method and the ceramic tube of the present invention will be described below with reference to FIGS. 1 to 25. 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.

[0035] The following embodiments are described with respect to production of one ceramic tube. It is to be understood that the embodiments are applicable to production of a large number of the ceramic tubes.

[0036] The ceramic tube is preferably used as an arc tube in a discharge lamp. A high-pressure discharge lamp containing the ceramic tube can be used in various illumination devices such as road illuminations, store illuminations, car headlamps, and liquid-crystal projectors. The arc tube may be used in a metal halide lamp or a high-pressure sodium vapor lamp.

[0037] A ceramic tube production method according to a first embodiment contains a compact preparation step of preparing a plurality of ceramic compacts, at least one of the ceramic compacts having a groove in its joining surface, and further contains a compact bonding step of bonding the joining surfaces of the ceramic compacts to produce a ceramic tube having a hole corresponding to the groove.

[0038] Several specific examples of the ceramic tube production method of the first embodiment will be described below with reference to FIGS. 1 to 9.

[0039] In a production method according to a first specific example (hereinafter referred to as a first production method), in step S1 of FIG. 1, a first ceramic compact 10A and a second ceramic compact 10B are prepared as shown in FIG. 2. The first ceramic compact 10A has a groove 14 in a joining surface 12a. The second ceramic compact 10B does not have the groove 14 in a joining surface 12b.

[0040] Specifically, in step S1a, a ceramic powder, a dispersion medium, a gelling agent, and the like are mixed to prepare a gel casting slurry (hereinafter referred to as a molding slurry). In step S1b, as shown in FIGS. 3A and 3B, the molding slurry 16 is cast into and then solidified in a first casting mold 18A for forming the first ceramic compact 10A (see FIG. 3A) and a second casting mold 18B for forming the second ceramic compact 10B (see FIG. 3B). The first casting mold 18A has a projection 20 in a position corresponding to the joining surface 12a, and the projection 20 has an inverted shape of the groove 14. Then, in step S1c, the first casting mold 18A and the second casting mold 18B are separated to obtain the first and second ceramic compacts 10A and 10B as shown in FIG. 2.

[0041] The first and second ceramic compacts 10A and 10B each have a cylindrical shape with a hollow portion 22.

More specifically, the first and second ceramic compacts 10A and 10B are similar to a shape obtained by dividing a first ceramic tube 24A as a final product (see FIG. 4B) into two parts at the length-direction center of an axis line m1, and each have a shape containing a cylindrical portion 26 and a curved (bowl-shaped) portion 28 integrally formed. Thus, the shape of a first bonded assembly 30A (see FIG. 4A), which is obtained by bonding the first and second ceramic compacts 10A and 10B, is geometrically similar to the shape of the first ceramic tube 24A, which is obtained by firing the first bonded assembly 30A. The first bonded assembly 30A is shrunk to produce the first ceramic tube 24A.

[0042] The joining surfaces 12a and 12b of the first and second ceramic compacts 10A and 10B are at the ends of the curved portions 28, and are parallel to a plane perpendicular to the axis direction of the first and second ceramic compacts 10A and 10B. One groove 14 is formed on the joining surface 12a of the first ceramic compact 10A. The groove 14 has a shape of a half cylinder, a prism, or a combination thereof. An axis line n1 of the groove 14 extends at an angle of 90° to an axis line m2 of the first ceramic compact 10A. The length of the groove 14 along the axis line n1 is equal to the thickness of the curved portion 28 of the first ceramic compact 10A. The size of the groove 14 in the direction perpendicular to the axis line n1 (the width of the groove 14) has to be 1 to 3 times as large as the diameter of a light-emitting material, which is introduced in the solid state. Thus, the inner circle diameter of the groove 14 is 0.25 to 0.9 mm. Though not shown in the drawings, the outer and inner peripheries of the joining surfaces 12a and 12b of the first and second ceramic compacts 10A and 10B may be chamfered to form e.g. an R- or C-surface.

[0043] In step S2 of FIG. 1, the first and second ceramic compacts 10A and 10B are bonded to each other to prepare the first bonded assembly 30A.

[0044] Specifically, in step S2a, a ceramic powder, a solvent, a binder, and the like are mixed to prepare a bonding slurry (hereinafter referred to as a bonding slurry 32). In step S2b, the bonding slurry 32 is applied (supplied) to the joining surface 12a of the first ceramic compact 10A, though the bonding slurry 32 is not applied to the groove 14. Then, in step S2c, the joining surface 12a of the first ceramic compact 10A is pressed toward the joining surface 12b of the second ceramic compact 10B to obtain the first bonded assembly 30A shown in FIG. 4A.

[0045] In step S3 of FIG. 1, the first bonded assembly 30A is fired to produce a sintered body (the first ceramic tube 24A). As shown in FIG. 4B, the first ceramic tube 24A has an expanded portion obtained by bonding and firing the curved portions 28 (a light-emitting portion 34) at the center, and further has electrode-sealing narrow pipes formed integrally with either end of the light-emitting portion 34 (electrode containers 36). A hollow portion 37 is formed in the first ceramic tube 24A, and extends from one electrode container 36 to the other electrode container 36. A first through-hole 38a (small hole) corresponding to the groove 14 on the joining surface 12a of the first ceramic compact 10A is formed at the center of the light-emitting portion 34 in the first ceramic tube 24A. In the case of using the first ceramic tube 24A as the arc tube, the first through-hole 38a is used as an inlet hole for introducing the light-emitting material into the light-emitting portion 34. Therefore, the first through-hole 38a is sealed after the introduction of the light-emitting material or the like. In addition to an inert start gas such as an argon gas, mercury and metal halide additives are contained in the light-emitting portion 34. Incidentally, the mercury additive is not an essential component.

[0046] For comparison, a conventional method for producing a ceramic tube having a through-hole will be described below with reference to FIG. 5.

[0047] In step S11 of FIG. 5, two second ceramic compacts 10B not having the grooves 14 in the joining surfaces 12b are prepared.

[0048] Specifically, in step S11a, the ceramic powder, the dispersion medium, the gelling agent, and the like are mixed to prepare the molding slurry 16. In step S11b, the molding slurry 16 is cast into and then solidified in the second casting mold 18B for forming the second ceramic compact 10B (see FIG. 3B). Then, the second casting mold 18B is separated to obtain the second ceramic compact 10B.

[0049] In step S12 of FIG. 5, a through-hole is formed in the curved portion 28 of one of the second ceramic compacts 10B by a hole forming processing using a drill or the like.

[0050] In step S13 of FIG. 5, the two second ceramic compacts 10B are bonded to each other.

[0051] Specifically, in step S13a, the ceramic powder, the solvent, the binder, and the like are mixed to prepare the bonding slurry. In step S13b, the bonding slurry 32 is applied (supplied) to the joining surface 12b of one second ceramic compact 10B. Then, in step S13c, the joining surfaces 12b of the two second ceramic compacts 10B are pressed toward each other to prepare a bonded assembly.

[0052] In step S14 of FIG. 5, the bonded assembly is fired to produce a sintered body having the through-hole (the ceramic tube).

[0053] In this conventional production method, the through-hole is formed in the curved portion 28 of one second ceramic compact 10B by using the drill. The second ceramic compact 10B is likely to be moved due to the rotational vibration of the drill, thereby failing to form the through-hole with a desired diameter. Therefore, the second ceramic compact 10B is held and fixed by a jig or the like. However, the holding force has to be such that the second ceramic compact 10B is not broken by the force, and it disadvantageously takes a long time to control the force. Furthermore, it is necessary to prepare the jig, the drill, and the like in accordance with the size of the second ceramic compact 10B, resulting in high production cost. In addition, a scratch is formed on the second ceramic compact 10B due to the rotational

vibration of the drill, an impact of a cutting waste, etc. Therefore, the resultant ceramic tube is likely to be cracked.

[0054] In contrast, in the first production method, the first ceramic compact 10A having the groove 14 in the joining surface 12a and the second ceramic compact 10B not having the groove 14 in the joining surface 12b are bonded to produce the first ceramic tube 24A having the first through-hole 38a corresponding to the groove 14, and the hole forming processing using the drill is not required. Therefore, the first production method is capable of simplifying the production operation, reducing the number of production steps, improving the throughput, and improving the yield. Thus, the first ceramic tube 24A having the first through-hole 38a for introducing the light-emitting material can be obtained at high productivity. In addition, since the drill is not used, the first production method is capable of preventing the scratches causing cracking and leakage in the first ceramic tube 24A. Though the mold for forming the first ceramic compact 10A is required in this method, this mold has the same simple shape as the mold for forming the second ceramic compact 10B except only for the projection 20 having the inverted shape of the groove 14, and thereby can be prepared at low cost. Thus, the mold does not result in cost increase in view of simplifying the production operation, reducing the number of production steps, improving the throughput, improving the yield, etc.

[0055] Though the curved portions 28 of the first and second ceramic compacts 10A and 10B have the same height and the first through-hole 38a is formed at the center of the light-emitting portion 34 in the above example, the curved portion 28 of the first ceramic compact 10A may have a height larger than that of the curved portion 28 of the second ceramic compact 10B as shown in FIG. 6A. Alternatively, the curved portion 28 of the first ceramic compact 10A may have a height smaller than that of the curved portion 28 of the second ceramic compact 10B. In this case, as shown in FIG. 6B, in the resultant first ceramic tube 24A, the first through-hole 38a is shifted closer to the one or other electrode container 36 from the center of the light-emitting portion 34.

[0056] In a production method according to a second specific example (hereinafter referred to as a second production method), in step S101 of FIG. 7, two first ceramic compacts 10A having the grooves 14 in the joining surfaces 12a are prepared as shown in FIG. 8.

[0057] Specifically, the ceramic powder, the dispersion medium, the gelling agent, and the like are mixed to prepare the molding slurry 16 (step S101a of FIG. 7). The molding slurry 16 is cast into and then solidified in the first casting mold 18A (step S101b). Then, the first casting mold 18A is separated to obtain the first ceramic compact 10A (step S101c).

[0058] As shown in FIG. 8, the length of the groove 14 in the joining surface 12a of the first ceramic compact 10A along the axis line n1 is equal to the thickness of the curved portion 28 of the first ceramic compact 10A. The size of the groove 14 in the direction perpendicular to the axis line n1 (the width of the groove 14) has to be 1 to 3 times as large as the diameter of the light-emitting material, which is introduced in the solid state. Thus, the inner circle diameter of the groove 14 is 0.25 to 0.9 mm.

[0059] In step S102 of FIG. 7, the two first ceramic compacts 10A are bonded to each other. Specifically, the ceramic powder, the solvent, the binder, and the like are mixed to prepare the bonding slurry 32 (step S102a), and the bonding slurry 32 is applied (supplied) to the joining surface 12a of one of the first ceramic compacts 10A, though the bonding slurry 32 is not applied to the groove 14 (step S102b). Then, as shown in FIG. 9A, the joining surfaces 12a of the two first ceramic compacts 10A are pressed toward each other to obtain a second bonded assembly 30B (step S102c).

[0060] In step S103 of FIG. 7, the second bonded assembly 30B is fired to produce a sintered body (a second ceramic tube 24B). As shown in FIG. 9B, the second ceramic tube 24B has the light-emitting portion 34 obtained by bonding and firing the curved portions 28 at the center, and further has the electrode containers 36 formed integrally with either end of the light-emitting portion 34. The hollow portion 37 is formed in the second ceramic tube 24B, and extends from one electrode container 36 to the other electrode container 36. A second through-hole 38b corresponding to the grooves 14 on the joining surfaces 12a of the two first ceramic compacts 10A (a through-hole derived from the facing grooves 14) is formed at the center of the light-emitting portion 34 in the second ceramic tube 24B. In the case of using the second ceramic tube 24B as the arc tube, the second through-hole 38b is used as an inlet hole for introducing the light-emitting material into the light-emitting portion 34.

[0061] Also in the second production method, as in the above first production method, the hole forming processing using the drill is not required. Therefore, the second production method is capable of simplifying the production operation, reducing the number of production steps, improving the throughput, and improving the yield. Thus, the second ceramic tube 24B having the second through-hole 38b for introducing the light-emitting material can be obtained at high productivity. In particular, only the first casting mold 18B for forming the first ceramic compact 10A is required in the second production method, thereby resulting in further lowered cost.

[0062] Though the curved portions 28 of the first ceramic compacts 10A have the same height and the second through-hole 38b is formed at the center of the light-emitting portion 34 in the above example, the curved portion 28 of one first ceramic compact 10A may have a height larger than that of the curved portion 28 of the other first ceramic compact 10A as in FIG. 6A. Alternatively, the curved portion 28 of the one first ceramic compact 10A may have a height smaller than that of the curved portion 28 of the other first ceramic compact 10A. In this case, in the resultant second ceramic tube 24B, the second through-hole 38b is shifted closer to the one or other electrode container 36 from the center of the light-emitting portion 34.

[0063] A ceramic tube production method according to a second embodiment will be described below.

[0064] The ceramic tube production method of the second embodiment contains a compact preparation step of preparing a plurality of ceramic compacts. At least one of the ceramic compacts has a first projection in the joining surface, and a continuous groove extends from the end of the first projection to the inside continuously in the joining surface.

The ceramic tube production method further contains a compact bonding step of bonding the joining surfaces of the ceramic compacts to each other to produce a ceramic tube having a hole corresponding to the continuous groove.

[0065] Several specific examples of the ceramic tube production method of the second embodiment will be described below with reference to FIGS. 10 to 23.

[0066] In a production method according to a third specific example (hereinafter referred to as a third production method), in step S201 of FIG. 10, one third ceramic compact 10C and one fourth ceramic compact 10D are prepared as shown in FIG. 11. The third ceramic compact 10C has a first projection 40a as a part of a joining surface 12c, and a continuous groove 42 continuously extends from the end of the first projection 40a to the inside of the third ceramic compact 10C. The fourth ceramic compact 10D has a second projection 40b as a part of a joining surface 12d, and the continuous groove 42 does not extend from the end of the second projection 40b to the inside of the fourth ceramic compact 10D. Thus, the joining surface 12d is a flat surface.

[0067] Specifically, in step S201a of FIG. 10, the ceramic powder, the dispersion medium, the gelling agent, and the like are mixed to prepare the molding slurry 16. In step S201b, as shown in FIGS. 12A and 12B, the molding slurry 16 is cast into and then solidified in a third casting mold 18C for forming the third ceramic compact 10C (see FIG. 12A) and a fourth casting mold 18D for forming the fourth ceramic compact 10D (see FIG. 12B). Then, the third casting mold 18C and the fourth casting mold 18D are separated to obtain the third and fourth ceramic compacts 10C and 10D. The third casting mold 18C has a first space 44a for forming the first projection 40a and the continuous groove 42 in a position corresponding to the joining surface 12c, and the fourth casting mold 18D has a second space 44b for forming the second projection 40b in a position corresponding to the joining surface 12d.

[0068] The third and fourth ceramic compacts 10C and 10D each have the cylindrical shape with the hollow portion 22. More specifically, the third and fourth ceramic compacts 10C and 10D are similar to a shape obtained by dividing a third ceramic tube 24C as a final product (see FIG. 15B) into two parts at the length-direction center of the axis line m1. The third ceramic compact 10C has a shape containing the cylindrical portion 26, the curved (bowl-shaped) portion 28, and the first projection 40a integrally formed, and the fourth ceramic compact 10D has a shape containing the cylindrical portion 26, the curved (bowl-shaped) portion 28, and the second projection 40b integrally formed.

[0069] The joining surfaces 12c and 12d of the third and fourth ceramic compacts 10C and 10D are positioned at the end surfaces of the curved portions 28, and are parallel to a plane perpendicular to the axis direction of the third and fourth ceramic compacts 10C and 10D. On the joining surface 12c of the third ceramic compact 10C, the above continuous groove 42 extends continuously from the end of the first projection 40a to the inside of the third ceramic compact 10C. As shown in FIG. 11, an axis line n2 of the first projection 40a may extend at an angle of 90° to an axis line m3 of the third ceramic compact 10C. Alternatively, as shown in FIGS. 13 and 14, when the first projection 40a has a base point 46, which is an intersection between the outer periphery of the joining surface 12c having the first projection 40a and the axis line n2 of the first projection 40a, the tangent line K1 at the base point 46 on the outer periphery of the joining surface 12c and the axis line n2 of the first projection 40a may form an angle θ of 30° to 60°. The second projection 40b may be formed in the same manner.

[0070] The length of the continuous groove 42 along the axis line n2 is equal to the total of the height of the first projection 40a and the thickness of the curved portion 28 of the third ceramic compact 10C. The size of the continuous groove 42 in the direction perpendicular to the axis line n2 (the width of the continuous groove 42) has to be 1 to 3 times as large as the diameter of the light-emitting material to be introduced. Thus, the inner circle diameter of the continuous groove 42 is 0.25 to 0.9 mm. Though not shown in the drawings, the outer and inner peripheries of the joining surfaces 12c and 12d of the third and fourth ceramic compacts 10C and 10D may be chamfered to form e.g. a C-surface.

