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(54) **BONDING METHOD AND BONDING APPARATUS**

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(57) **ABSTRACT**

The present invention relates to a bonding method or an apparatus for projecting a conductive element from a nozzle onto an object to be bonded and electrically bonding the object to be bonded and the conductive element. The method of invention comprises the steps of: preparing the conductive element having an outer diameter with a curvature radius larger than a curvature radius of a portion of an opening of the nozzle which is in contact with the conductive element; pressurizing and attaching the conductive element to the opening of the nozzle; and supplying a compressed gas into an inner space of the nozzle and projecting the conductive element in a solid phase state onto the object to be bonded.

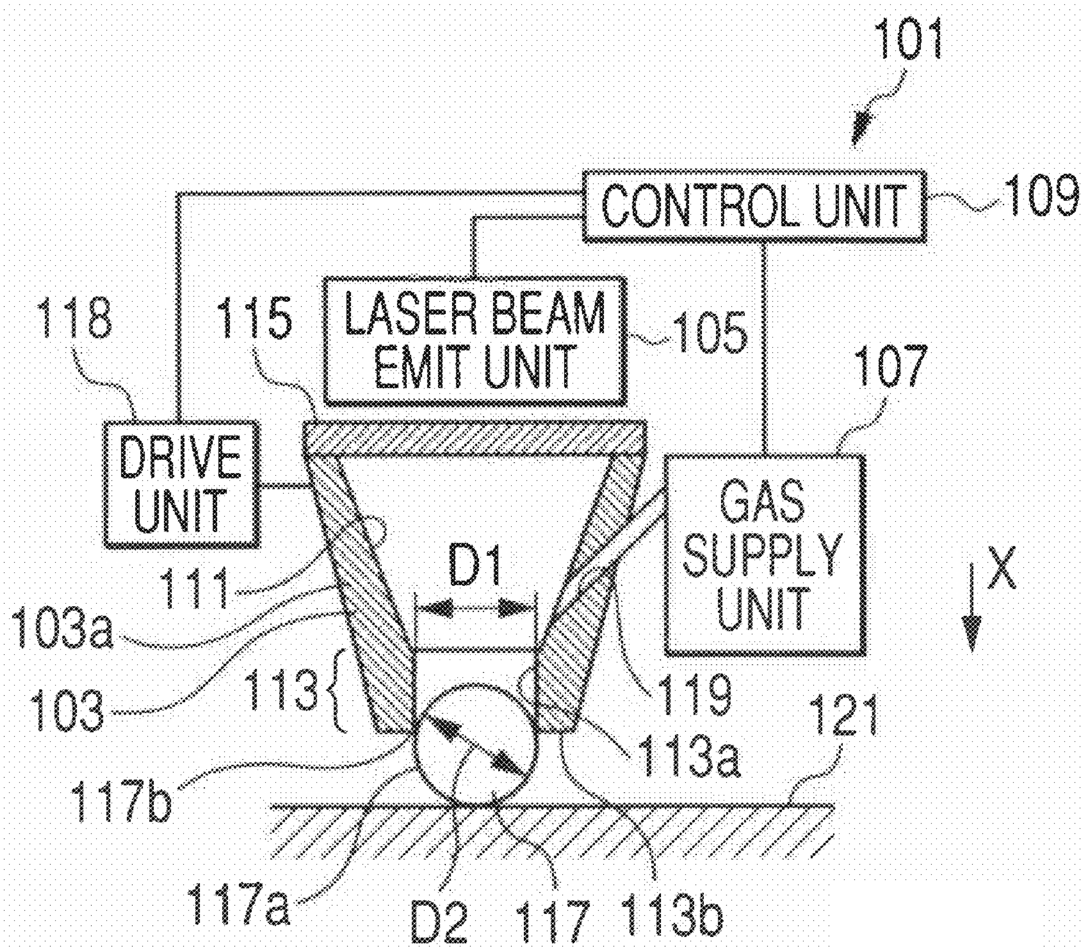


FIG. 1A

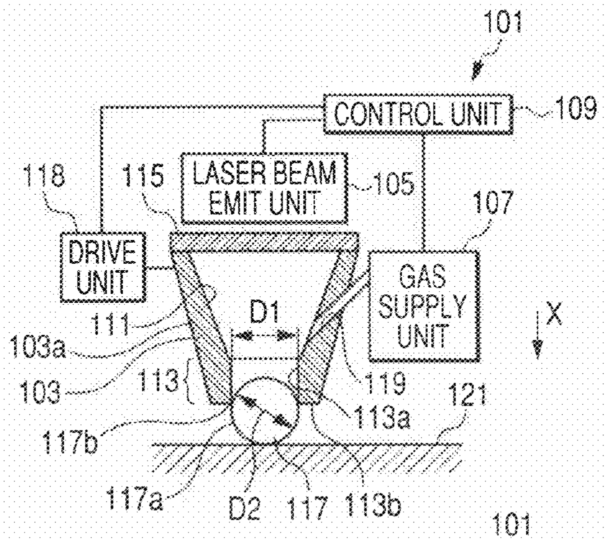


FIG. 1B

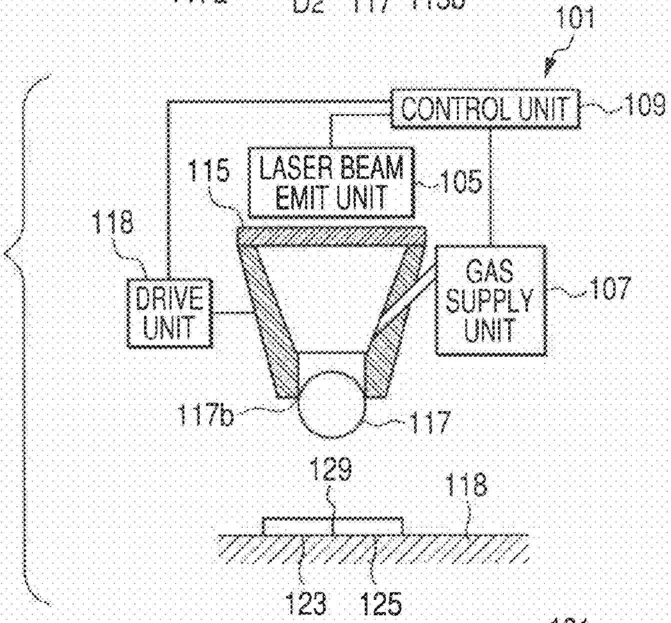


FIG. 1C

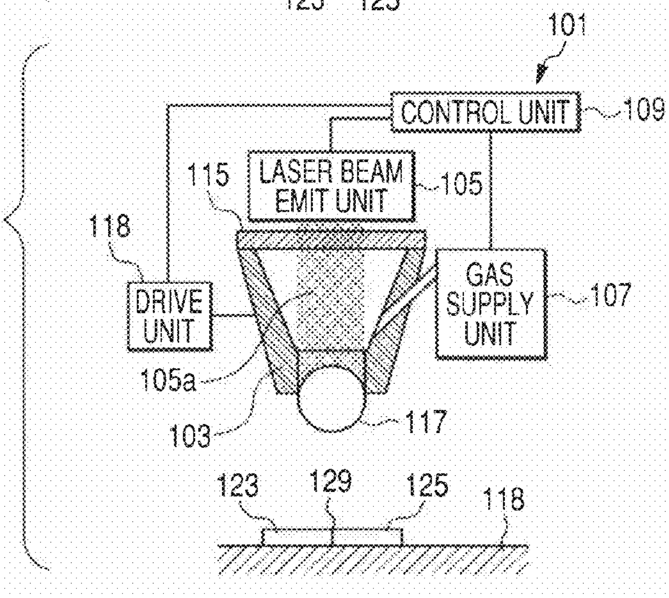


FIG. 1D

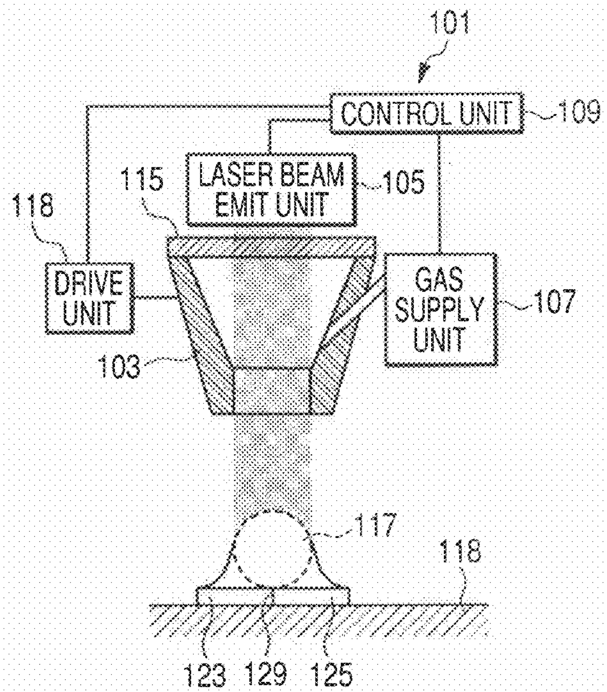


FIG. 1E

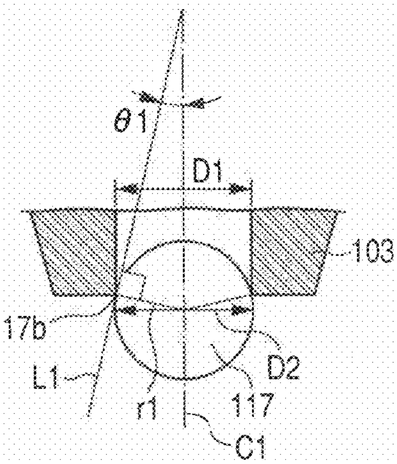


FIG. 1F

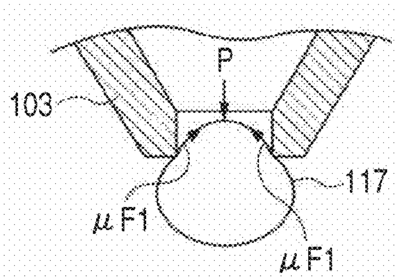


FIG. 1G

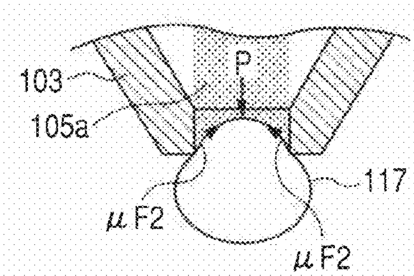


FIG. 2

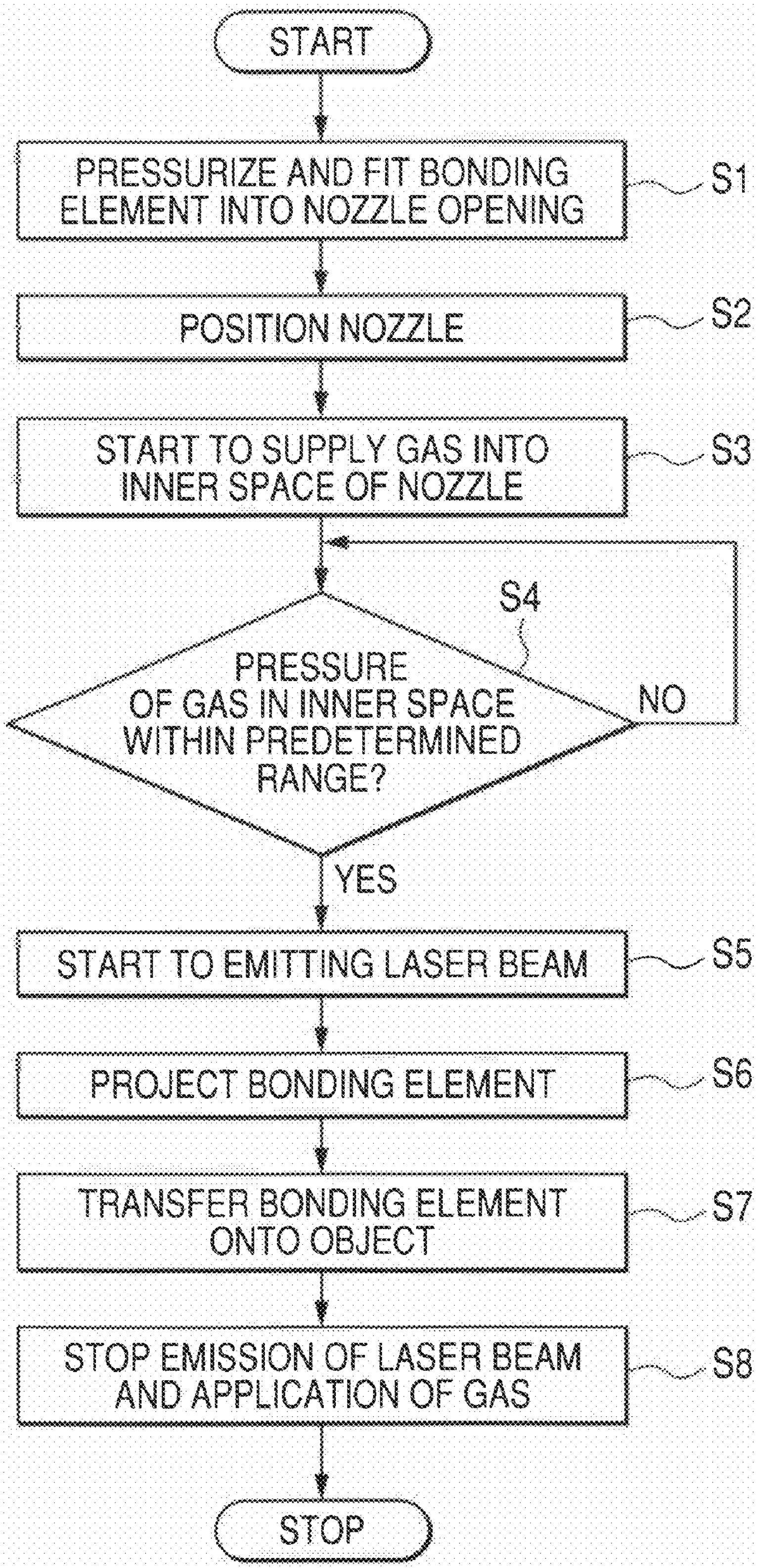

START
PRESSURIZE AND FIT BONDING ELEMENT INTO NOZZLE OPENING
S1
POSITION NOZZLE
S2
START TO SUPPLY GAS INTO INNER SPACE OF NOZZLE
S3
S4
PRESSURE OF GAS IN INNER SPACE WITHIN PREDETERMINED RANGE?
NO
YES
START TO EMITTING LASER BEAM
S5
PROJECT BONDING ELEMENT
S6
TRANSFER BONDING ELEMENT ONTO OBJECT
S7
STOP EMISSION OF LASER BEAM AND APPLICATION OF GAS
S8
STOP

FIG. 3

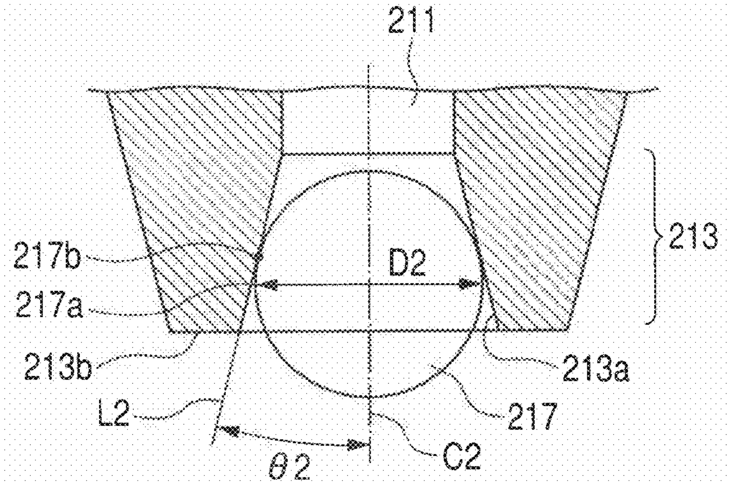

211
213
217b
D2
217a
213b
213a
L2
217
θ2
C2

FIG. 4

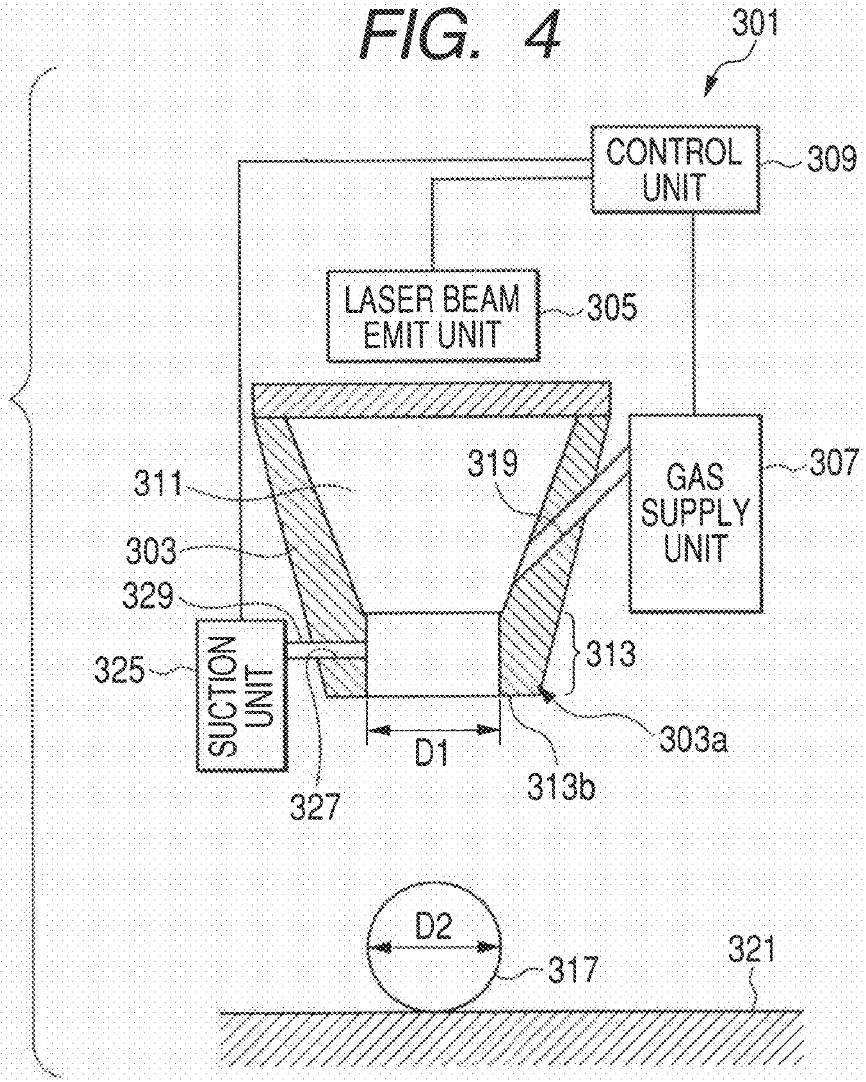

301
CONTROL UNIT
309
LASER BEAM EMIT UNIT
305
319
GAS SUPPLY UNIT
307
311
303
329
313
325
SUCTION UNIT
303a
D1
327
313b
D2
317
321