[0071] In step S202 of FIG. 10, the third and fourth ceramic compacts 10C and 10D are bonded to each other.

[0072] Specifically, in step S202a, the ceramic powder, the solvent, the binder, and the like are mixed to prepare the bonding slurry. In step S202b, the bonding slurry is applied (supplied) to the joining surface 12c of the third ceramic compact 10C, though the bonding slurry is not applied to the continuous groove 42. Then, in step S202c, the joining surface 12c of the third ceramic compact 10C is pressed toward the joining surface 12d of the fourth ceramic compact 10D to obtain a third bonded assembly 30C (see FIG. 15A). In this step, the joining surface 12c of the first projection 40a is aligned with the joining surface 12d of the second projection 40b.

[0073] In step S203 of FIG. 10, the first bonded assembly 30C is fired to produce a sintered body (the third ceramic tube 24C). As shown in FIG. 15B or 16A, the third ceramic tube 24C has the light-emitting portion 34 obtained by bonding and firing the curved portions 28 at the center, and further has the electrode containers 36 formed integrally with either end of the light-emitting portion 34. The hollow portion 37 is formed in the third ceramic tube 24C, and extends from one electrode container 36 to the other electrode container 36. A cylindrical projection 50 (narrow pipe) extends outward from the light-emitting portion 34 of the third ceramic tube 24C.

[0074] The cylindrical projection 50 shown in FIG. 15B is formed by bonding and firing the first and second projections 40a and 40b shown in FIG. 11, and the axis line n3 thereof extends at an angle of 90° to the axis line m1 of the third ceramic tube 24C. The cylindrical projection 50 shown in FIG. 16A is formed by bonding and firing the first and second projections 40a and 40b shown in FIG. 13. As shown in FIG. 16B, the outer surface of the light-emitting portion 34 has a cross-sectional outline 52 in a plane containing the axis line n3 of the cylindrical projection 50, and the axis line n3 and the tangent line K2 at an intersection 54 between the cross-sectional outline 52 and the axis line n3 form an angle of 30° to 60°.

[0075] In the cylindrical projection 50, a third through-hole 38c corresponding to the continuous groove 42 of the first projection 40a extends along the axis line n3. In the case of using the third ceramic tube 24C as the arc tube, the third through-hole 38c is used as an inlet hole for introducing the light-emitting material into the light-emitting portion 34.

[0076] For comparison, a conventional method for producing a sintered body having a cylindrical projection will be described below with reference to FIG. 17.

[0077] In step S211 (steps S211a to S211c) of FIG. 17, two second ceramic compacts 10B not having the grooves 14 in the joining surfaces 12b are prepared. In step S212, a through-hole is formed in the curved portion 28 of one of the second ceramic compacts 10B by a hole forming processing using a drill or the like. In step S213 (steps S213a to S213c), the two second ceramic compacts 10B are bonded to each other. In step S214, a bonding slurry is applied to an outer surface of a ceramic compact pipe, and the pipe is bonded to the through-hole, whereby a bonded assembly is prepared. Then, in step S215, the bonded assembly is fired to produce a sintered body (ceramic tube) having the cylindrical projection.

[0078] In this conventional production method, the through-hole is formed in the curved portion 28 of one second ceramic compact 10B by using the drill. Therefore, the method has the above-described disadvantages. In addition, the steps of preparing and bonding the pipe are required in the method. Thus, the method disadvantageously contains complicated procedures, resulting in high production cost.

[0079] In contrast, also in the third production method, as in first production method, the hole forming processing using the drill is not required. Therefore, the third production method is capable of simplifying the production operation, reducing the number of production steps, improving the throughput, and improving the yield. Thus, the third ceramic tube 24C having the third through-hole 38c for introducing the light-emitting material can be obtained at high productivity. In particular, the cylindrical projection 50 having the third through-hole 38c for introducing the light-emitting material is formed by bonding the first projection 40a having the continuous groove 42 to the second projection 40b. The cylindrical projection 50 acts as a guide for introducing the light-emitting material and for discharging a gas. Therefore, the light-emitting material can be easily introduced, and the gas can be easily discharged. Furthermore, the third through-hole 38c can be easily sealed. For example, the end of the cylindrical projection 50 may be sealed by fusion bonding using a laser light or by introducing a sealant into the end of the third through-hole 38c. Such procedures are preferably used to simplify the sealing step.

[0080] The cylindrical projection 50 shown in FIG. 15B extends in the direction perpendicular to the axis line m1 of the third ceramic compact 10C. As shown in FIG. 18A, the third ceramic tube 24C has an intersection Ca between the outer periphery of the light-emitting portion 34 and a line connecting the center Oa of the light-emitting portion 34 with an end point Pa of the projection 50, and has a projection amount La as a distance between the intersection Ca and the end point Pa. In production of a lamp, the arc tube is inserted into an outer bulb. In a case where the projection 50 has a large projection amount La as shown in FIG. 18A, it is necessary to increase the diameter of the outer bulb, and it is difficult to produce a small lamp. Furthermore, in this case, the projection 50 is likely to be contacted with a component such as a lead wire in the outer bulb, and is often broken. In addition, the end (to be sealed) of the projection 50 is distant from the light-emitting portion 34, so that the end is the coldest point. Therefore, a corrosive light-emitting material may be accumulated in the end, tending to corrode the sealing portion when used as an arc tube. On the other hand, in a case where the projection 50 has an excessively small projection amount La, it may be difficult to seal the third through-hole 38c. For example, only an insufficient amount of the projection 50 may be melted in the fusion bonding of the third through-hole 38c, and only an insufficient amount of the sealant may be inserted into the third through-hole 38c, thereby resulting in leakage. Thus, the projection amount La of the projection 50 is preferably 1/20 to 10/20, more preferably 2/20 to 5/20, of the maximum diameter of the light-emitting portion 34.

[0081] In the case of forming the cylindrical projection 50 shown in FIG. 16A, the projection amount La of the projection 50 can be reduced as shown in FIG. 18B. Therefore, in this case, the third ceramic tube 24C can be used in a small lamp, and the projection 50 is hardly contacted with other components in the lamp and is hardly broken. Furthermore, the end of the projection 50 is closer to the light-emitting portion 34 in FIG. 18B than in FIG. 18A, and the end does not contain the coldest point. Consequently, the corrosion of the sealing portion can be prevented in the arc tube, and the third ceramic tube 24C exhibits an improved reliability.

[0082] Though the curved portions 28 of the third and fourth ceramic compacts 10C and 10D have the same height and the cylindrical projection 50 is formed at the center of the light-emitting portion 34 in the above example, the curved portion 28 of the third ceramic compact 10C may have a height greater than that of the curved portion 28 of the fourth

ceramic compact 10D as in FIG. 6A. Alternatively, the curved portion 28 of the third ceramic compact 10C may have a height smaller than that of the curved portion 28 of the fourth ceramic compact 10D. In this case, in the resultant third ceramic tube 24C, the cylindrical projection 50 is shifted closer to the one or other electrode container 36 from the center of the light-emitting portion 34.

[0083] In a production method according to a fourth specific example (hereinafter referred to as a fourth production method), in step S301 of FIG. 19, two third ceramic compacts 10C are prepared as shown in FIGS. 20 and 21.

[0084] Specifically, the ceramic powder, the dispersion medium, the gelling agent, and the like are mixed to prepare the molding slurry (step S301a of FIG. 19). The molding slurry is cast into and then solidified in the third casting mold 18C (step S301b). Then, the third casting mold 18C is separated to obtain the third ceramic compact 10C (step S301c).

[0085] The length of the continuous groove 42 in the joining surface 12c of the third ceramic compact 10C along the axis line n2 is equal to the total of the height of the first projection 40a and the thickness of the curved portion 28 in the third ceramic compact 10C. The size of the continuous groove 42 in the direction perpendicular to the axis line n2 (the width of the continuous groove 42) has to be 1 to 3 times as large as the diameter of the light-emitting material to be introduced. Thus, the inner circle diameter of the continuous groove 42 is 0.25 to 0.9 mm.

[0086] In step S302 of FIG. 19, the two third ceramic compacts 10C are bonded to each other. Specifically, the ceramic powder, the solvent, the binder, and the like are mixed to prepare the bonding slurry 32 (step S302a), and the bonding slurry 32 is applied (supplied) to the joining surface 12c of one of the third ceramic compacts 10C, though the bonding slurry 32 is not applied to the continuous groove 42 (step S302b). Then, the joining surfaces 12c of the two third ceramic compacts 10C are pressed toward each other to obtain a fourth bonded assembly 30D shown in FIG. 22A (step S302c).

[0087] In step S303 of FIG. 19, the fourth bonded assembly 30D is fired to produce a sintered body (a fourth ceramic tube 24D). As shown in FIG. 22B or FIG. 23, the fourth ceramic tube 24D has the light-emitting portion 34 obtained by bonding and firing the curved portions 28 at the center, and further has the electrode containers 36 formed integrally with either end of the light-emitting portion 34. The hollow portion 37 is formed in the fourth ceramic tube 24D, and extends from one electrode container 36 to the other electrode container 36. A fourth through-hole 38d corresponding to the continuous grooves 42 on the joining surfaces 12c of the two third ceramic compacts 10C (a through-hole derived from the facing continuous grooves 42) is formed on the light-emitting portion 34 in the fourth ceramic tube 24D. In the case of using the fourth ceramic tube 24D as an arc tube, the fourth through-hole 38d is used as an inlet hole for introducing the light-emitting material into the light-emitting portion 34. Also in the fourth ceramic tube 24D shown in FIG. 22B, the projection amount of the projection 50 is preferably 1/20 to 10/20, more preferably 2/20 to 5/20, of the maximum diameter of the light-emitting portion 34. In the structure shown in FIG. 23, the projection amount of the projection 50 can be reduced. Therefore, the fourth ceramic tube 24D can be used in a small lamp, and the projection 50 is hardly contacted with a component in the lamp and is hardly broken. Furthermore, the end of the projection 50 is closer to the light-emitting portion 34 in FIG. 23 than in FIG. 22B, and the end does not contain the coldest point. Consequently, the corrosion of the sealing portion can be prevented in the arc tube, and the fourth ceramic tube 24D exhibits an improved reliability.

[0088] Also in the fourth production method, as in the above first production method, the hole forming processing using the drill is not required. Therefore, the fourth production method is capable of simplifying the production operation, reducing the number of production steps, improving the throughput, and improving the yield. Thus, the fourth ceramic tube 24D having the fourth through-hole 38d for introducing the light-emitting material can be obtained at high productivity. In addition, in the fourth production method, as in the third production method, the light-emitting material can be easily introduced, and the gas can be easily discharged. Furthermore, the fourth through-hole 38d can be easily sealed. In particular, only the third casting mold 18C for forming the third ceramic compact 10C is required in the fourth production method, thereby resulting in further lowered cost.

[0089] Though the curved portions 28 of the two third ceramic compacts 10C have the same height and the cylindrical projection 50 is formed at the center of the light-emitting portion 34 in the above example, the curved portion 28 of one third ceramic compact 10C may have a height larger than that of the curved portion 28 of the other third ceramic compact 10C as in FIG. 6A. Alternatively, the curved portion 28 of the one third ceramic compact 10C may have a height smaller than that of the curved portion 28 of the other third ceramic compact 10C. In this case, in the resultant fourth ceramic tube 24d, the cylindrical projection 50 is shifted closer to the one or other electrode container 36 from the center of the light-emitting portion 34.

[0090] Preferred embodiments of materials and the like used in the production method of this invention will be described below. The above first to fourth production methods may be referred to simply as the production methods. When it is not necessary to distinguish the above first to fourth ceramic compacts 10A to 10D, they may be referred to simply as the ceramic compacts 10. When it is not necessary to distinguish the joining surfaces 12a to 12d, they may be referred to as the joining surfaces 12. When it is not necessary to distinguish the first to fourth through-holes 38a to 38d, they may be referred to as the through-holes 38.

(Ceramic compact)

[0091] In the above-described production method, the ceramic compact 10 is prepared. The ceramic compact 10 can be easily produced by various known method. For example, the ceramic compact 10 may be produced by a gel casting method. In the gel casting method, the molding slurry 16 containing an inorganic powder and an organic compound is cast into the casting mold, a chemical reaction of the organic compound (such as a reaction between the dispersion medium and the gelling agent or a reaction of the gelling agent) is carried out to solidify the molding slurry 16, and the casting mold is separated. The molding slurry 16 contains the dispersion medium and the gelling agent in addition to the raw material powder, and may further contain a dispersing agent or catalyst for controlling the viscosity or solidification. The components will be described below.

(Raw material powder)

[0092] The ceramic powder used for the ceramic compact 10 may contain alumina, aluminum nitride, zirconia, YAG, or a mixture of two or more thereof. A sintering aid such as magnesium oxide may be used to improve the sintering or the property. Preferred examples of the sintering aids include ZrO_2 , Y_2O_3 , La_2O_3 , and Sc_2O_3 .

(Dispersion medium)

[0093] The dispersion medium is preferably a reactive medium such as an organic dispersion medium having a reactive functional group. It is preferred that the organic dispersion medium having the reactive functional group is a liquid substance that can be chemically bonded to the gelling agent to solidify the molding slurry 16 and can be used for preparing the molding slurry 16 with a high fluidity suitable for the casting. The organic dispersion medium, which can be chemically bonded to the gelling agent to solidify the molding slurry 16, preferably has a functional group capable of forming a chemical bond with the gelling agent (such as a hydroxyl, carboxyl, or amino group) in the molecule.

[0094] In view of preparing the molding slurry 16 with a high fluidity suitable for the casting, the organic dispersion medium preferably has a lower viscosity, and particularly preferably has a viscosity of 20 cps or less at 20°C.

[0095] A small amount of a polyol or a polybasic acid can be effectively used for improving the strength as long as it does not act to greatly increase the viscosity of the molding slurry 16.

(Gelling agent)

[0096] The gelling agent can be reacted with the reactive functional group of the dispersion medium to solidify the slurry. Examples of such gelling agents are described in International Publication No. WO 2002/085590. The gelling agent may be as follows.

[0097] The reactive functional group of the gelling agent is preferably such that the bonding step can be carried out while maintaining the groove shape after the solidification. Thus, it is preferred that after the solidification, the groove shape is not deteriorated by dissolution of the gelling agent in the bonding slurry or the like or by the load exerted at the bonding step. From this viewpoint, the gelling agent particularly preferably has an isocyanate group ($-N=C=O$) and/or an isothiocyanate group ($-N=C=S$) to exhibit a high solvent resistance after the solidification and exhibit a high reactivity with the dispersion material.

[0098] The molding slurry 16 for producing the ceramic compact 10 may be selected from examples described in Japanese Laid-Open Patent Publication No. 2008-044344, International Publication No. WO 2002/085590, etc. For example, the molding slurry 16 may be prepared in the following manner. Thus, the raw material powder may be dispersed first in the dispersion medium, and then the gelling agent may be added thereto to prepare the molding slurry 16. Alternatively, the raw material powder and the gelling agent may be simultaneously added to and dispersed in the dispersion medium to prepare the molding slurry 16.

(Bonding slurry)

[0099] In the preparation of the bonded assembly, the bonding slurry 32 is used to bond the ceramic compacts 10 to each other. The bonding slurry 32 is preferably a non-self-curable slurry, which is not solidified by a chemical reaction. The non-self-curable bonding slurry 32 can form a layer under a surface tension. Therefore, the shape of the layer of the bonding slurry 32 can be easily controlled, and the clogging and deformation of the small hole can be prevented after the bonding.

[0100] The bonding slurry 32 may contain the raw material powder used in the molding slurry 16 and the unreactive dispersion medium, and may further contain a binder such as a polyvinyl acetal or ethyl cellulose resin.

[0101] The bonding slurry 32 can be prepared by mixing the raw material powder, the solvent, and the binder in a

common ceramic paste or slurry production method using a triroll mill, a pot mill, etc. A dispersing agent or an organic solvent may be appropriately added to the bonding slurry 32. Specifically, butyl carbitol, butyl carbitol acetate, terpineol, or the like may be used in the bonding slurry 32. The bonding slurry 32 preferably has a viscosity of 10000 to 400000 cps at 20°C. When the viscosity falls within this range, the layer of the bonding slurry 32 can be moderately deformed in the bonding step to prevent air bubble formation in the layer. Furthermore, the bonding slurry 32 can have a surface tension suitable for forming the layer to prevent groove clogging of the ceramic compact 10. The viscosity is more preferably 30000 to 200000 cps. When the viscosity falls within this range, the shape of the applied bonding slurry 32 can be accurately controlled. Therefore, particularly even in a case where the through-hole 38 has a diameter of 0.6 mm or less, the through-hole 38 is prevented from being filled with the bonding slurry 32 due to deformation or protrusion of the bonding slurry 32 after the bonding, and the shape of the through-hole can be appropriately controlled.