FIG. 5

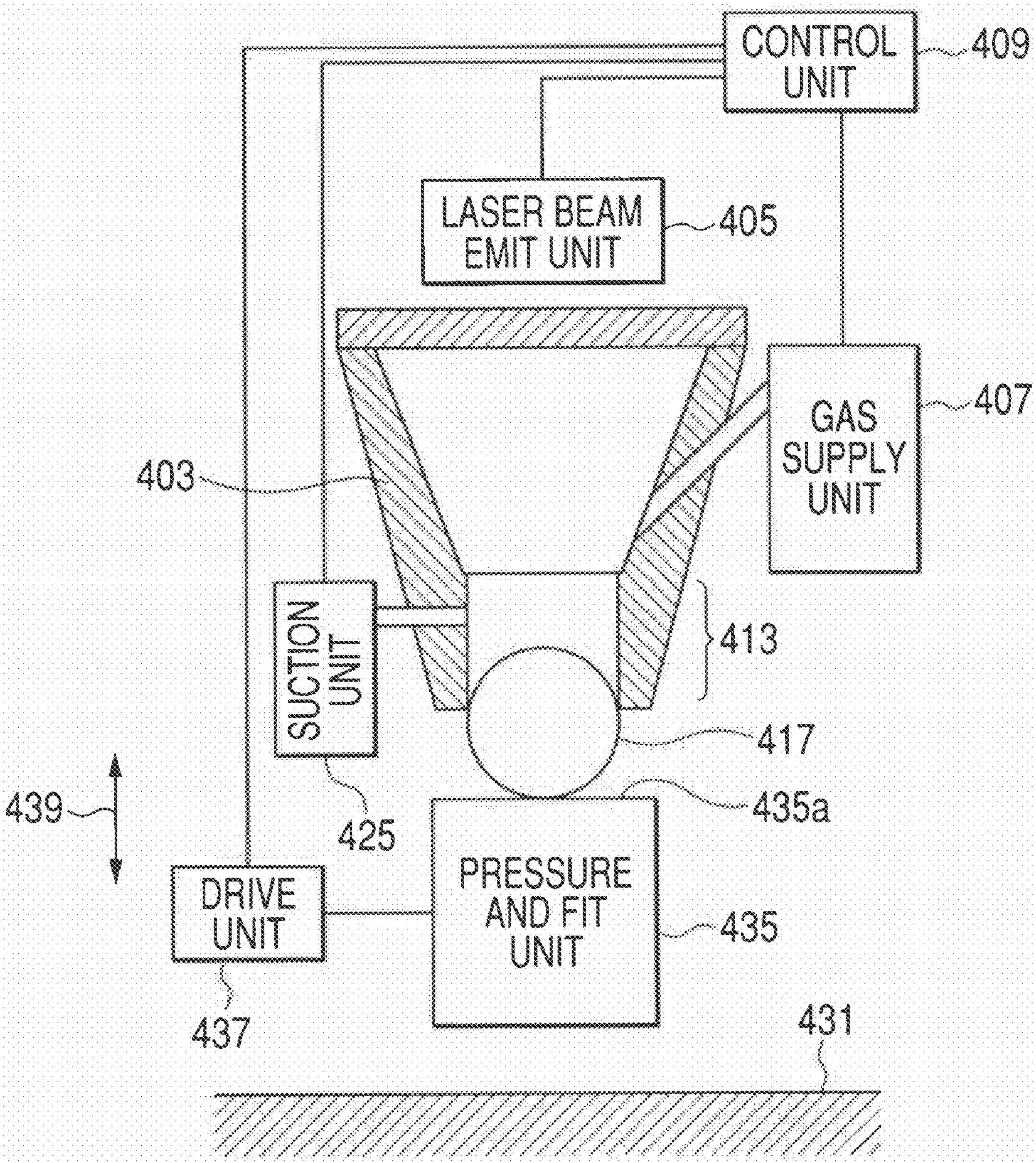

CONTROL UNIT
409
LASER BEAM EMIT UNIT
405
GAS SUPPLY UNIT
407
403
413
SUCTION UNIT
417
435a
425
439
DRIVE UNIT
PRESSURE AND FIT UNIT
435
437
431

FIG. 6A

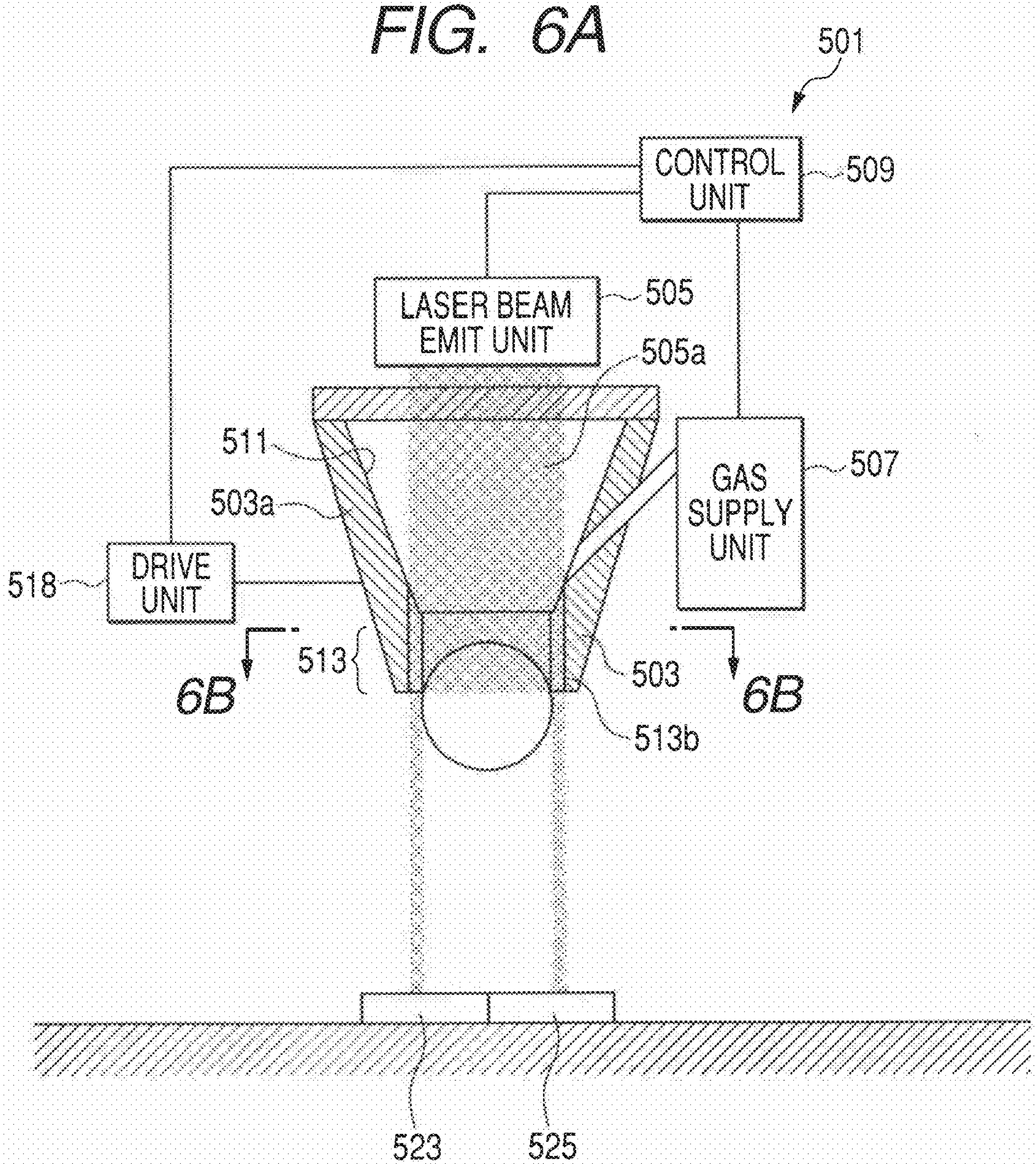

501
CONTROL UNIT
509
LASER BEAM EMIT UNIT
505
505a
511
503a
GAS SUPPLY UNIT
507
518
DRIVE UNIT
513
6B
503
6B
513b
523
525