(Preparation of bonded assembly)

[0102] Two or more ceramic compacts 10 are bonded to each other by the bonding slurry 32 to prepare the bonded assembly.

(Bonding slurry layer formation step)

[0103] In the preparation of the bonded assembly, first the layer of the bonding slurry 32 is formed, while maintaining the surface tension, between the joining surfaces 12 of the two or more ceramic compacts 10 to be bonded. In this step, it is preferred that the bonding slurry 32 is not applied to the groove of the ceramic compact 10 from the viewpoint of preventing the clogging or deformation of the through-hole 38 after the bonding.

[0104] The bonding slurry 32 may be applied between the joining surfaces 12 of the ceramic compacts 10 by a known method such as a dispenser, dipping, spray, screen printing, or metal mask printing method.

[0105] For example, in the case of forming the layer of the bonding slurry 32 having a thickness of 200 μm or less (preferably 10 μm or more) on the joining surface 12 of the ceramic compact 10, the screen printing method is preferably used for applying the bonding slurry 32. In the screen printing method, the bonding slurry 32 can be accurately applied to form the layer with a uniform thickness. Furthermore, the application position of the bonding slurry 32 can be controlled by appropriately forming a pattern of a screen plate (for example, the bonding slurry 32 is not applied to the groove of the compact) to prevent the clogging or deformation of the through-hole 38. Thus, in the case of using the screen printing method, the through-hole 38 can be accurately formed without the clogging and deformation due to the protrusion of the bonding slurry 32. When the layer of the bonding slurry 32 has an excessively small thickness, an air bubble is likely to remain in the layer. On the other hand, when the layer of the bonding slurry 32 has an excessively large thickness, the bonding slurry 32 is likely to be deformed to clog the through-hole 38 in the bonding step. Therefore, in view of forming a desired shape without these problems, the layer of the bonding slurry 32 preferably has a thickness of 5 to 100 μm after the bonding step. The application amount of the bonding slurry 32 is preferably controlled in view of achieving the thickness within the range. Particularly in a case where the through-hole 38 has a diameter of 0.6 mm or less, the layer of the bonding slurry 32 preferably has a thickness of 5 to 40 μm after the bonding step. The application amount of the bonding slurry 32 is preferably controlled in view of achieving the thickness within the range.

[0106] The bonding slurry 32 is moderately deformed in the bonding step to be formed into a layer while maintaining the surface tension acting on the bonding slurry 32 without the air bubble formation in the bonding slurry 32. Therefore, after the bonding slurry 32 is applied between the joining surfaces 12 of the ceramic compacts 10 or to the joining surface 12 of the ceramic compact 10, before the applied bonding slurry 32 is dried, the joining surfaces 12 of the ceramic compacts 10 may be maintained at a predetermined distance. In a case where the bonding slurry 32 is the non-self-curable slurry, after the bonding slurry 32 is applied to the joining surface 12, before the drying, the shape of the bonding slurry 32 is maintained due to the surface tension for a certain time and can be deformed by an external force.

[0107] The desired layer thickness of the bonding slurry 32 can be easily obtained by controlling the load acting in the direction perpendicular to the joining surfaces 12 and/or the distance between the joining surfaces 12. Consequently, the layer of the bonding slurry 32 can be easily formed with the desired thickness, and the through-hole 38 can be easily formed with the desired shape without the clogging and deformation.

(Drying)

[0108] The layer of the bonding slurry 32, formed between the joining surfaces 12 of the ceramic compacts 10 facing each other, is dried. The drying step may be appropriately controlled depending on the composition and the application amount of the bonding slurry 32. In general, the drying is carried out at a temperature of 40°C to 200°C for about 5 to 120 minutes. In the drying step, by applying a load in the direction perpendicular to the joining surfaces 12, the air bubble formation due to the dry shrinkage of the layer of the bonding slurry 32 can be prevented, and the layer of the bonding

slurry 32 can be obtained with the desired thickness.

[0109] In thus obtained bonded assembly, at least two ceramic compacts 10 are bonded by a joining portion (dried layer) formed by drying the layer of the bonding slurry 32, and the through-hole is derived from the groove of the ceramic compact 10. Though the two ceramic compacts 10 are bonded in the preparation of the bonded assembly, the preparation is not limited thereto. Three or more ceramic compacts 10 may be bonded by the layers of the bonding slurry 32 simultaneously or successively, to obtain the bonded assembly.

(Production of sintered body (ceramic tube))

[0110] The bonded assembly is fired, whereby sinterable components in the ceramic compacts 10 and the joining portion (the dried layer) are sintered to obtain the sintered body. Before the sintering step, the bonded assembly may be degreased or calcined.

Examples

[First Example]

[0111] Sintered bodies (ceramic tubes) were produced by production methods according to Examples 1 to 4 and Comparative Examples 1 and 2 respectively. The cracking of each sintered body and the leakage of the light-emitting portion were measured.

(Example 1)

[0112] Ten second ceramic tubes 24B shown in FIG. 9B were produced by the second production method of FIG. 7.

[0113] The molding slurry 16 for forming the first ceramic compact 10A (see FIG. 8) was prepared in the following manner. A raw material powder containing 100 parts by weight of an alumina powder and 0.025 parts by weight of a magnesia, 30 parts by weight of a dispersion medium of a polybasic acid ester, 4 parts by weight of a gelling agent of an MDI resin, 2 parts by weight of a dispersing agent, and 0.2 parts by weight of a triethylamine catalyst were mixed to obtain the molding slurry 16.

[0114] The molding slurry 16 was cast into the first casting mold 18A composed of an aluminum alloy (see FIG. 3A) at the room temperature, and solidified at the room temperature for 1 hour. Then, the first casting mold 18A was separated from the solidified slurry, and the resultant was left at the room temperature for 2 hours and at 90°C for 2 hours. Twenty first ceramic compacts 10A were prepared in this manner. The outer and inner peripheries of the joining surface 12a of each first ceramic compact 10A were chamfered (to form e.g. an R-surface) within a radius range of 0.05 to 0.15 mm.

[0115] The bonding slurry 32 was prepared in the following manner. 100 parts by weight of a raw material powder of an alumina powder, 0.025 parts by weight of a magnesia, 100 parts by weight of terpineol, 30 parts by weight of butyl carbitol, and 8 parts by weight of a polyvinyl acetal resin were mixed to obtain the bonding slurry 32.

[0116] A screen plate having an emulsion thickness of 100 μm and a mesh of #290 was prepared. As shown in FIG. 24, the screen plate had a ring-shaped pattern 62 (having an inner diameter of 12.8 mm and an outer diameter of 13.7 mm) with a cut 60 corresponding to the groove 14 of the first ceramic compact 10A. The first ceramic compact 10A was positioned on a stage of a screen printer such that the joining surface 12a (having an inner diameter of 12.5 mm and an outer diameter of 14.0 mm) was parallel to the screen plate. The bonding slurry 32 was applied to the joining surface 12a of the first ceramic compact 10A by the screen printer using the screen plate. Then, the joining surfaces 12a of each pair of the first ceramic compacts 10A were pressed toward each other, and dried by a dryer at 95°C for 15 minutes.

Ten second bonded assemblies 30B (see FIG. 9A) were prepared in this manner.

[0117] Each of the prepared second bonded assemblies 30B was calcined in the air at 1200°C, and fired at 1800°C in a hydrogen/nitrogen (3/1) atmosphere, to increase the density and translucency. Consequently, the sintered body (second ceramic tube 24B), which had the second through-hole 38b on the light-emitting portion 34 as shown in FIG. 9B, was obtained. The light-emitting portion 34 had an outer diameter of 11 mm, and the electrode containers 36 had a length of 17 mm.

[0118] Thus produced ten sintered bodies (second ceramic tubes 24B) of Example 1 did not have a cracked or deformed portion. The thermal shock resistances of the sintered bodies were evaluated by an in-water rapid cooling method. As a result, in all the sintered bodies, any cracking was not caused even at 150°C. Thus, the sintered bodies had resistances equal to that of a ceramic tube having the same shape except for the second through-hole 38b. Furthermore, after the thermal shock resistance evaluation, the second through-holes 38b on the light-emitting portions 34 of the sintered bodies were closed, and the leakages of the light-emitting portions 34 were measured by an He (helium) leakage measuring apparatus. As a result, each sintered body exhibited a leakage of 1×10^{-8} atm·cc/sec or less.

(Example 2)

[0119] Ten sintered bodies of Example 2 (fourth ceramic tubes 24D) shown in FIG. 22B were produced by the fourth production method of FIG. 19.

[0120] The molding slurry 16 was prepared in the same manner as Example 1. The molding slurry 16 was cast into the third casting mold 18C composed of an aluminum alloy (see FIG. 12A) at the room temperature, and solidified at the room temperature for 1 hour. Then, the third casting mold 18C was separated from the solidified slurry, and the resultant was left at the room temperature for 2 hours and at 90°C for 2 hours. Twenty third ceramic compacts 10C were prepared in this manner. After the firing shrinkage, the first projection 40a of each third ceramic compact 10C had a projection amount of 4.0 mm, an outer width of 0.9 mm, and a continuous groove 42 width of 0.3 mm. Also in this example, the outer and inner peripheries of the joining surface 12c of each third ceramic compact 10C were chamfered.

[0121] The bonding slurry 32 was prepared in the same manner as Example 1, and was applied to the joining surface 12a of the third ceramic compact 10C by a screen printer using a screen plate. The screen plate had an emulsion thickness of 100 μm and a mesh of #290 in the same manner as Example 1. However, as shown in FIG. 25, this screen plate had a ring-shaped pattern 68 with a cut 64 corresponding to the continuous groove 42 of the third ceramic compact 10C. The ring-shaped pattern 68 had, at an edge, a projection 66 to be aligned with the joining surface 12c of the third ceramic compact 10C (portions other than the continuous groove 42).

[0122] Then, the joining surfaces 12c of each pair of the third ceramic compacts 10C were pressed toward each other, and dried by a dryer at 95°C for 15 minutes. Ten fourth bonded assemblies 30D (see FIG. 22A) were prepared in this manner.

[0123] Each of the prepared second bonded assemblies 30B was calcined and fired in the same manner as Example 1, to increase the density and translucency. Consequently, the sintered body (fourth ceramic tube 24D), which had the cylindrical projection 50 extending outward from the center of the light-emitting portion 34 as shown in FIG. 22B, was obtained. The light-emitting portion 34 had an outer diameter of 11 mm, the electrode containers 36 had a length of 17 mm, the cylindrical projection 50 had a projection amount of 4.0 mm, and the fourth through-hole 38d had a diameter of 0.4 mm.

[0124] Thus produced ten sintered bodies of Example 2 did not have a cracked or deformed portion. The thermal shock resistances of the sintered bodies were evaluated by an in-water rapid cooling method. As a result, in all the sintered bodies, the cracking was not caused even at 150°C. Thus, the sintered bodies had resistances equal to that of an arc tube having the same shape except for the cylindrical projection 50. Furthermore, after the thermal shock resistance evaluation, the leakages of the sintered bodies were measured by an He leakage measuring apparatus. As a result, each sintered body exhibited a leakage of 1×10^{-8} atm-cc/sec or less.

(Example 3)

[0125] The fourth ceramic tubes 24D of Example 3 were produced in the same manner as Example 2 except that two third ceramic compacts 10C having the curved portions 28 with different heights were bonded to each other, whereby the cylindrical projection 50 was shifted by 1 mm from the center of the light-emitting portion 34 toward one electrode container 36.

[0126] Thus produced ten sintered bodies of Example 3 did not have a cracked or deformed portion. The thermal shock resistances of the sintered bodies were evaluated by an in-water rapid cooling method. As a result, in all the sintered bodies, the cracking was not caused even at 150°C. Thus, the sintered bodies had resistances equal to that of an arc tube having the same shape except for the cylindrical projection 50. Furthermore, after the thermal shock resistance evaluation, the leakages of the sintered bodies were measured by an He leakage measuring apparatus. As a result, each sintered body exhibited a leakage of 1×10^{-8} atm-cc/sec or less.

(Example 4)

[0127] The fourth ceramic tubes 24D of Example 4 were produced in the same manner as Example 2 except that two third ceramic compacts 10C shown in FIG. 13 were bonded to each other. Thus, as shown in FIGS. 16A and 16B, the outer surface of the light-emitting portion 34 has a cross-sectional outline 52 in a plane containing the axis line n3 of the cylindrical projection 50, and the axis line n3 and the tangent line K2 at the intersection 54 between the cross-sectional outline 52 and the axis line n3 form an angle of 45°.

[0128] Thus produced ten sintered bodies of Example 4 did not have a cracked or deformed portion. The thermal shock resistances of the sintered bodies were evaluated by an in-water rapid cooling method. As a result, in all the sintered bodies, the cracking was not caused even at 160°C. Thus, the sintered bodies had resistances equal to that of an arc tube having the same shape except for the cylindrical projection 50. Furthermore, after the thermal shock resistance evaluation, the leakages of the sintered bodies were measured by an He leakage measuring apparatus. As a result,

each sintered body exhibited a leakage of 1×10^{-8} atm·cc/sec or less.

(Comparative Example 1)

[0129] Ten sintered bodies of Comparative Example 1 were produced by the production method of FIG. 5.

[0130] The molding slurry 16 was prepared in the same manner as Example 1. The molding slurry 16 was cast into the second casting mold 18B composed of an aluminum alloy (see FIG. 3B) at the room temperature, and solidified at the room temperature for 1 hour. Then, the second casting mold 18B was separated from the solidified slurry, and the resultant was left at the room temperature for 2 hours and at 90°C for 2 hours. Twenty second ceramic compacts 10B were prepared in this manner. One of each pair of the second ceramic compacts 10B was subjected to a hole forming processing using a drill or the like, whereby a through-hole was formed on the curved portion 28 such that the diameter was 0.4 mm after firing shrinkage.

[0131] The bonding slurry 32 was prepared in the same manner as Example 1, and was applied to the joining surface 12b of the one second ceramic compact 10B by a screen printer using a screen plate. Then, the joining surfaces 12b of each pair of the second ceramic compacts 10B were pressed toward each other, and dried by a dryer at 95°C for 15 minutes. Ten bonded assemblies were prepared in this manner. Each of the prepared bonded assemblies was calcined and fired in the same manner as Example 1. Consequently, ten sintered bodies of Comparative Example 1 were obtained.

[0132] Thus produced ten sintered bodies of Comparative Example 1 did not have a cracked or deformed portion. The thermal shock resistances of the sintered bodies were evaluated by an in-water rapid cooling method. As a result, the sintered bodies were cracked at 150°C. Furthermore, after the thermal shock resistance evaluation, the leakages of the sintered bodies were measured by an He leakage measuring apparatus. As a result, each sintered body exhibited a leakage of 1×10^{-8} atm·cc/sec or less.

(Comparative Example 2)

[0133] Ten sintered bodies of Comparative Example 2 were produced by the production method of FIG. 17.

[0134] Twenty second ceramic compacts 10B were prepared in the same manner as Comparative Example 1. One of each pair of the second ceramic compacts 10B was subjected to a hole forming processing using a drill or the like, whereby a through-hole was formed on the curved portion 28 such that the diameter was 0.9 mm after firing shrinkage.

[0135] Then, each pair of the second ceramic compacts 10B were bonded to each other, and a ceramic pipe was connected to the through-hole portion. The pipe was formed such that the outer diameter was 0.9 mm and the inner diameter was 0.4 mm after the firing shrinkage. Ten bonded assemblies were prepared in this manner. Each of the prepared bonded assemblies was calcined and fired in the same manner as Example 1. Consequently, ten sintered bodies of Comparative Example 2 were obtained.

[0136] Thus produced ten sintered bodies of Comparative Example 2 did not have a cracked or deformed portion. The thermal shock resistances of the sintered bodies were evaluated by an in-water rapid cooling method. As a result, the sintered bodies were cracked at 140°C. Furthermore, after the thermal shock resistance evaluation, the leakages of the sintered bodies were measured by an He leakage measuring apparatus. As a result, a leakage was caused in two of the ten sintered bodies.

[Second Example]

[0137] In Examples 11 to 15 and Reference Examples 1 and 2, several properties were evaluated under various projection amounts of the cylindrical projections.

(Example 11)

[0138] Ten sintered bodies of Example 11 were produced in the same manner as Example 2 except that the projection amount of the cylindrical projection 50 was 1/20 of the maximum diameter D of the light-emitting portion 34 (= D/20).

(Example 12)

[0139] Ten sintered bodies of Example 12 were produced in the same manner as Example 2 except that the projection amount of the cylindrical projection 50 was 2D/20.

(Example 13)

[0140] Ten sintered bodies of Example 13 were produced in the same manner as Example 2 except that the projection

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amount of the cylindrical projection 50 was 3D/20.