FIG. 6B

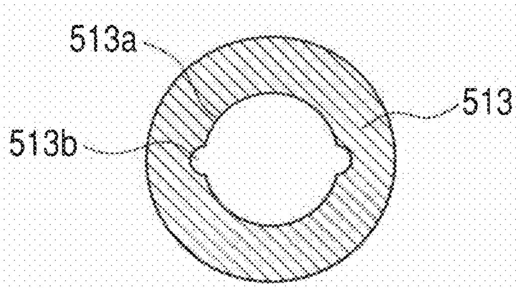

513a
513
513b

FIG. 7

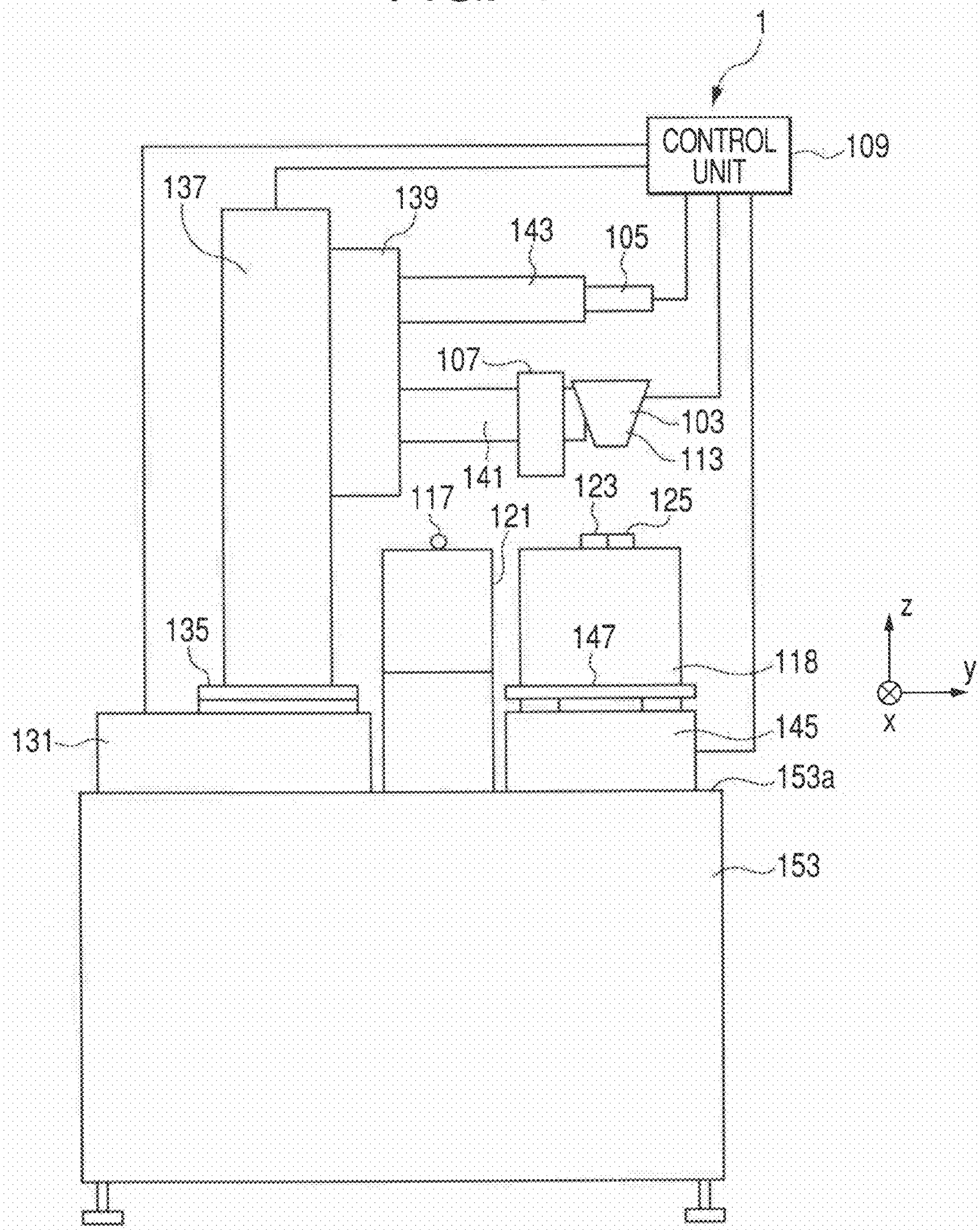
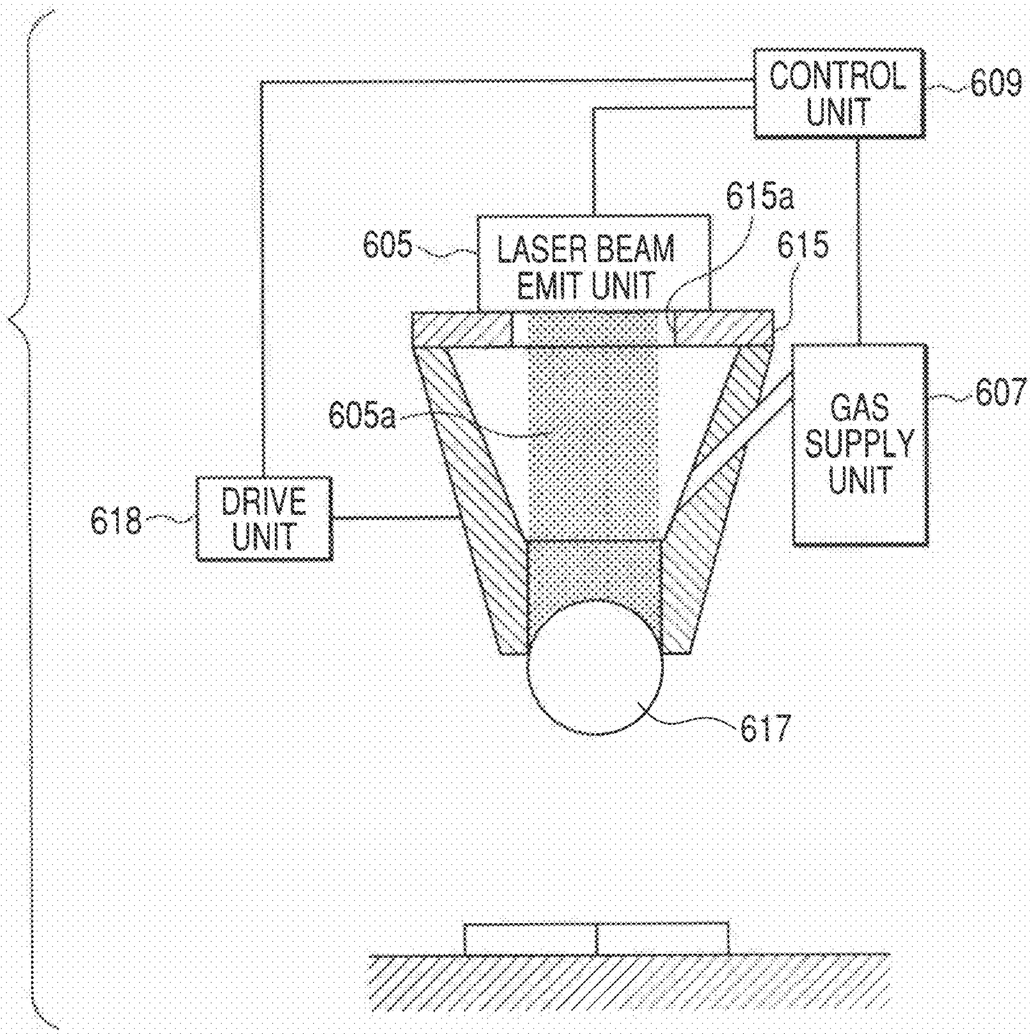