(Example 14)

- 5 **[0141]** Ten sintered bodies of Example 14 were produced in the same manner as Example 2 except that the projection amount of the cylindrical projection 50 was 5D/20.

(Example 15)

- 10 **[0142]** Ten sintered bodies of Example 15 were produced in the same manner as Example 2 except that the projection amount of the cylindrical projection 50 was 10D/20.

(Reference Example 1)

- 15 **[0143]** Ten sintered bodies of Reference Example 1 were produced in the same manner as Example 2 except that the projection amount of the cylindrical projection 50 was 0.5D/20.

(Reference Example 2)

- 20 **[0144]** Ten sintered bodies of Reference Example 2 were produced in the same manner as Example 2 except that the projection amount of the cylindrical projection 50 was 12D/20.

<Evaluation>

- 25 **[0145]** The following properties were evaluated.

Cracking and deformation

[0146] Whether cracking or deformation was caused or not was confirmed in the produced sintered bodies.

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Thermal shock resistance

[0147] The thermal shock resistance was evaluated by an in-water rapid cooling method. Each example was evaluated as "Poor" when at least one of ten sintered bodies was cracked at 140°C, as "Fair" when at least one of ten sintered bodies was cracked at 150°C, as "Good" when at least one of ten sintered bodies was cracked at 160°C, and as "Excellent" when ten sintered bodies were not cracked even at 160°C.

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Leakage test

- 40 **[0148]** After the thermal shock resistance evaluation, the through-holes were closed by thermal fusion bonding, and the leakages of the light-emitting portions 34 were measured by an He (helium) leakage measuring apparatus.

[0149] In each example, the sintered bodies exhibiting a leakage of more than 1×10^{-8} atm-cc/sec were counted.

(Evaluation results)

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- [0150]** The evaluation results are shown in Table 1.

Table 1

	Projection amount	Cracking and deformation	Thermal shock resistance	Leakage
50 Reference Example 1	0.5D/20	Not observed	Fair	3/10
Example 11	D/20	Not observed	Good	0/10
Example 12	2D/20	Not observed	Excellent	0/10
55 Example 13	3D/20	Not observed	Excellent	0/10
Example 14	5D/20	Not observed	Excellent	0/10

(continued)

	Projection amount	Cracking and deformation	Thermal shock resistance	Leakage
Example 15	10D/20	Not observed	Good	0/10
Reference Example 2	12D/20	Not observed	Fair	2/10

[0151] In Examples 11 to 15, good evaluation results were obtained. Particularly in Examples 12 to 14, the sintered bodies were not cracked even at 160°C in the thermal shock resistance evaluation. In Reference Example 1, it was difficult to seal the through-hole as compared with Examples 11 to 15, so that the leakage was caused in three of the ten sintered bodies. Furthermore, the sintered bodies were cracked at 150°C in the thermal shock resistance evaluation. This was considered to be caused because the light-emitting portion 34 was deformed and weakened by the thermal fusion bonding. In Reference Example 2, the sintered bodies were cracked at 150°C in the thermal shock resistance evaluation, and the leakage was caused in two of the ten sintered bodies. This was considered to be caused because the cylindrical projection had an excessively large length, the cylindrical projection is fatigued to deteriorate the stiffness of the bottom.

[Third Example]

[0152] In Examples 21 to 25 and Reference Examples 11 and 12, several properties were evaluated under various angles φ shown in FIGS. 16A and 16B. The angle φ is formed between the tangent line K2 at the intersection 54 and the axis line n3 of the projection 50.

(Example 21)

[0153] Ten sintered bodies of Example 21 were produced in the same manner as Example 4 except that an angle φ formed between the tangent line K2 at the intersection 54 and the axis line n3 of the projection 50 was set to be 30°.

(Example 22)

[0154] Ten sintered bodies of Example 22 were produced in the same manner as Example 4 except that the angle φ was 40°.

(Example 23)

[0155] Ten sintered bodies of Example 23 having an angle φ set to be 45° were produced in the same manner as Example 4.

(Example 24)

[0156] Ten sintered bodies of Example 24 were produced in the same manner as Example 4 except that the angle φ was 50°.

(Example 25)

[0157] Ten sintered bodies of Example 25 were produced in the same manner as Example 4 except that the angle φ was 60°.

(Reference Example 11)

[0158] Ten sintered bodies of Reference Example 11 were produced in the same manner as Example 4 except that the angle φ was 20°.

(Reference Example 12)

[0159] Ten sintered bodies of Reference Example 12 were produced in the same manner as Example 4 except that the angle φ was 70°.

<Evaluation>

[0160] The properties were evaluated in the same manner as Second Example (Examples 11 to 15 and Reference Examples 1 and 2), and therefore the explanations therefor are herein omitted.

(Evaluation results)

[0161] The evaluation results are shown in Table 2.

Table 2

	Angle φ	Cracking and deformation	Thermal shock resistance	Leakage
Reference Example 11	20°	Not observed	Fair	2/10
Example 21	30°	Not observed	Excellent	0/10
Example 22	40°	Not observed	Excellent	0/10
Example 23	45°	Not observed	Excellent	0/10
Example 24	50°	Not observed	Excellent	0/10
Example 25	60°	Not observed	Excellent	0/10
Reference Example 12	70°	Not observed	Good	2/10

[0162] In Examples 21 to 25, good evaluation results were obtained, and the sintered bodies were not cracked even at 160°C in the thermal shock resistance evaluation. In Reference Example 11, the sintered bodies were cracked at 150°C in the thermal shock resistance evaluation, and the leakage was caused in two of the ten sintered bodies. This was considered to be caused because the projection 50 was excessively close to the light-emitting portion 34, whereby the light-emitting portion 34 was deformed in the thermal fusion bonding. In Reference Example 12, the sintered bodies were cracked at 160°C in the thermal shock resistance evaluation.

[0163] It is to be understood that the ceramic tube production method and the ceramic tube of the present invention are not limited to the above embodiments, and various changes and modifications may be made therein without departing from the scope of the present invention.

Claims

1. A method for bonding a plurality of ceramic compacts to produce one ceramic tube for a high-intensity discharge lamp, comprising
a compact preparation step of preparing a plurality of ceramic compacts (10), which include at least one ceramic compact (10A) having a groove (14) in the joining surface (12a), and
a compact bonding step of bonding the joining surfaces (12) of the ceramic compacts (10) to each other, to produce a ceramic tube having a through-hole (38) corresponding to the groove (14).
2. The method according to claim 1, wherein
in the compact preparation step, one first ceramic compact (10A) having the groove (14) in the joining surface (12a) and one second ceramic compact (10B) not having the groove (14) in the joining surface (12b) are prepared, and
in the compact bonding step, the one first ceramic compact (10A) and the one second ceramic compact (10B) are bonded to each other.
3. The method according to claim 1, wherein
in the compact preparation step, two first ceramic compacts (10A) having the grooves (14) in the joining surfaces (12a) are prepared, and
in the compact bonding step, the two first ceramic compacts (10A) are bonded to each other such that the grooves (14) in the joining surfaces (12a) are aligned with each other.
4. A method for bonding a plurality of ceramic compacts to produce one ceramic tube for a high-intensity discharge lamp, comprising
a compact preparation step of preparing a plurality of ceramic compacts (10), which includes at least one ceramic

compact (10C) having a first projection (40a) in the joining surface (12a), a continuous groove (42) extending from the end of the first projection (40a) to an inside continuously in the joining surface (12a), and a compact bonding step of bonding the joining surfaces (12) of the ceramic compacts (10) to each other, to produce a ceramic tube having a hole formed of the continuous groove (42).

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5. The method according to claim 4, wherein
in the compact preparation step, at least one third ceramic compact (10C) having the first projection (40a) and one fourth ceramic compact (10D) having a second projection (40b) in the joining surface (12d) are prepared, the continuous groove (42) being not formed in the second projection (40b), and
in the compact bonding step, the joining surfaces (12c, 12d) of the third ceramic compact (10C) and the fourth ceramic compact (10D) are bonded to each other such that the first projection (40a) and the second projection (40b) are aligned with each other.
6. The method according to claim 4, wherein
in the compact preparation step, at least two third ceramic compacts (10C) having the first projections (40a) are prepared, and
in the compact bonding step, the joining surfaces (12c) of the third ceramic compacts (10C) are bonded to each other such that the first projections (40a) are aligned with each other.
7. The method according to any one of claims 4 to 6, wherein the first projection (40a) has a base point (46), which is an intersection between an outer periphery of the joining surface (12c) having the first projection (40a) and an axis line (n2) of the continuous groove (42) in the first projection (40a), and
the tangent line (K1) at the base point (46) on the outer periphery of the joining surface (12c) and the axis line (n2) of the continuous groove (42) form an angle (θ) of 30° to 60°.
8. The method according to any one of claims 1 to 7, wherein the joining surfaces (12) of the ceramic compacts (10) are parallel to a plane perpendicular to an axis direction.
9. A ceramic tube (24C) for a high-intensity discharge lamp, obtained by bonding a plurality of ceramic compacts (10), wherein
the ceramic tube (24C) comprises a light-emitting portion (34) and electrode containers (36) formed integrally, the light-emitting portion (34) is provided for emitting a light inside the ceramic tube (24C), the electrode containers (36) are disposed on either side of the light-emitting portion (34), electrodes being introduced and sealed therein,
the light-emitting portion (34) has a projection (50) with a through-hole (38c) independent from the electrode containers (36), a light-emitting material being introduced from the through-hole (38c) into the light-emitting portion (34), an axis line (n3) of the projection (50) extends toward an axis line (m1) of the ceramic tube (24C), and the axis line (n3) of the projection (50) and the axis line (m1) of the ceramic tube (24C) form an angle of 90°, and
the projection amount of the projection (50) is within a range of 1/20 to 10/20 of the maximum diameter of the light-emitting portion (34).
10. A ceramic tube for a high-intensity discharge lamp, obtained by bonding a plurality of ceramic compacts (10), wherein
the ceramic tube comprises a light-emitting portion (34) and electrode containers (36) formed integrally, the light-emitting portion (34) is for emitting a light inside the ceramic tube,
the electrode containers (36) are disposed on either side of the light-emitting portion (34), electrodes being inserted thereinto,
the light-emitting portion (34) has a projection (50) with a through-hole (38c) independent from the electrode containers (36), a light-emitting material being introduced from the through-hole (38c) into the light-emitting portion (34), an outer surface of the light-emitting portion (34) has a cross-sectional outline (52) in a plane containing an axis line (n3) of the projection (50), and
the axis line (n3) and a tangent line (K2) at an intersection (54) between the outline (52) and the axis line (n3) form an angle of 30° to 60°.

FIG. 1

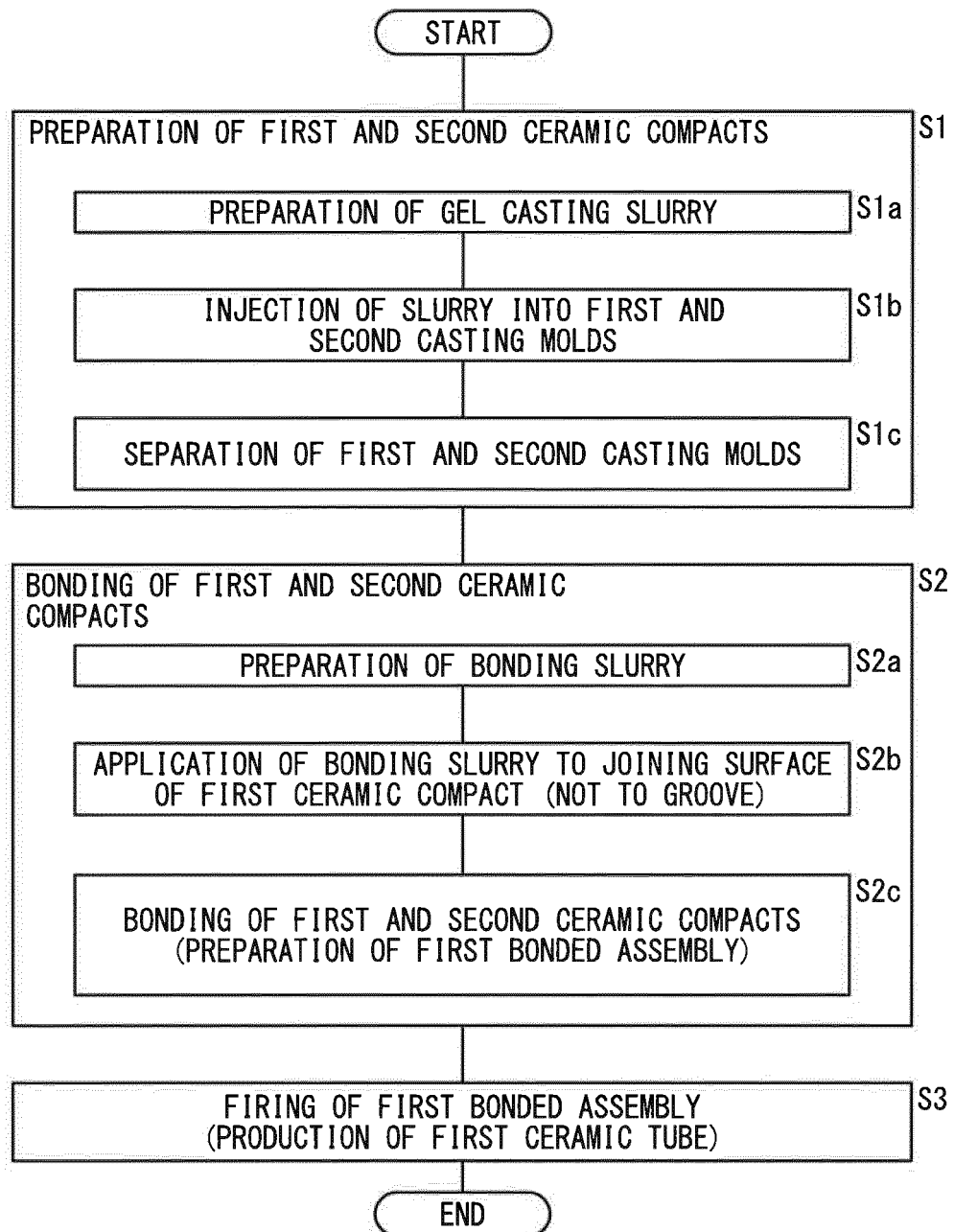


FIG. 2

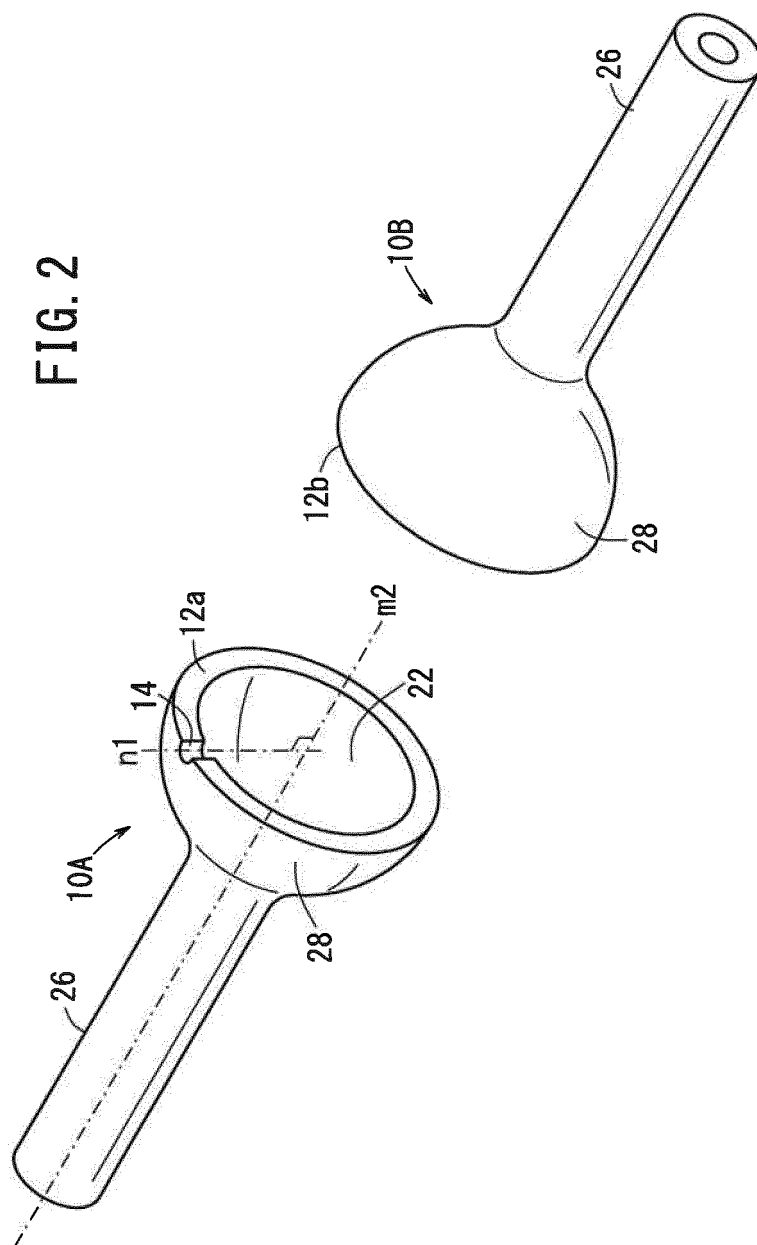


FIG. 3B

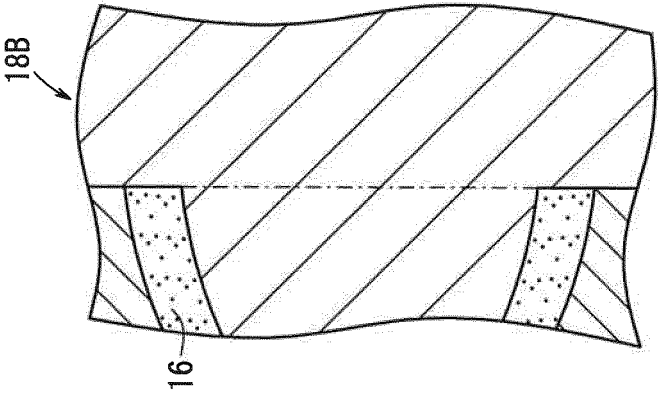


FIG. 3A

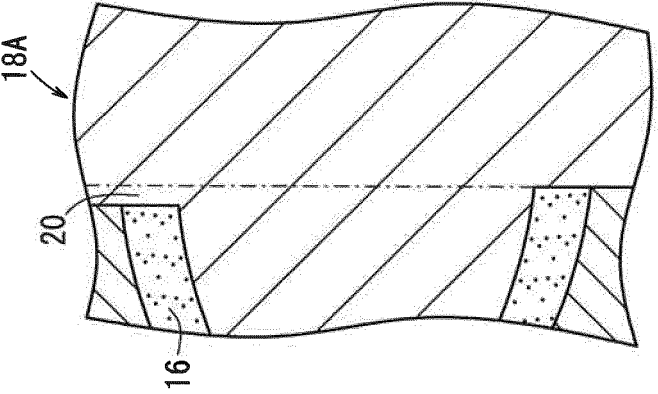


FIG. 4A

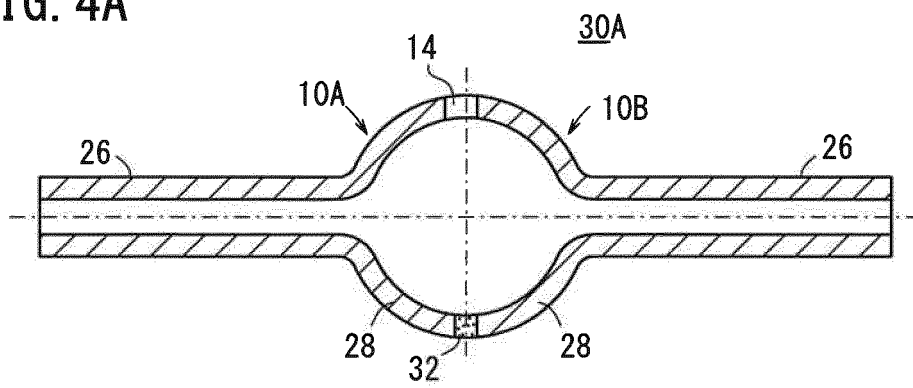


FIG. 4B

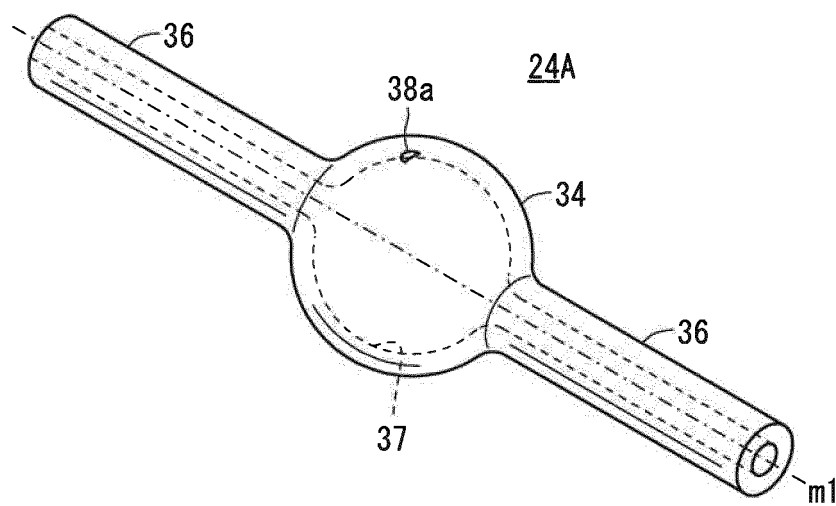


FIG. 5

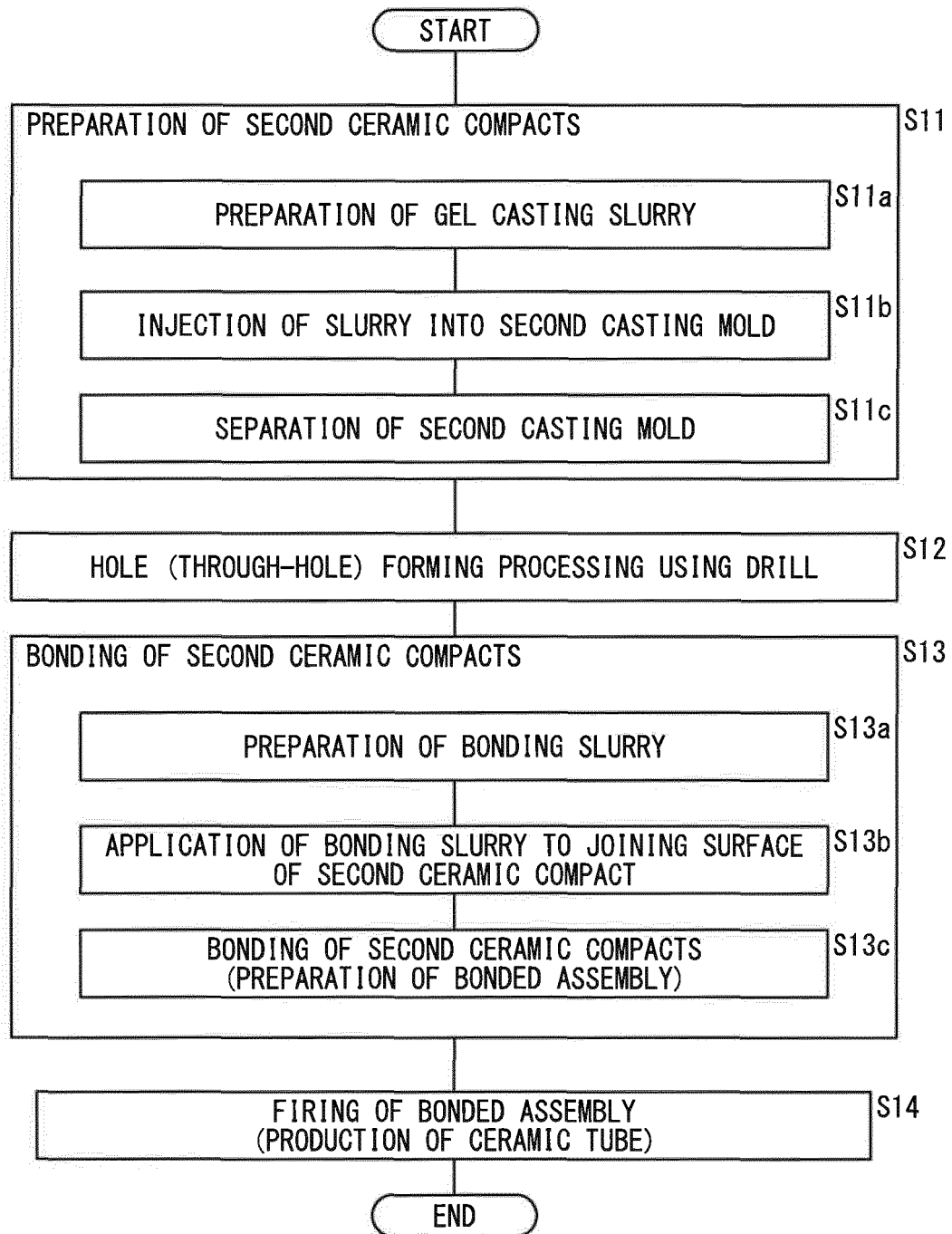


FIG. 6A

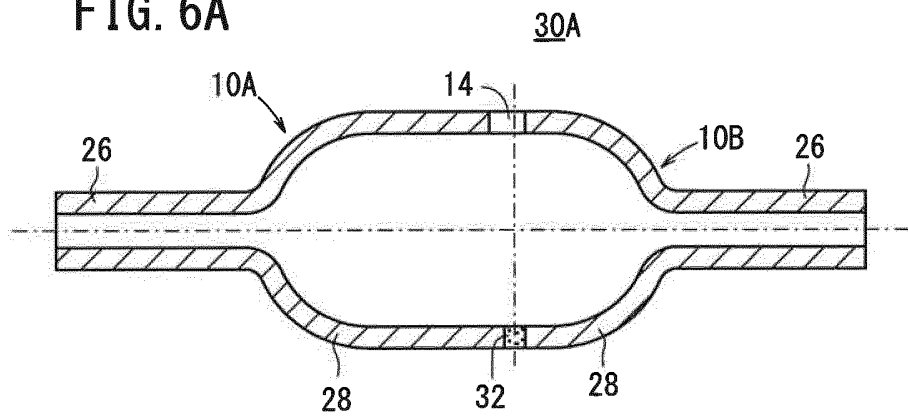


FIG. 6B

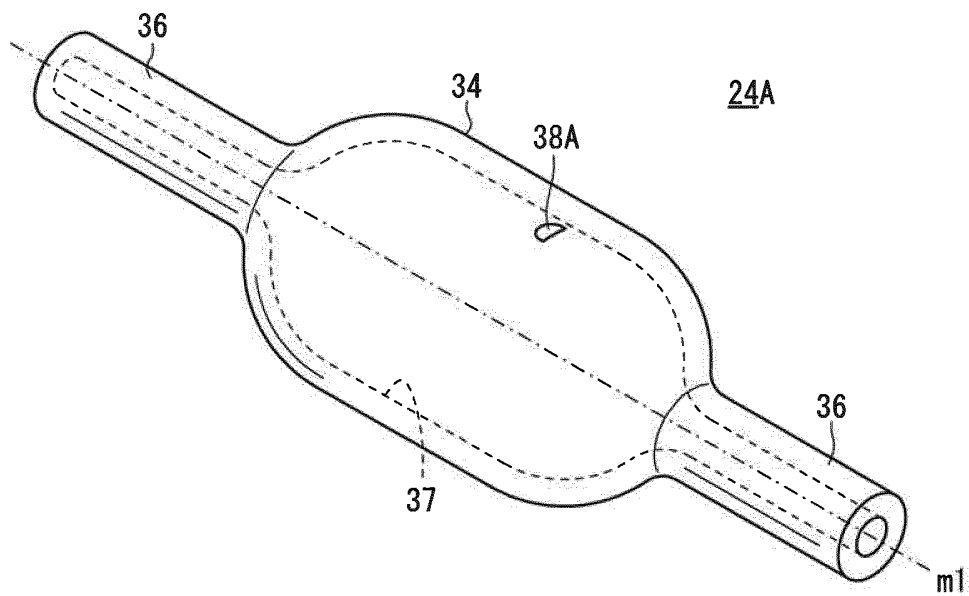


FIG. 7