1
CONTROL UNIT
109
137
139
143
105
107
103
113
141
117
121
123
125
135
147
118
145
131
153a
153
z
y
x

FIG. 8



CONTROL UNIT
609
615a
605
LASER BEAM EMIT UNIT
615
607
605a
GAS SUPPLY UNIT
618
DRIVE UNIT
617

FIG. 9

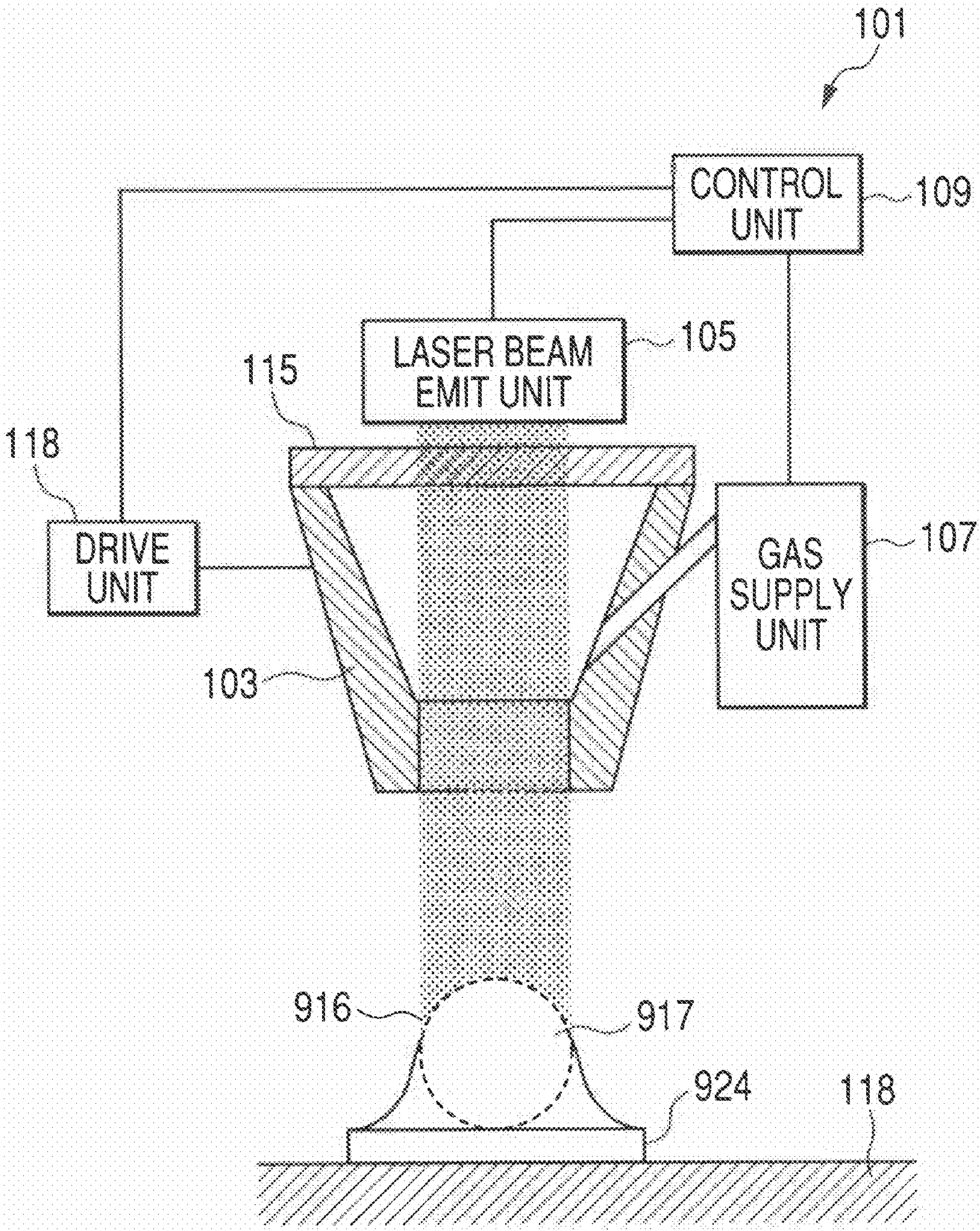

101
CONTROL UNIT
109
LASER BEAM EMIT UNIT
105
115
118
DRIVE UNIT
GAS SUPPLY UNIT
107
103
916
917
924
118

FIG. 10

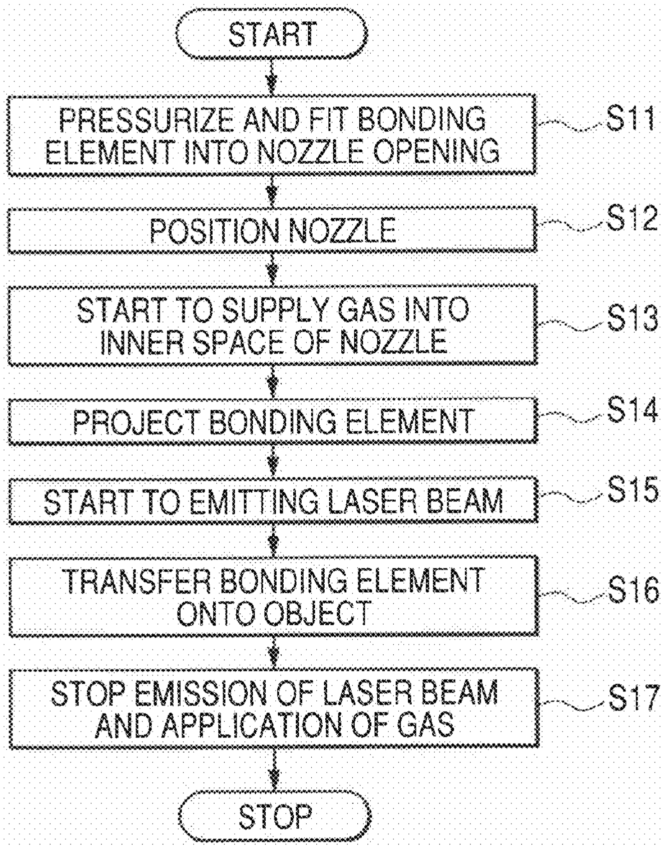

START
PRESSURIZE AND FIT BONDING ELEMENT INTO NOZZLE OPENING
S11
POSITION NOZZLE
S12
START TO SUPPLY GAS INTO INNER SPACE OF NOZZLE
S13
PROJECT BONDING ELEMENT
S14
START TO EMITTING LASER BEAM
S15
TRANSFER BONDING ELEMENT ONTO OBJECT
S16
STOP EMISSION OF LASER BEAM AND APPLICATION OF GAS
S17
STOP

FIG. 11

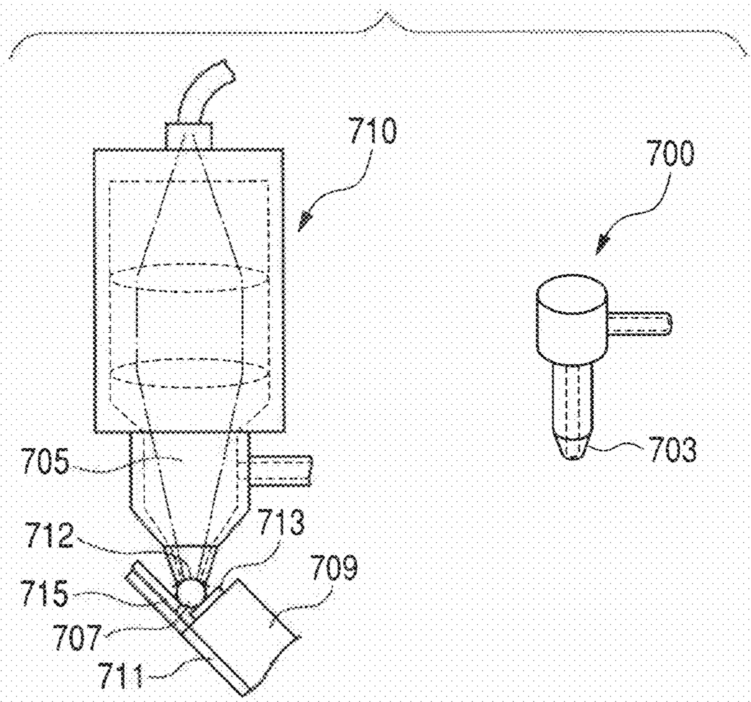
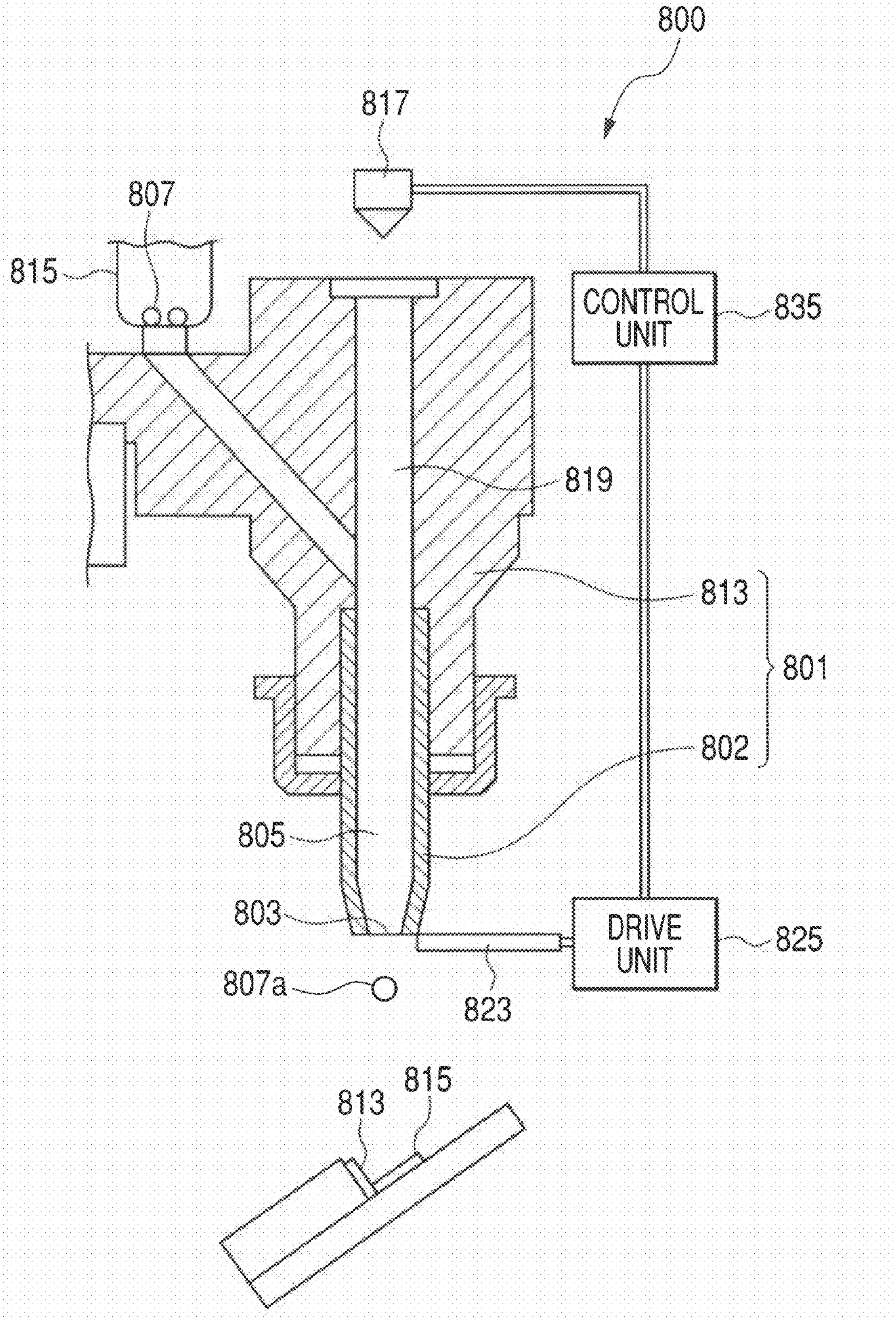

710
700
705
703
712
713
709
715
707
711

FIG. 12



800
817
807
815
CONTROL UNIT
835
819
813
801
802
805
803
DRIVE UNIT
825
807a
823
813
815

BONDING METHOD AND BONDING APPARATUS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a bonding method and a bonding apparatus for electrically bonding a conductive element and an object to be bonded.

[0003] 2. Related Background Art

[0004] In a process for manufacturing magnetic heads, an electrode of a magnetic head slider and an electrode of a flexure are bonded by soldering by using a solder ball. More specifically, electrical bonding of the electrodes is performed by disposing the both electrodes with an angle of 90 degrees therebetween, disposing a solder ball between the electrodes and melting the solder ball by heat radiation or the like. Conventional solder ball soldering apparatuses will be described below with reference to the drawings.

[0005] FIG. **11** illustrates a first conventional soldering apparatus described in Japanese Patent Application Laid-Open No. 2002-25025. In the drawing, reference numeral **709** denotes a substantially rectangular solid slider, and reference numeral **711** denotes a flexure. A slider electrode **713** is provided at one end of the slider **709**. Also, the slider **709** is attached to the thin-plate flexure **711**, and a flexure electrode **715** of the flexure **711** extends so as to be at about 90 degrees with respect to the slider electrode **713**.

[0006] First, a suction nozzle **700** sucks and holds a solder ball **707** in a suction opening **703** by a suction force from an unshown suction source, and carries the solder ball **707** to a position in contact with the slider electrode **713** and the flexure electrode **715**. The suction force of the suction nozzle **700** is released to leave the solder ball **707** in the position in contact with the both electrodes, and the suction nozzle **700** moves away from the position. A laser beam is emitted to the solder ball **707** via an inner space **705** of an optical apparatus **710** to melt the solder ball **707** in the state in which the solder ball **707** is partially inserted in a laser output opening **712** of the optical apparatus **710**. The solder ball **707** is fixed between the slider electrode **713** and the flexure electrode **715** to electrically bond the both electrodes.

[0007] Recently, as magnetic heads are reduced in size, objects to be bonded, such as the slider electrode and the flexure electrode described above, are also becoming increasingly smaller. It is necessary for the above soldering apparatus to stably and reliably move the suction opening **703** of the suction nozzle **700** or the laser output opening **712** of the optical apparatus **710** close to the electrodes **715** and **713** with the solder ball **707** being sucked. However, as the electrodes are becoming smaller, it is becoming difficult to carry and melt the solder ball **707** using the suction nozzle **700** and the optical apparatus **710** without contacting other electronic components. Also, there is a possibility that the residue of the molten solder ball **707** adheres to the laser output opening **712**. Accordingly, another type of soldering apparatus has been proposed. The configuration of a second conventional soldering apparatus will be described below.

[0008] FIG. **12** is a partial cross-sectional view of the second conventional soldering apparatus disclosed in Japanese Patent Application Laid-Open No. 2006-305625. In a soldering apparatus **800**, a solid solder ball **807** is projected and then is melted. The molten solder ball **807** adheres between a slider electrode **813** and a flexure electrode **815** to thereby perform soldering.

[0009] The soldering apparatus **800** comprises a nozzle assembly **801** constituted by a nozzle **802** for projecting the solder ball **807** and a nozzle main body **813** for holding the nozzle **802**, a reservoir **815** for storing the solder ball **807**, a laser apparatus **817** for melting the solder ball **807**, a shutter **823** for opening and closing an opening **803** of the nozzle **802**, a drive unit **825** for opening and closing the shutter **823**, and a control unit **835** for synchronizing the actions of the laser apparatus **817** and the drive unit **825**.

[0010] The curvature radius of the inner diameter in the vicinity of the opening **803** of an inner space **805** disposed inside the nozzle **802** is set to be larger than the curvature radius of the outer diameter of the solder ball **807**. Therefore, the solid solder ball **807** introduced into the inner space **805** of the nozzle **802** is held by the shutter **823** in the inner space **805** in the vicinity of the opening **803**.

[0011] Also, a laser beam from the laser apparatus **817** is introduced into the inner space **805** of the nozzle **802** through a laser introduction path **819** of the nozzle main body **813**. The control unit **835** drives the laser apparatus **817** to melt the solder ball **807***a* such that the solder ball **807***a* is melted after the shutter **823** is opened and the solder ball **807***a* passes through the opening **803**.

[0012] In the soldering apparatus of Japanese Patent Application Laid-Open No. 2002-25025 described above, the solder ball **707** in the suction opening **703** of the suction nozzle **700** is placed between and adjacent to the flexure electrode **715** and the slider electrode **713**. After that, the solder ball **707** is put into the laser output opening **712** of the optical apparatus **710**, and a laser beam is emitted to melt the solder ball **707**. Thus, there is a possibility that the residue of the solder element adheres to the periphery of the laser output opening **712**.

[0013] The soldering apparatus **800** of Japanese Patent Application Laid-Open No. 2006-305625 described above is configured to melt the solder ball **807***a* and bond the slider electrode **813** and the flexure electrode **815** after the shutter **823** opens the opening **803** to project the solder ball **807**. There is no possibility that a portion or all of the molten solder ball **807***a* adheres to an inner wall surface of the inner space **805** and an outer wall surface around the opening **803**.

[0014] With the arrangement interval and the dimensions of electronic components which are presently used, there is no trouble caused by landing accuracy of the bonding element. However, if the bonding element such as the solder ball is further reduced in size along with further miniaturization of electronic components in the future, the influence on the bonding element (for example, a force component in the right direction in the drawing) is expected to become noticeable when the shutter **823** moves to open the opening **803**, so that deviation in the projecting direction is caused.

[0015] Also, in the soldering apparatus of Japanese Patent Application Laid-Open No. 2006-305625, it is necessary to synchronize the action timing of the shutter **823** and the action timing of the laser apparatus **817**, and the configuration tends to be complicated. Thus, it is difficult to further reduce the size of and simplify a bonding apparatus.

SUMMARY OF THE INVENTION

[0016] In light of the above circumstances, an object of the present invention is to provide a bonding method and a bonding apparatus, which has a small and simple configuration, in which the residue of a bonding element does not adhere to a nozzle opening and the vicinity thereof, and which allows to improve landing accuracy.

[0017] In order to achieve the above object, a first aspect of a bonding method of the present invention is a bonding method for projecting a conductive element from a nozzle onto an object to be bonded and electrically bonding the object to be bonded and the conductive element, comprising the steps of: preparing the conductive element having an outer diameter with a curvature radius larger than a curvature radius of a portion of an opening of the nozzle which is in contact with the conductive element; pressurizing and attaching the conductive element to the opening of the nozzle; and supplying a compressed gas into an inner space of the nozzle and projecting the conductive element in a solid phase state onto the object to be bonded.

[0018] According to a second aspect of the bonding method of the present invention, heat radiation is emitted to the conductive element pressurized and attached to the opening when a pressure inside the inner space is at a predetermined value.

[0019] According to a third aspect of the bonding method of the present invention, the conductive element is pressurized and attached to the opening by pressing the nozzle against the conductive element.

[0020] According to a fourth aspect of the bonding method of the present invention, the conductive element is pressurized and attached to the opening by a suction force imparted to the opening via the inner space.

[0021] According to a fifth aspect of the bonding method of the present invention, the conductive element is pressurized and attached to the opening by pushing the conductive element in abutment with the opening by the suction force into the opening by a pressure and fit unit.

[0022] According to a sixth aspect of the bonding method of the present invention, after the conductive element is projected, the heat radiation continues to be emitted to the conductive element.

[0023] Also, in order to achieve the above object, a first aspect of a bonding apparatus of the present invention is a bonding apparatus for disposing a conductive element on an object to be bonded and electrically bonding the object to be bonded and the conductive element, comprising: a nozzle having an opening with a curvature radius smaller than a curvature radius of an outer diameter of the conductive element, and an inner space in communication with an outside via the opening; gas supply means for supplying a compressed gas into the inner space; pressure and fit means for pressurizing and fitting the conductive element into the opening of the nozzle and pressurizing and attaching the conductive element to the opening; and a control unit for controlling the gas supply means such that, with the conductive element being pressurized and attached to the opening, the compressed gas is supplied into the inner space and the conductive element is projected in a solid phase state.

[0024] According to a second aspect of the bonding apparatus of the present invention, the bonding apparatus further comprises heat radiation emit means for emitting heat radiation to the conductive element pressurized and attached to the opening, wherein the control unit controls the heat radiation emit means such that heat radiation is emitted to the conductive element when the inner space has the predetermined pressure.

[0025] According to a third aspect of the bonding apparatus of the present invention, the pressure and fit means pressurizes and fits the conductive element into the opening such that the conductive element is pressurized and attached with a portion of the conductive element having a larger dimension than an inner diameter of the opening being located outside of the nozzle.

[0026] According to a fourth aspect of the bonding apparatus of the present invention, the pressure and fit means has drive means for moving the opening and the conductive element in directions toward and away from each other.

[0027] According to a fifth aspect of the bonding apparatus of the present invention, the pressure and fit means has suction means for imparting a suction force to the opening via the inner space and assisting the pressure-attachment of the conductive element to the opening.

[0028] The term outside of the nozzle in the present specification is defined as an area other than the inner space by regarding the inner space which is defined by a member forming the nozzle as the inside. Accordingly, the opening of the nozzle, an opening area defined by the opening, and an outer space of the nozzle are regarded as outside of the nozzle.

[0029] As the compressed gas used in the gas supply means, an inert gas (nitrogen) or a gas (hydrogen or the like) capable of reducing the conductive element can be used.

[0030] Also, in the present specification, the term conductive element means a member composed of a metal material such as solder and gold, or alloy, which can electrically connect members to each other as the object to be bonded.

[0031] Moreover, in the present specification, the term object to be bonded means a conductor electrode and the like for electrical connection between a substrate (printed circuit board (PCB), flexible printed circuit (FPC)) and an electronic component, and includes a conductive element for directly performing electrical bonding between a substrate and an electronic component by the conductive element, or a member on which a bump for performing the electrical bonding in a subsequent process is formed.

[0032] Since the present invention is configured such that the conductive element is projected in a solid phase state, the residue of the conductive element does not adhere to the nozzle opening and the vicinity thereof.

[0033] Furthermore, the conductive element is pressurized and attached to the opening, and is projected by supplying a compressed air such that the compressed air exceeds a frictional force between the opening and the conductive element. Accordingly, it is not necessary to provide another member for holding the conductive element in the nozzle, and it is not necessary to synchronize another element and the heat radiation emit means. Therefore, it is possible to reduce the size of and simplify the configuration of the bonding apparatus.

[0034] Since the shutter is not required, the influence of the shutter on the conductive element can be eliminated, and there is no possibility that a force in a direction different from the projecting direction is imparted. Accordingly, it is possible to improve the landing position accuracy of the bonding element.