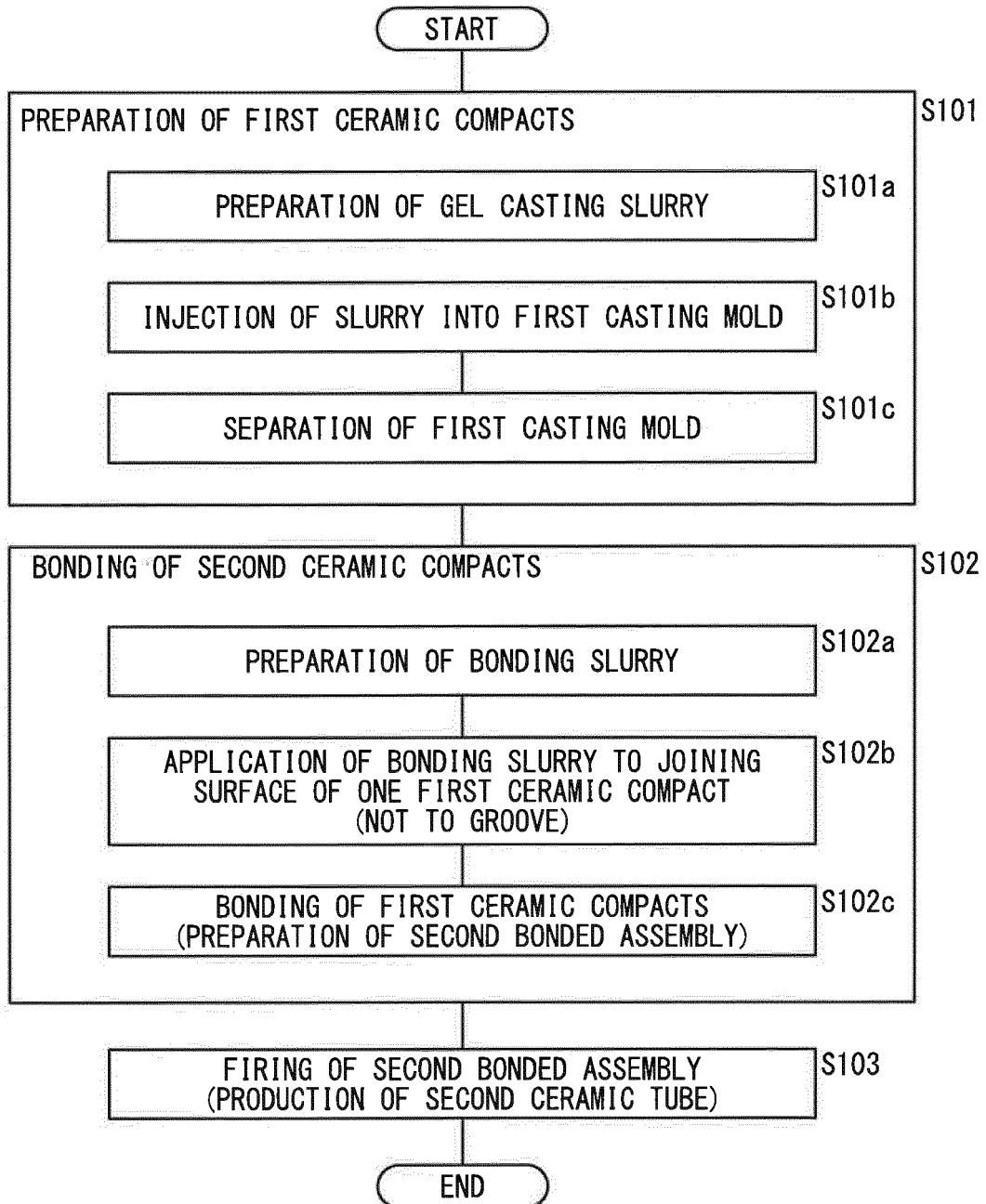


FIG. 8

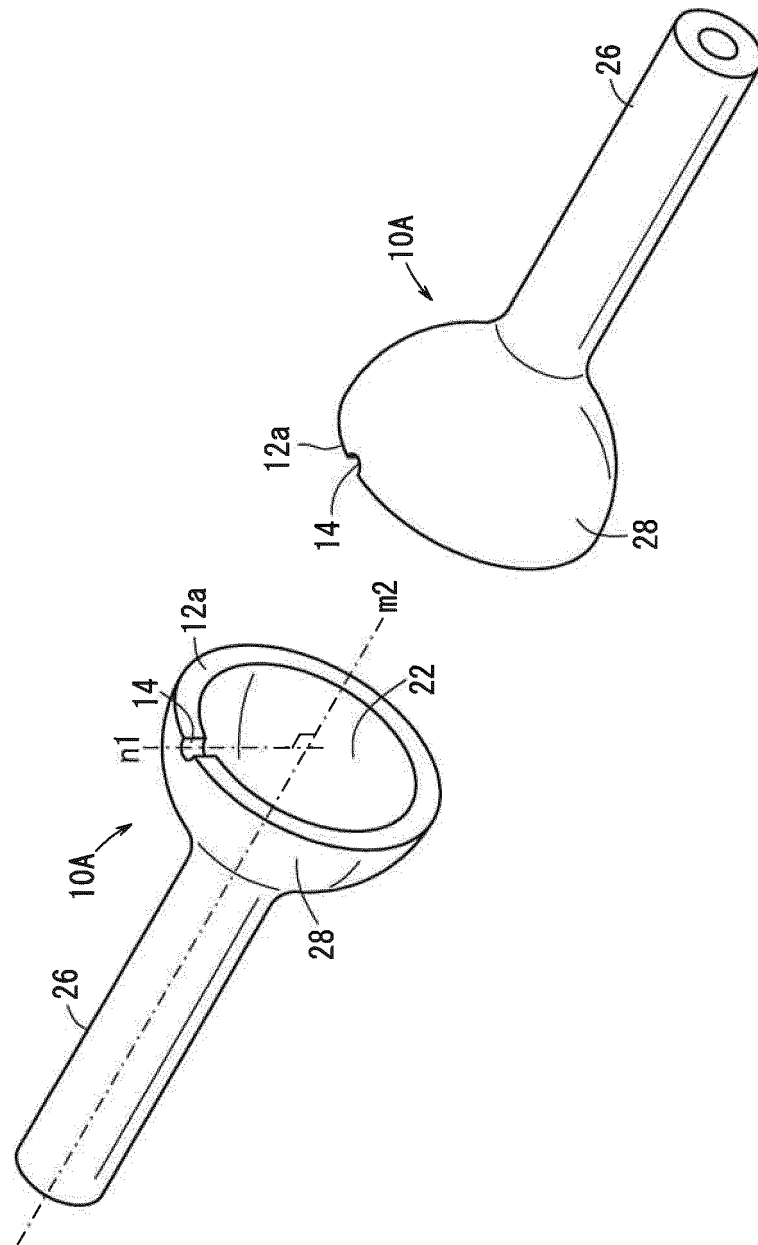


FIG. 9A

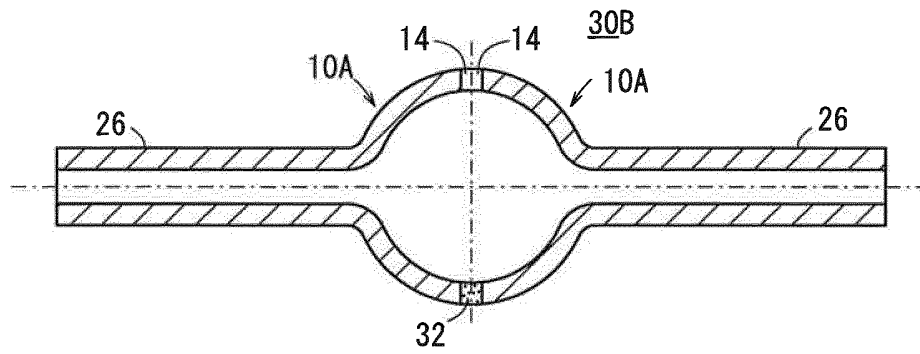


FIG. 9B

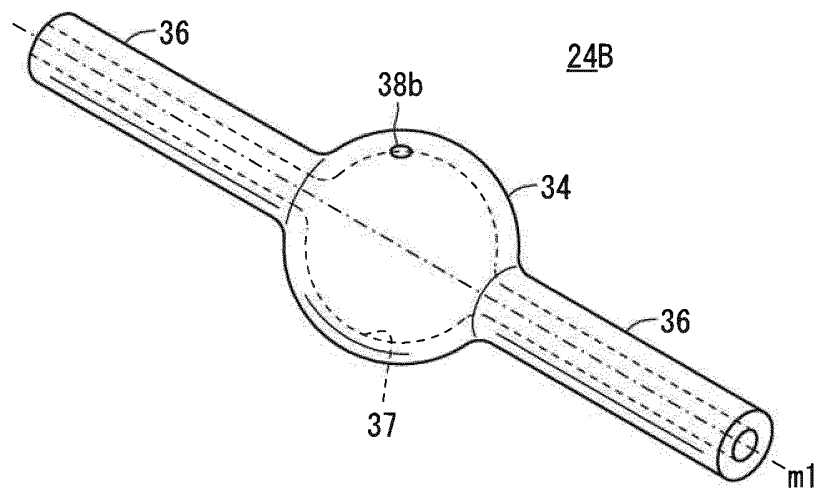


FIG. 10

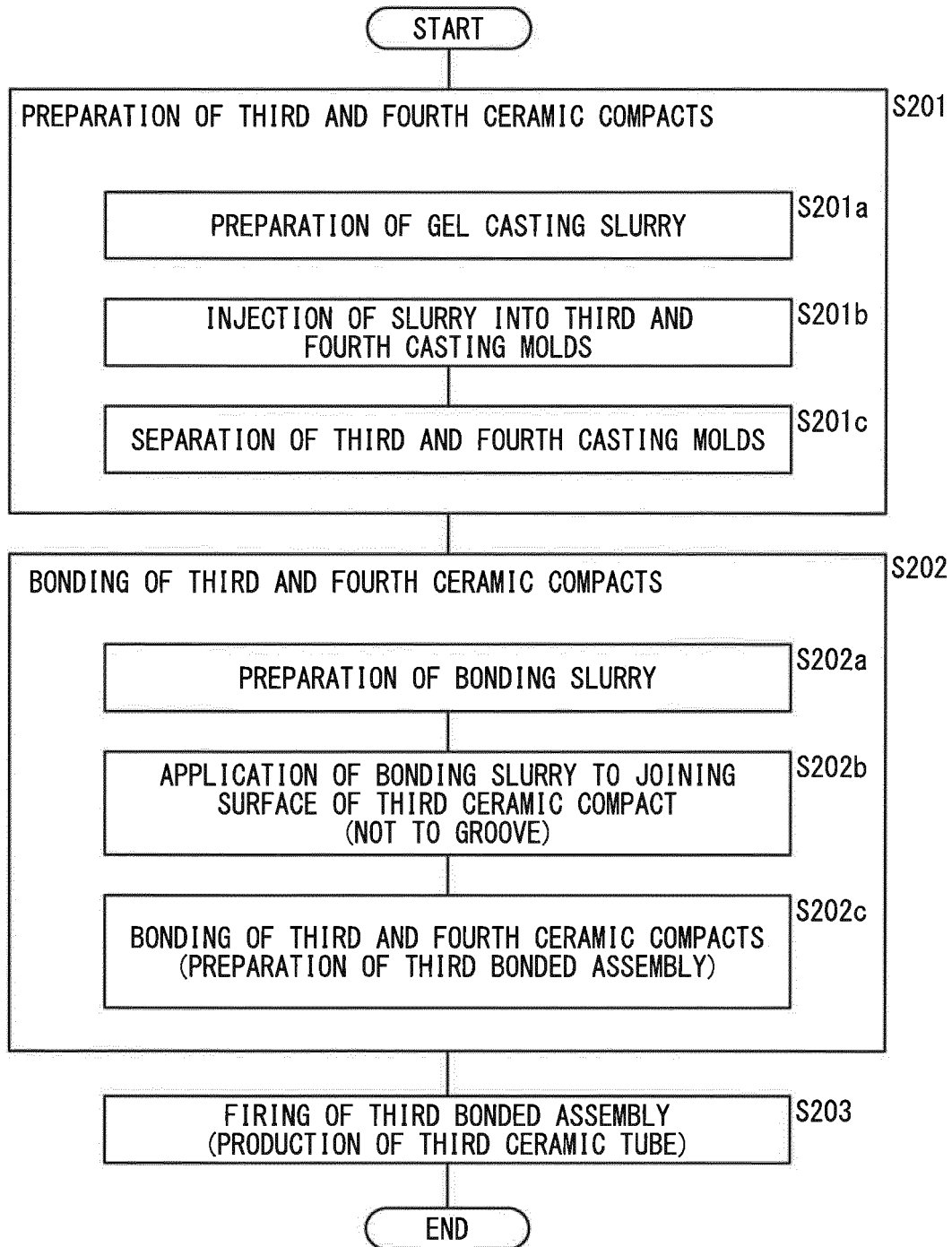


FIG. 11

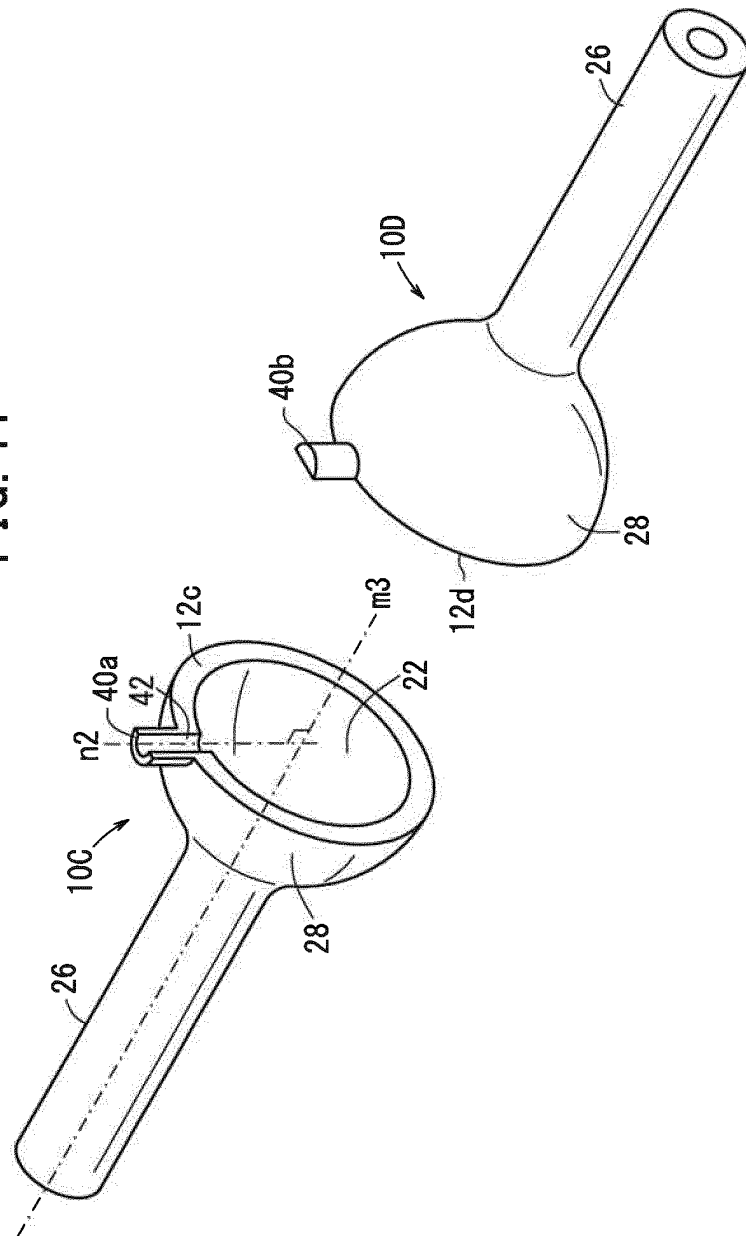


FIG. 12B

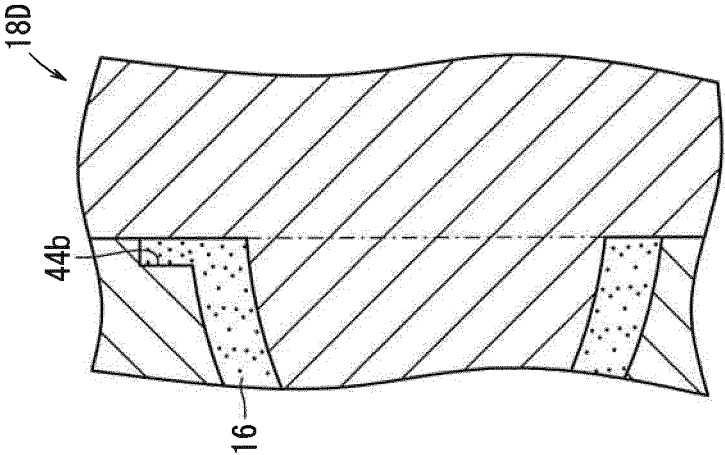


FIG. 12A

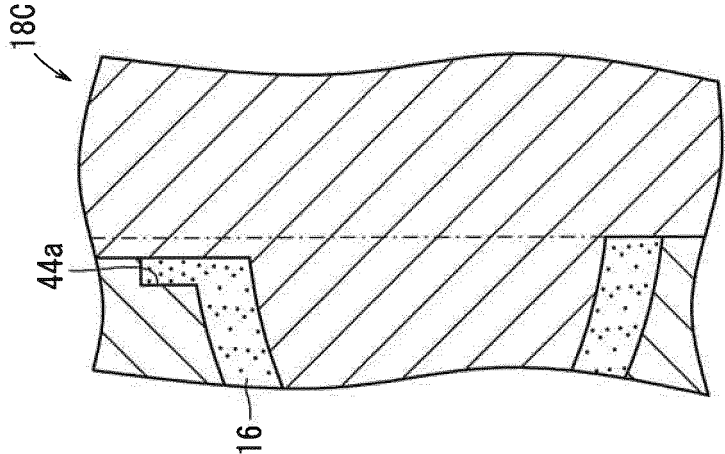


FIG. 13

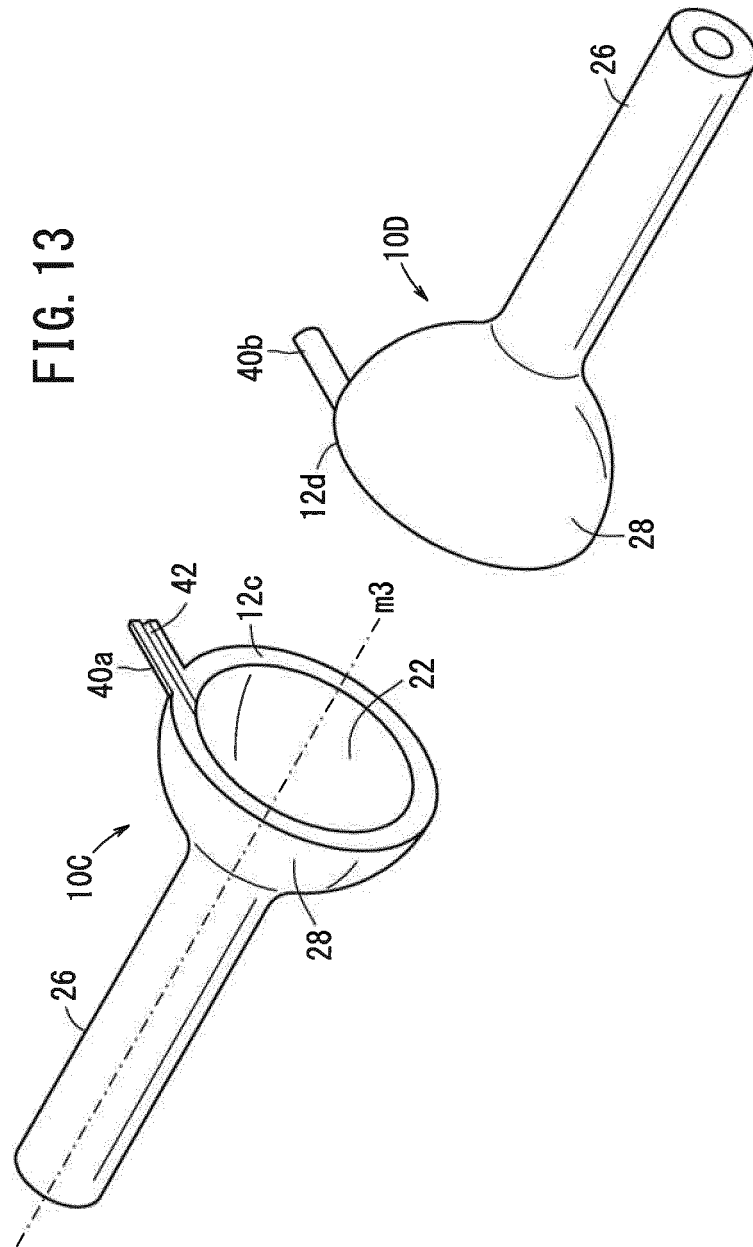


FIG. 14

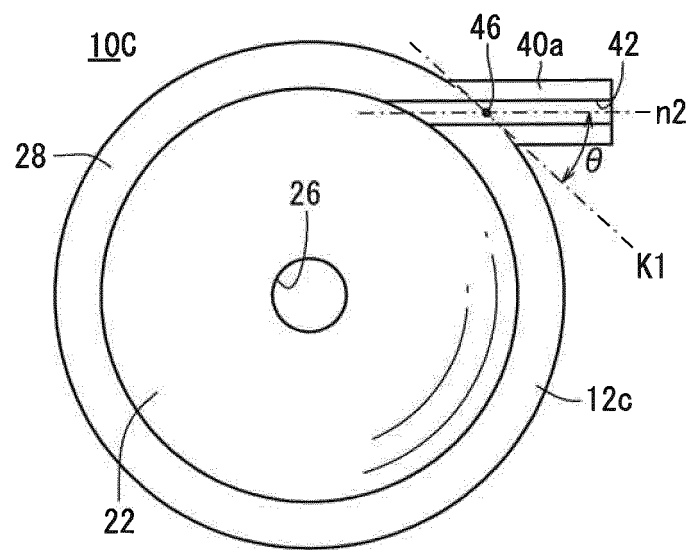