BRIEF DESCRIPTION OF THE DRAWINGS

[0035] FIGS. **1**A, **1**B, **1**C, and **1**D are partial cross-sectional views in respective soldering steps of a soldering apparatus according to an embodiment 1, FIG. **1**E is a cross-sectional view illustrating the relationship between a nozzle and a solder ball in the embodiment 1, and FIGS. **1**F and **1**G are cross-sectional views respectively illustrating the state of a force acting on a pressurized and attached solder ball;

[0036] FIG. **2** is a flowchart of a soldering process;

[0037] FIG. **3** is a cross-sectional view of a nozzle according to a modification;

[0038] FIG. **4** is a partial cross-sectional view of a soldering apparatus according to an embodiment 2;

[0039] FIG. **5** is a partial cross-sectional view of a soldering apparatus according to a modification **2**;

[0040] FIG. **6**A is a partial cross-sectional view of a soldering apparatus according to an embodiment 3, and FIG. **6**B is a cross-sectional view along a line **6**B-**6**B in FIG. **6**A;

[0041] FIG. **7** is a side schematic view of a soldering apparatus **1**;

[0042] FIG. **8** is a partial cross-sectional view of a soldering apparatus in which a laser beam emit unit is fixed to a nozzle;

[0043] FIG. **9** illustrates the state in which a solder ball is projected onto an object to be bonded which is a planar conductor and a solder bump is formed thereon by using a soldering apparatus **101** in FIG. **1**;

[0044] FIG. **10** is a flowchart of a soldering process as another example of the embodiment 1;

[0045] FIG. **11** is a partial cross-sectional view of a first conventional soldering apparatus; and

[0046] FIG. **12** is a partial cross-sectional view of a second conventional soldering apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0047] Embodiments in which a bonding apparatus for bonding objects to be bonded according to the present invention is applied to a soldering apparatus will be described below with reference to the drawings.

Embodiment 1

[0048] FIGS. **1**A, **1**B, **1**C, and **1**D are partial cross-sectional views in respective soldering steps of a soldering apparatus according to an embodiment 1. FIG. **1**E is a cross-sectional view illustrating the relationship between a nozzle and a solder ball in the embodiment 1. FIGS. **1**F and **1**G are cross-sectional views respectively illustrating the state of a force acting on a solder ball pressurized and attached to an opening. FIG. **2** is a flowchart of a soldering process.

[0049] As shown in FIG. **1**A, a soldering apparatus **101** mainly comprises a nozzle **103** for projecting a solder ball **117**, a laser beam emit unit **105**, a gas supply unit **107**, a drive unit **118** (namely, pressure and fit means) for moving the nozzle **103** and pressurizing and fitting the solder ball **117** thereinto, and a control unit **109**. The nozzle **103** comprises an inner space **111** therein, through which a laser beam described below passes and into which a compressed gas is supplied, and is a cylindrical member which opens at both ends thereof in the longitudinal direction. One end of the nozzle **103** in the longitudinal direction is closed by a top plate **115** formed of glass or the like through which only a laser beam can be transmitted, and the other end constitutes an opening **113** to which the solder ball **117** is pressurized and attached. The opening **113** has a predetermined length in the longitudinal direction of the nozzle **103**. Also, the opening **113** connects to the inner space **111**, and has an inner peripheral surface **113***a* with a uniform inner diameter (or a curvature radius). The inner diameter is at least set to be smaller than the outer diameter (or the curvature radius) of the solder ball **117**.

[0050] Furthermore, the nozzle **103** is provided with the drive unit **118** for moving the nozzle **103** toward and away from the solder ball **117**. Accordingly, after the opening **113** of the nozzle **103** is moved closer to the solder ball **117** and the opening **113** is brought into abutment with the solder ball **117**, the opening **113** is further pressed against the solder ball **117** to pressurize and attach the solder ball **117** to a top end portion **113***b* of the opening **113**. The inner space **111** is in a substantially sealed state when the solder ball **117** is being pressurized and attached to the opening **113**.

[0051] Also, a gas introduction path **119** for bringing the outside of the nozzle **103** and the inner space **111** into communication with each other is provided in a peripheral wall **103***a* of the nozzle **103**. The gas introduction path **119** is coupled to the gas supply unit **107** which is a gas source, and a compressed gas from the gas supply unit **107** is supplied into the inner space **111**.

[0052] Furthermore, the laser beam emit unit **105** which is heat emit means is disposed in the vicinity of the top plate **115** of the nozzle **103**. A well known laser beam emit unit is used as the laser beam emit unit **105**. The optical axis of a laser beam emitted from the laser beam emit unit **105** is aligned in a straight line with the central axis of the inner space **111** and the opening **113**. Accordingly, the laser beam is transmitted through the top plate **115**, and enters the inner space **111** of the nozzle **103**. Then, the laser beam passes through the inner space **111** and travels to the outside of the nozzle **103** through the opening **113**. As described above, the inner space **111** also functions as a laser introduction path for guiding the laser beam to the solder ball **117**.

[0053] After lowering the nozzle **103** to bring the nozzle **103** into abutment with the solder ball **117** which is placed on a reservoir **121**, the opening **113** of the nozzle **103** is further pressed against the solder ball **117** with a predetermined force, and the solder ball **117** is thereby pressurized and fitted into the opening **113**.

[0054] A diameter portion **117***a* of the solder ball **117**, which is the maximum dimension portion of a cross section along a horizontal plane extending in the horizontal (lateral) direction in the drawing, is located in a side closer to the reservoir **121** than an abutment portion **117***b* of the solder ball **117** which is in abutment with the top end portion **113***b* in the projecting direction x. That is, the solder ball **117** is pressurized and attached to the nozzle **103** in the state in which the diameter portion **117***a* is located outward from a contact portion of the opening **113** of the nozzle **103** and the solder ball **117**. In other words, the solder ball **117** is located outside of the nozzle **103** (the opening or an outer space), and does not exist inside of the nozzle **103**.

[0055] The term maximum dimension portion means the maximum length of a line segment connecting any two points on the outer periphery which defines the cross section of the solder ball by a plane extending perpendicular to the projecting direction (the vertical direction in the present embodiment).

[0056] Also, the laser beam emit unit **105**, the gas supply unit **107**, and the drive unit **118** are coupled to the control unit **109**, and are actuated by the control unit **109**. When the laser beam emit unit **105** receives a drive signal from the control unit **109**, a laser beam is emitted from the laser beam emit unit **105**. Similarly, when the gas supply unit **107** receives a drive signal from the control unit **109**, a compressed gas is supplied into the inner space **111**. When the solder ball **117** is softened by the laser beam from the laser beam emit unit **105**, the pressure-attachment of the solder ball **117** is released and the solder ball **117** is projected since the inner pressure of the inner space **111** is increased by the compressed gas from the gas supply unit **107**.

[0057] The process steps of a soldering method using the soldering apparatus **101** having the above configuration will be described with reference to FIGS. **1**A, **1**B, **1**C, **1**D and FIG. **2**.

[0058] As shown in FIG. **1**A, the drive unit **118** moves the nozzle **103** to the reservoir **121**, and pressurizes and fits the solder ball **117** into the opening **113** to pressurize and attach the solder ball **117** to the top end portion **113***b* (the step S**1**). In the present embodiment, the solder ball **117** is pressurized and fitted into the opening **113** by lowering the nozzle **103** with respect to the reservoir **121** on which the solder ball **117** is placed.

[0059] The state of the opening **113** of the nozzle **103** at this time is shown in FIG. **1**F. The pressurized and attached solder ball **117** is deformed, and an internal stress is thereby generated. The solder ball **117** is held by the opening **113** by a frictional force μF**1** arising from the internal stress. In the state in which the solder ball **117** is pressurized and fitted as shown in FIG. **1**A, the diameter portion **117***a* of the solder ball **117** is located further from the inner space **111** than the top end portion **113***b* in the projecting direction x.

[0060] Next, as shown in FIG. **1**B, positioning of the nozzle **103** with respect to electrodes or conductive patterns **123** and **125** (for details, see a contact portion **129** in FIG. **1**D) which are the objects to be bonded placed on a work bench **118** is performed (the step S**2**). Of course, the work bench **118** may be moved with the nozzle **103** being fixed.

[0061] Subsequently, a compressed gas is supplied from the gas supply unit **107** into the inner space **111** (the step S**3**). It is determined by the control unit **109** whether the pressure in the inner space **111** reaches a predetermined value (the step S**4**). When the control unit **109** determines that the pressure in the inner space **111** reaches a predetermined value, a laser beam **105***a* is emitted from the laser beam emit unit **105** through the inner space **111** to the solder ball **117** (FIG. **1**C, the step S**5**). Whether the pressure in the inner space **111** reaches a predetermined pressure or not can be determined, for example, by measuring in advance a predetermined time until the pressure reaches a predetermined pressure after the gas supply, and determining whether the predetermined time has elapsed after the gas supply by the control unit.

[0062] When the laser beam **105***a* is emitted to heat a portion of the solder ball **117** which faces the inner space **111**, the elastic coefficient of the solder ball **117** is lowered, resulting in that the internal stress is reduced. At this time, an urging force P of the compressed gas filled inside the inner space **111** exceeds a frictional force (holding force) μF**2** arising from the internal stress of the solder ball, and the pressure-attachment of the solder ball **117** to the top end portion **113***b* of the opening **113** is thereby released. Accordingly, the substantially spherical solder ball **117** is projected in a solid phase state (FIGS. **1**D and **1**G, the step S**6**). Since the solder ball **117** to which the laser beam **105***a* is emitted is heated and the elastic coefficient thereof is lowered, the internal stress is reduced. As a result, the frictional force μF**2** arising from the internal stress becomes relatively smaller than the friction force μF**1** generated in the solder ball **117** which is not heated.

[0063] The projected solder ball **117** lands on the contact portion **129** of the objects to be bonded **123** and **125** on the work bench **118** (FIG. **1**D, the step S**7**). The laser beam emit unit **105** continues to emit the laser beam **105***a* until the solder ball **117** is melted.