FIG. 15A

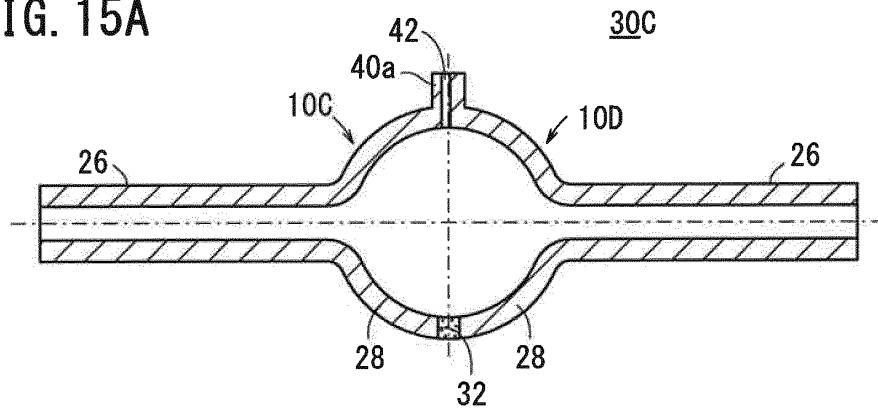


FIG. 15B

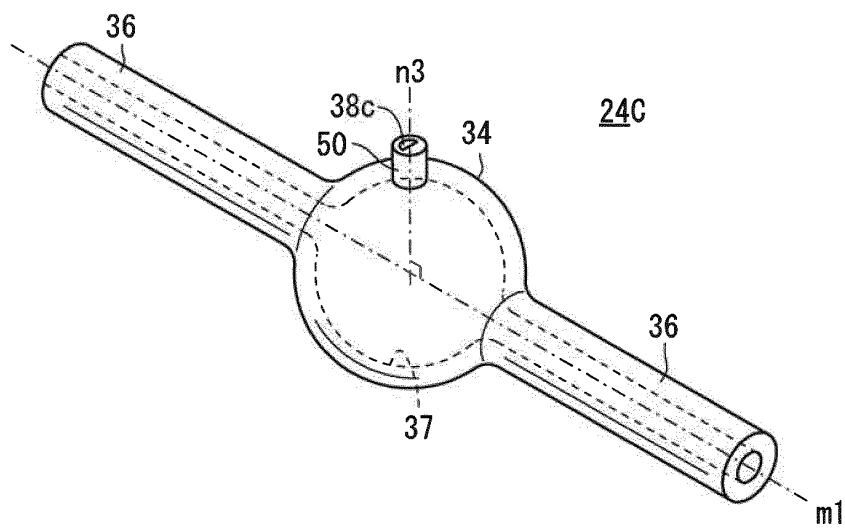


FIG. 16A

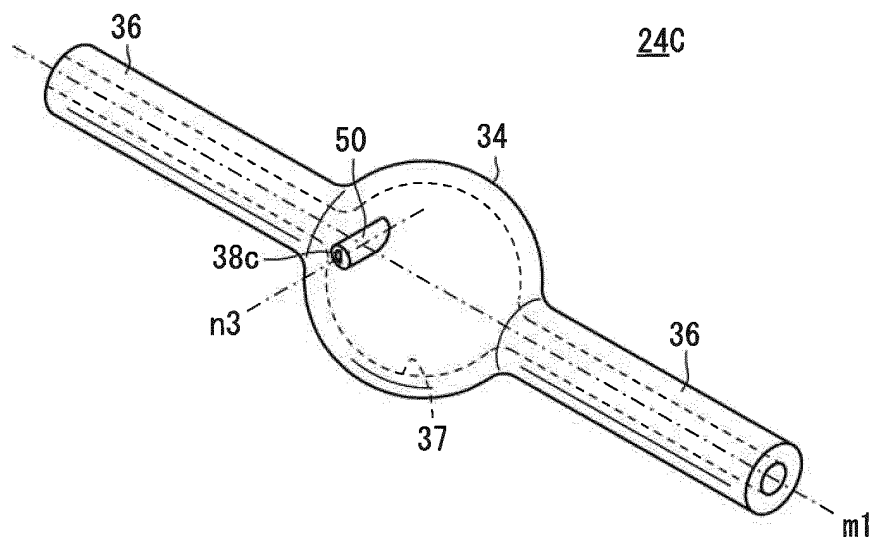


FIG. 16B

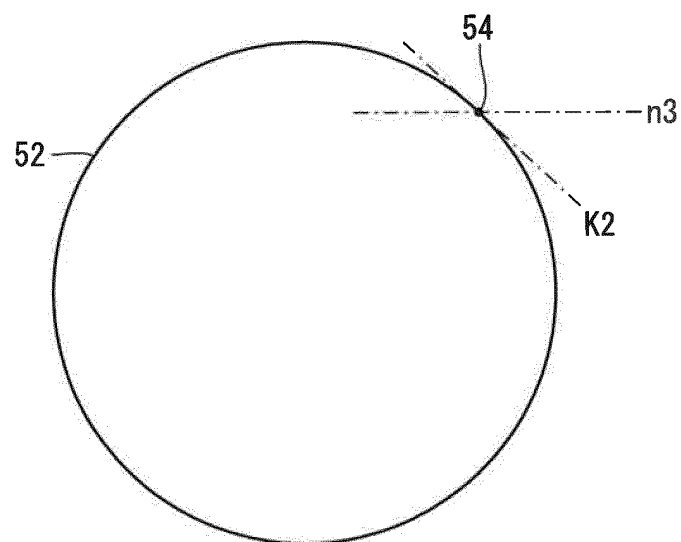


FIG. 17

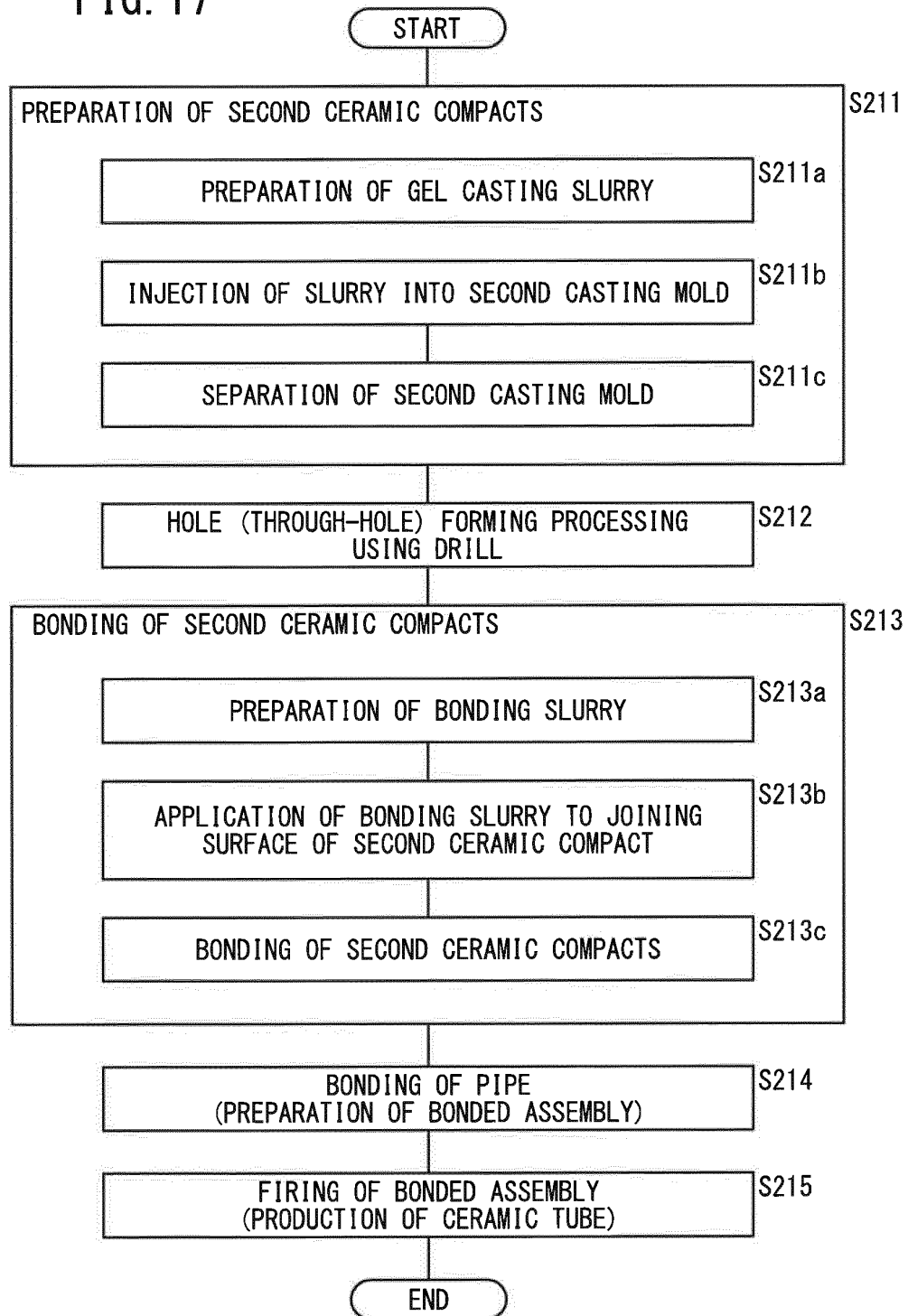


FIG. 18A

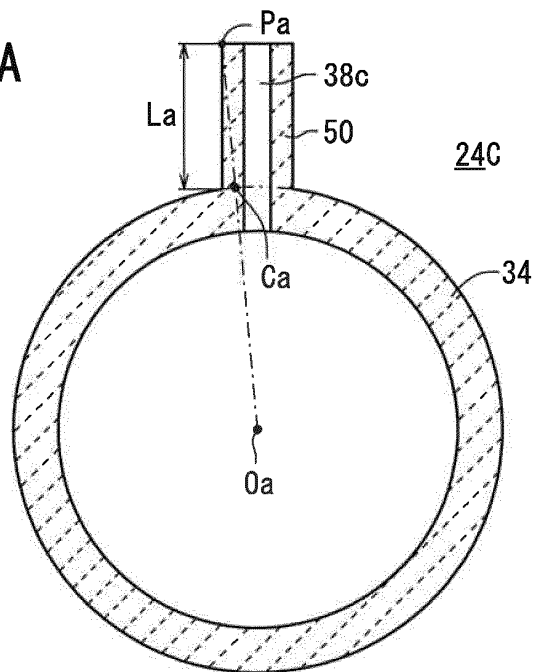


FIG. 18B

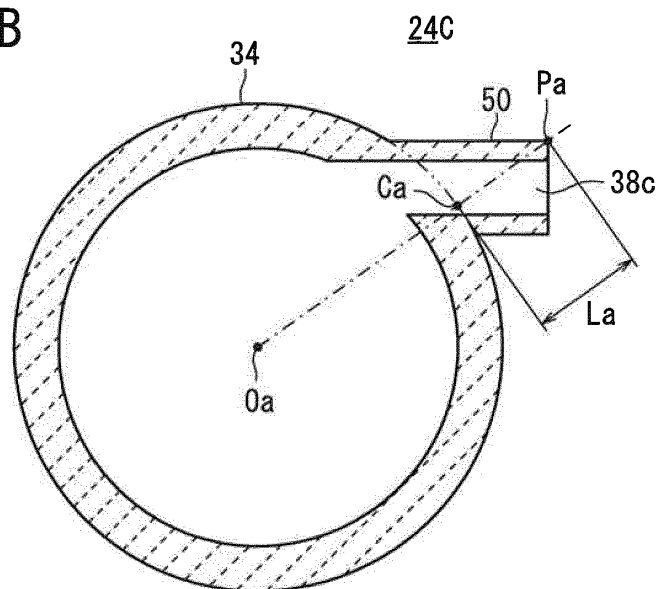


FIG. 19

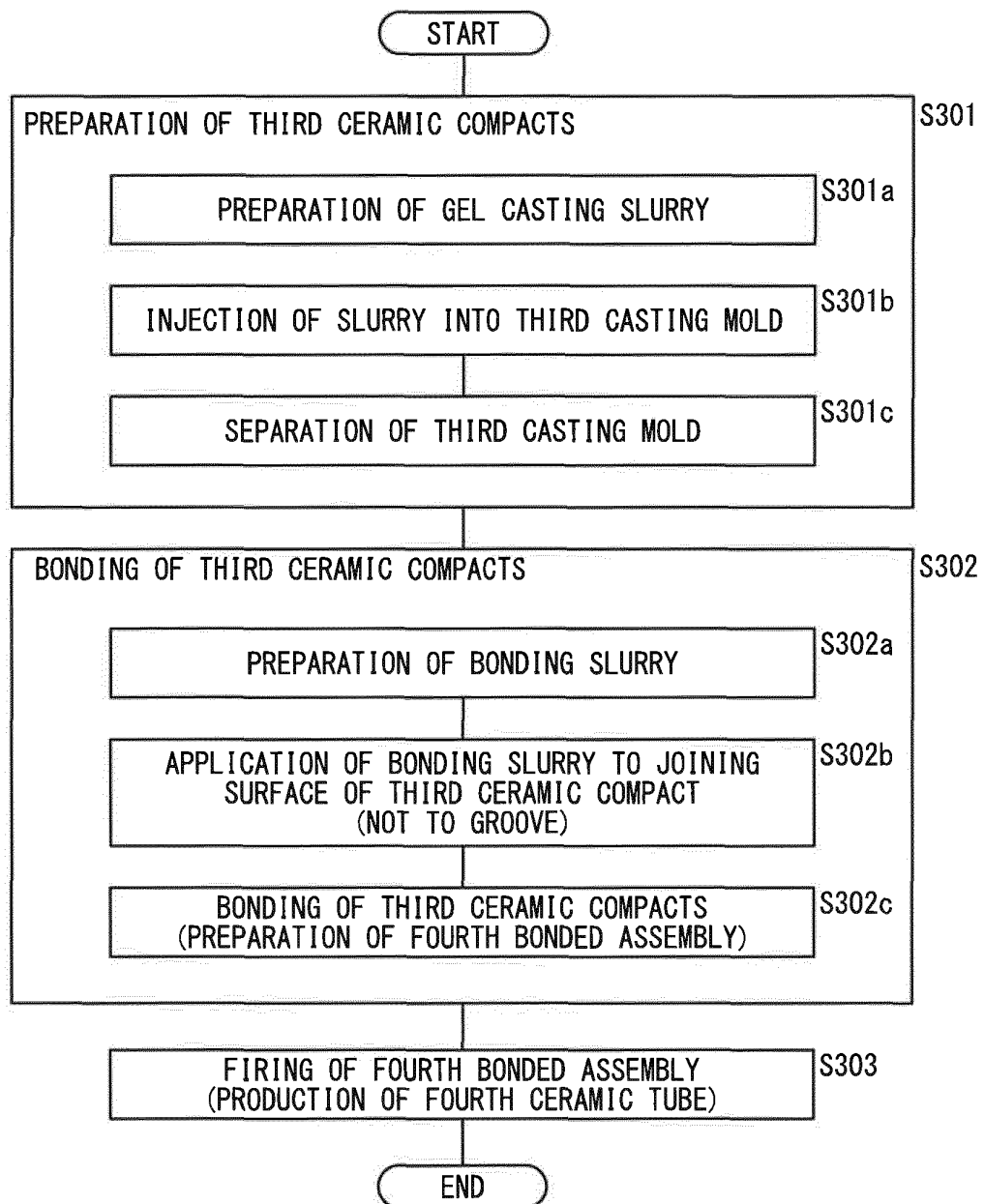
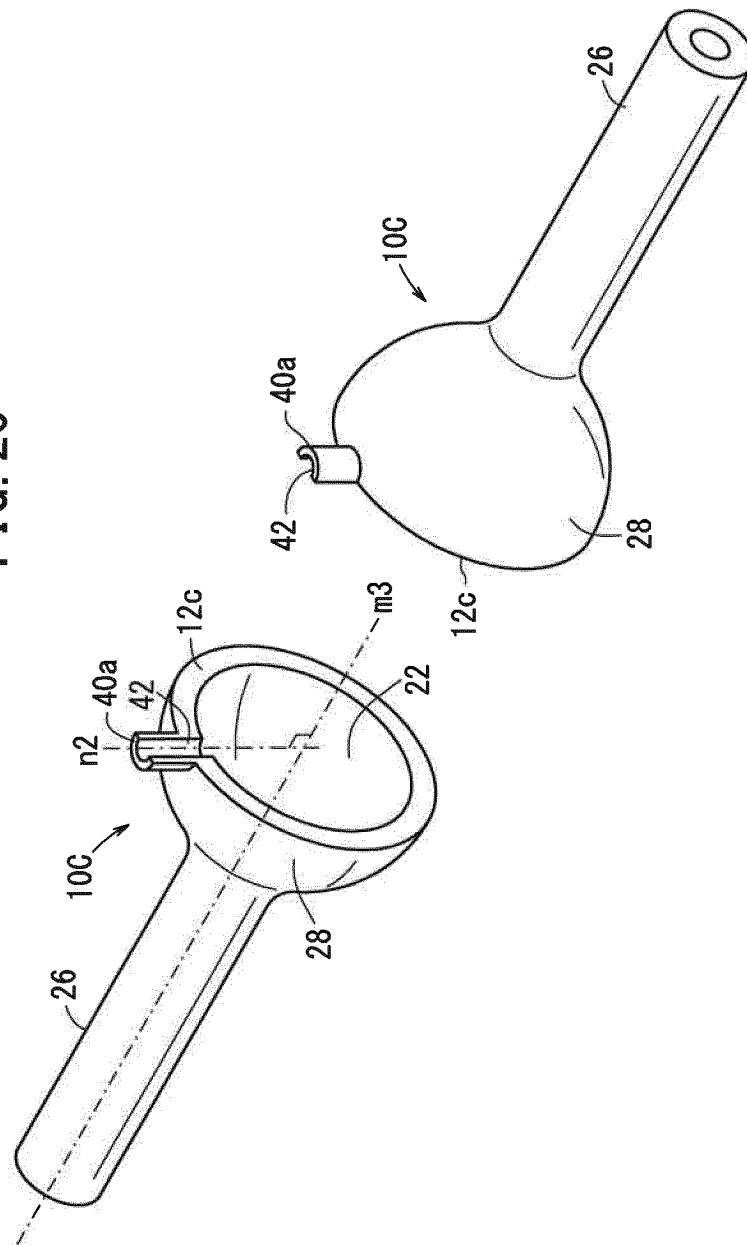


FIG. 20



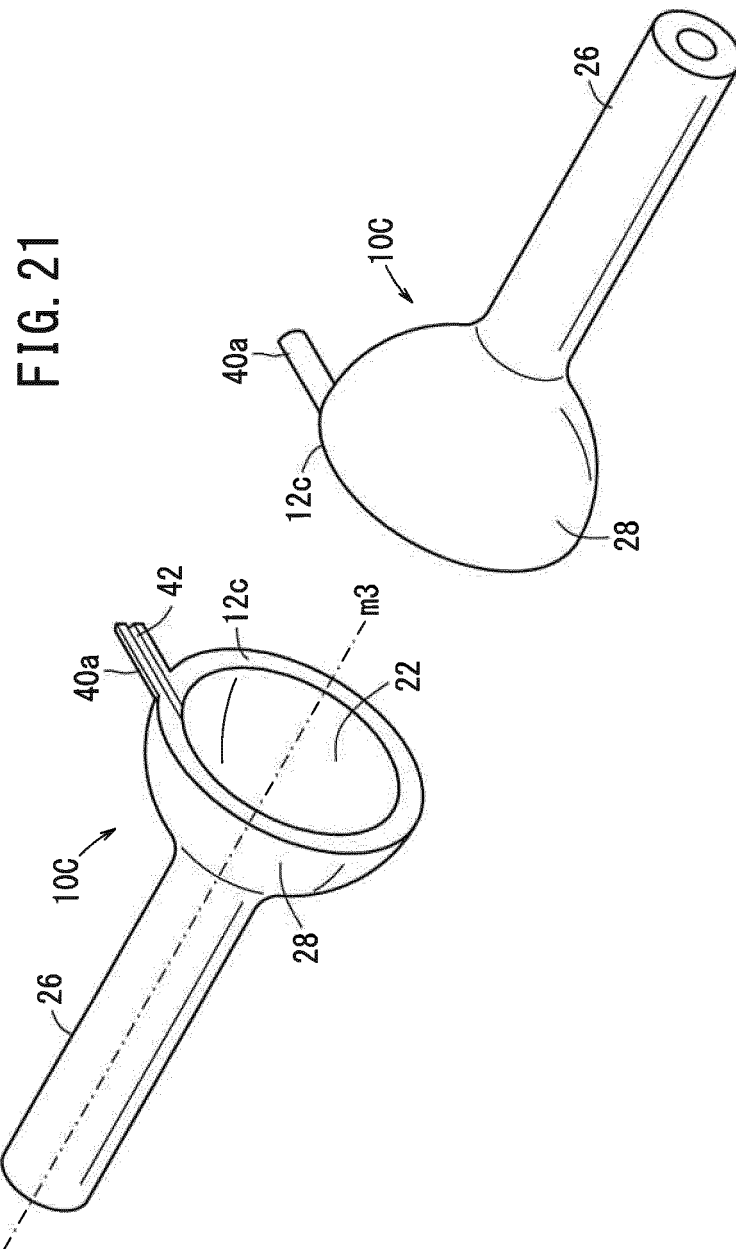


FIG. 22A

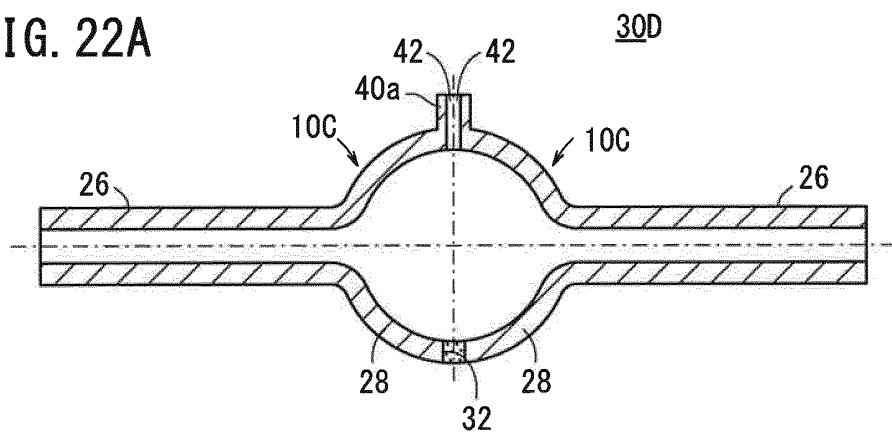


FIG. 22B

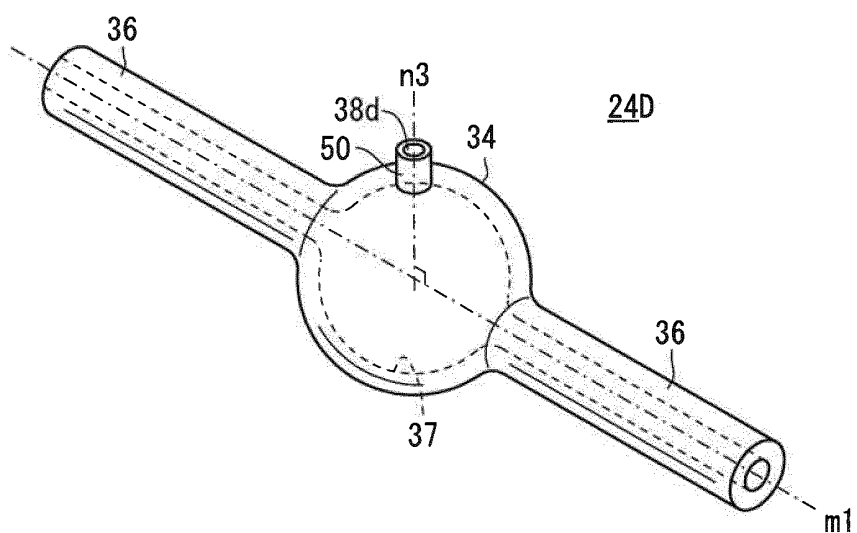


FIG. 23

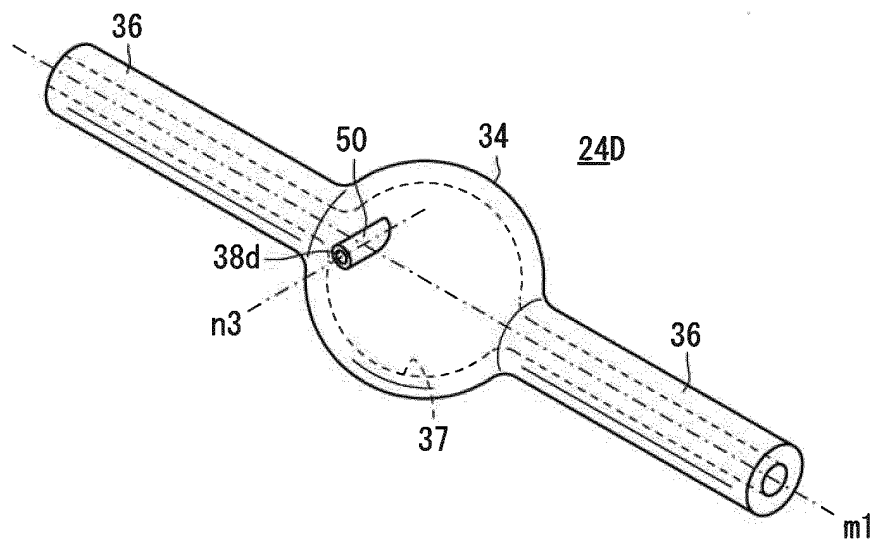


FIG. 24

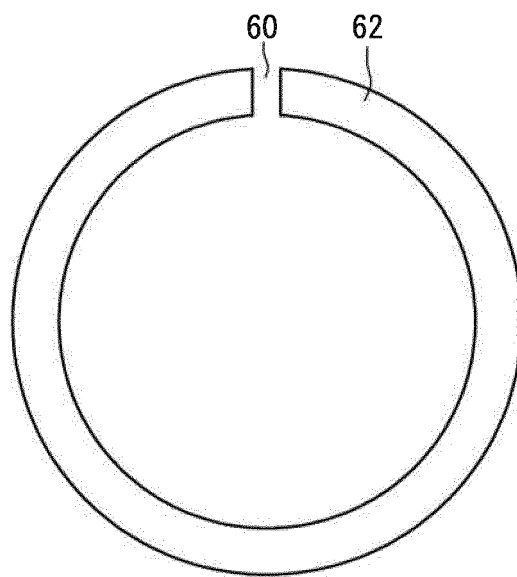
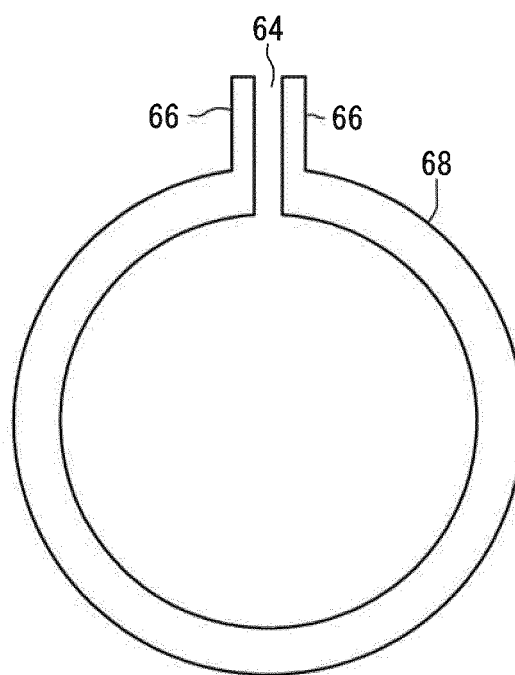


FIG. 25



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/072112

A. CLASSIFICATION OF SUBJECT MATTER

H01J9/24(2006.01) i, B28B1/14(2006.01) i, B28B11/00(2006.01) i, H01J61/30(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)

H01J9/24-9/40, B28B1/14, B28B11/00, H01J61/30

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	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

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 A	JP 2010-514127 A (Koninklijke Philips Electronics N.V.), 30 April 2010 (30.04.2010), paragraphs [0037] to [0039]; fig. 2B & US 2010/0026183 A1 & EP 2122654 A & WO 2008/078228 A1 & CN 101589448 A	1, 3-4, 6, 8, 9 2, 5 7, 10
X Y A	JP 2010-514125 A (Koninklijke Philips Electronics N.V.), 30 April 2010 (30.04.2010), paragraphs [0044] to [0045]; fig. 6 & US 2010/0026184 A1 & EP 2122653 A & WO 2008/078225 A1 & KR 10-2009-0089478 A & CN 101563747 A	1, 3-4, 6, 8, 9 2, 5 7, 10

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
20 October, 2011 (20.10.11)Date of mailing of the international search report
01 November, 2011 (01.11.11)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/072112

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2006-164907 A (Lecip Corp.), 22 June 2006 (22.06.2006), paragraph [0003]; fig. 14 (Family: none)	2, 5
Y	JP 2007-80787 A (Lecip Corp.), 29 March 2007 (29.03.2007), paragraphs [0037] to [0043]; fig. 3 to 6 (Family: none)	2, 5
Y	JP 2008-21584 A (Harison Toshiba Lighting Corp.), 31 January 2008 (31.01.2008), paragraphs [0013] to [0015]; fig. 3 (Family: none)	2, 5
A	JP 2003-346723 A (Toshiba Lighting & Technology Corp.), 05 December 2003 (05.12.2003), paragraphs [0067] to [0073]; fig. 6 to 8 (Family: none)	1-10

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/072112

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
See extra sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/072112

Continuation of Box No.III of continuation of first sheet(2)

Document 1: JP 2010-514127 A (Koninklijke Philips Electronics N.V.), 30 April, 2010 (30.04.2010) discloses the feature of a ceramic electric discharge container having a hole in the portion where a separate tube (68) is fused thereto, said electric discharge container being formed by bonding substantially same portions (22C), and the features wherein the substantially same portions (22C) are ceramic molded bodies, and the substantially same portions are molded without having the tube (68), and since the electric discharge container is molded by bonding the two portions, the above-mentioned molded body is considered to have a groove at a portion that corresponds to the above-mentioned hole, the invention in claim 1 is not novel to the invention disclosed in document 1, and does not have a special technical feature.

Furthermore, since document 1 also discloses the configuration wherein each of the substantially the same portions (22C) includes the half portion of the tube (68), the invention in claim 4 is not novel to the invention disclosed in document 1 and does not have a special technical feature.

Judging from the special technical feature of the dependent claims on claim 1 at the time when the request of payment of additional search fees was to be made, this international application includes three invention groups linked by each of the special technical features stated below.

Document 1 also discloses the inventions in claims 3, 6 and 8, and the invention in claim 9 is only slightly different in design from the inventions in document 1, and the inventions in claims 3, 6 and 8 and the invention in claim 9 do not have a special technical feature. Therefore, the inventions in claims 1, 3-4, 6 and 9 and the invention in claim 8 depending on claims 1, 3-4 and 6 are classified as the inventions of the main invention group.

(1) The inventions in claims 2 and 5 are different from those in document 1 in the feature wherein a ceramic tube is manufactured by bonding one molded body having a groove formed therein with the other molded body having no groove formed therein on the areas where a hole is to be formed.

(2) The inventions in claims 7 and 10 are different from the inventions in document 1 in the feature wherein, in the molded body having a protrusion, an angle formed by the direction of the tangent line on the outer circumference at the base point of a protrusion and the axis line of the protrusion is 30-60°.

Consequently, this international application includes the three invention groups not satisfying the requirement of unity of invention.

Main invention group: Claims 1, 3-4, 6, 8 (Parts depending on claims 1, 3-4 and 6), and 9

Second invention group: Claims 2, 5 and 8 (Parts depending on claims 2 and 5)

Third invention group: Claims 7, 8 (parts depending on claim 7) and 10

Since the International Searching Authority could search all the searchable claims without making a request of payment of additional search fees, the Authority searched all the claims without making a request of payment of additional search fees.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 63143738 A [0003] [0005] [0015]
- JP 5334962 A [0003] [0006] [0015] [0017]
- JP 7021990 A [0003] [0007] [0015] [0017]
- JP 8055606 A [0003] [0008] [0015]
- JP 2010514125 W [0003] [0015]
- WO 2010514127 A [0003]
- US 20060001346 A [0003] [0011] [0015]
- JP 2009530127 W [0003] [0012] [0013]
- WO 2008044344 A [0003]
- JP 2010514125 A [0009]
- JP 2010514127 W [0010] [0015]
- JP 2008044344 A [0012] [0014] [0098]
- WO 2002085590 A [0096] [0098]