[0064] After the solder ball is melted on the landing position (the contact position **129**), the control unit **109** sends a signal to the laser beam emit unit **105** and the gas supply means **107** to stop the operations thereof (the step S**8**).

[0065] As described above, in a bonding apparatus **1** in the present embodiment, after pressurizing and attaching the solid solder ball **117** to the opening **113** of the nozzle **103**, the compressed gas is supplied into the inner space, and when the inner space has a predetermined pressure value, the laser beam **105***a* is emitted from the laser beam emit unit **105**, and the pressure-attachment of the solder ball **117** is released in a solid phase state by the compressed gas. Because of the configuration, the configuration of the soldering apparatus is simplified and the soldering apparatus is more easily controlled.

[0066] The inventors have keenly studied, and as a result, found out that, when an inner diameter D**1** of the opening **113** of the nozzle **103** is 0.095 mm and a diameter D**2** of the solder ball **117** is 0.11 mm, desired landing accuracy can be obtained by setting a D**1**/D**2** ratio to 0.78 to 0.95, and more preferably, to 0.82 to 0.91. When expressed as a contact angle θ**1** of the solder ball **117** and the opening **113**, it is preferable to set the contact angle θ**1** to 18 to 38 degrees, and more preferably, to 25 to 35 degrees. The contact angle is an angle formed between a central line C**1** (a vertical line passing through the center of the solder ball) of the opening **113** and a perpendicular line L**1** with respect to a radius r**1** which connects the center of the solder ball **117** and the abutment portion **117***b* in contact with the opening **113**.

(Modification 1)

[0067] A modification of the embodiment 1 will be described. FIG. **3** is a cross-sectional view of a nozzle according to the modification **1**. An opening **213** of the present modification has a shape widening toward the top unlike the embodiment 1. That is, the opening **213** has such a configuration that the inner diameter increases gradually from an inner space **211** side toward a top end portion **213***b*.

[0068] In the state in which a solder ball **217** is pressurized and attached to the opening **213**, the solder ball **217** is pressurized and attached such that a diameter portion **217***a* which is the maximum dimension portion of the solder ball **217** is located closer to the top end portion **213***b* side than an abutment portion **217***b* of the solder ball **217**. With the configuration as described above, even if there are variations in the dimensions of the solder balls to be used, it is possible to locate the maximum dimension portion **217***a* closer to the top end portion **213***b* side of the nozzle than the abutment portion **217***b*. Other configurations and operations are the same as those of the embodiment 1, and therefore, the descriptions thereof are omitted.

[0069] The inventors have keenly studied and as a result, found out that, when a diameter D**2** of the solder ball **217** is 0.11 mm, desired projecting accuracy can be obtained by setting an inclination angle of an inner peripheral surface **213***a* (a line L**2**) of the opening **213** against the vertical direction (a line C**2**), namely, a contact angle θ**2** of the solder ball **217** and the opening **213**, to 3 to 35 degrees, and more preferably, to 5 to 30 degrees.

Embodiment 2

[0070] An embodiment 2 is a soldering apparatus using suction means as pressure and attach means for pressurizing and attaching the solder ball to the opening, and will be described below with reference to FIG. **4**. FIG. **4** is a partial cross-sectional view of the soldering apparatus according to the embodiment 2.

[0071] A soldering apparatus **301** mainly comprises a nozzle **303**, a laser beam emit unit **305**, a gas supply unit **307**, a control unit **309**, and a suction unit **325** which constitutes the suction means. The laser beam emit unit **305**, the gas supply unit **307** and a gas introduction path **319** have the same configurations and operations as those in the embodiment 1, and therefore, the descriptions thereof are omitted. Also, for simplicity of the drawing, a drive unit having the same configuration and operation as that in the embodiment 1 for moving the nozzle **303** is omitted from the drawing.

[0072] The suction means comprises the suction unit **325** which is a well known vacuum pump or the like, a suction hole **327** disposed in a peripheral wall **303***a* of the nozzle **303** and bringing an inner space **311** and the outside into communication with each other, and a tube **329** for coupling the suction unit **325** and the suction hole **327**. The suction hole **327** extends by penetrating the side wall **303***a* in the vicinity of an opening **313** of the nozzle **303** in the horizontal direction. Thus, a suction force from the suction unit **325** is imparted to the outside of the nozzle **303** via the tube **329**, the suction hole **327** and the opening **313**.

[0073] The position of the suction hole **327** can be changed as needed, and the suction hole **327** may be configured to bring the inner space **311** and the outside into communication with each other. Also, such a configuration that only one of the suction hole **327** or the gas introduction path **319**, as a through hole for bringing the outside of the nozzle and the inner space **311** into communication with each other, is provided in the nozzle to use the single through hole as both the suction hole and the gas introduction path and the gas supply unit **307** and the suction unit **325** are connected to the single through hole, may be employed. In other words, as long as the suction force can be imparted to the outside of the nozzle **303** via the opening **313**, any change may be made.

[0074] In the above configuration, by imparting the suction force of the suction unit **325** to a solder ball **317** through the inner space **311** and the opening **313**, the solder ball **317** is sucked and is pressurized and attached to a top end portion **313***b* of the opening **313** by the suction force.

[0075] Also, the suction unit **325** is connected to the control unit **309** and is actuated upon reception of a signal from the control unit **309** like the laser beam emit unit **305** and the gas supply unit **307**. The soldering process by the soldering apparatus in the present embodiment differs from the process of the embodiment 1 in the pressurizing and attaching step shown in FIG. **2** (corresponding to the step S**1** in FIG. **2**). That is, in the step of pressurizing and attaching the solder ball **317** (corresponding to the step S**1** in FIG. **2**), in order to bring the opening **313** of the nozzle **303** and the solder ball **317** into abutment with each other, the nozzle **303** is not lowered, but the suction unit **325** is actuated to pressurize and attach the solder ball **317** to the opening **313** by the suction force. The suction unit **325** is then stopped to terminate the pressurizing and attaching step. The subsequent steps are the same as those shown in FIG. **2** of the embodiment 1.

[0076] Also, the embodiment 1 and the embodiment 2 may be combined. That is, at the same time as, or before or after moving the opening **313** of the nozzle **303** closer to and into abutment with the solder ball **317**, the suction unit **325** is actuated to pressurize and attach the solder ball **317** to the opening **313**.

[0077] In the case of the configuration, by setting the suction timing to be earlier than the timing when the opening **313** and the solder ball **317** abut each other, even if the relative position of the solder ball **317** with respect to the opening **313** is deviated, the solder ball **317** is sucked to the opening **313** and can be reliably brought into abutment with the top end portion **313***b*. Also, with the solder ball **317** being sucked to the nozzle **303**, the solder ball **317** can be pressurized and attached by pressing the nozzle against the solder ball **317** on a work bench **321**.

(Modification 2)

[0078] FIG. **5** is a cross-sectional view of a nozzle according to a modification **2**. In the embodiment 2, the solder ball **317** is pressurized and attached to the opening **313** of the nozzle **303** by the suction force. In the modification **2**, a bonding apparatus may be provided with pressure and fit means, namely, a pressure and fit unit **435** for pushing a solder ball **417** into an opening **413** after the solder ball **417** is sucked and is brought into abutment with the opening **413**. The pressure and fit unit **435** is a member having any shape, and has a flat pressure and fit surface **435***a* which faces the opening **413**. Also, the pressure and fit unit **435** is moved toward and away from (moved in the (vertical) direction of an arrow **439**) the opening **413** by a drive unit **437**. A laser beam emit unit **405**, a gas supply unit **407**, a control unit **409**, a suction unit **425** and the drive unit **437** have the same configurations and operations as the corresponding units described in the embodiment 2, and therefore, the descriptions thereof are omitted here.

[0079] For example, after the solder ball **417** is sucked by the suction unit **425**, the solder ball **417** is pressed in the direction toward the opening **413** (the arrow **439**) by the pressure and fit surface **435***a* of the pressure and fit unit **435**, and the solder ball **417** is thereby pressurized and fitted into the opening **413**. After the solder ball **417** is pressurized and attached, the pressure and fit unit **435** is moved away from the opening **413** to terminate the pressure-fitting.

[0080] According to the modification, even if the solder ball **417** is not sufficiently pressurized and fitted only by the suction force, the solder ball **417** can be reliably pushed into the opening **413** by the pressure and fit unit **435**. The steps after the pressure-fitting are the same as those in the embodiment 1. For simplicity of the drawing, a drive unit having the same configuration and operation as that in the embodiment 1 for moving a nozzle **403** is omitted from the drawing.

Embodiment 3

[0081] FIG. **6**A is a partial cross-sectional view of a soldering apparatus **501** according to an embodiment 3, and FIG. **6**B is a cross-sectional view along a line **6**B-**6**B in FIG. **6**A. The soldering apparatus **501** of the embodiment 3 differs from the embodiment 1 described above in the opening shape of an opening **513** of a nozzle **503**. Other configurations such as a gas supply unit **507**, a control unit **509** a drive unit **518** or the like have the same operations as the corresponding configurations therein. Thus, the descriptions of the same configurations and functions are omitted.

[0082] As shown in FIG. **6**B, the opening **513** is constituted by a circular portion **513***a* having a predetermined curvature radius and a slit portion **513***b* traversing the circular portion **513***a*. The curvature radius of the circular portion **513***a* is set to be smaller than the curvature radius of a solder ball **517**. Also, the slit portion **513***b* has a substantially semicircular shape with a predetermined curvature radius. In the present embodiment, when the solder ball **517** is pressurized and fitted into the opening **513**, a portion of the outer peripheral surface of the solder ball **517** is pressurized and attached to the circular portion **513***a*, and a gap is formed between the slit portion **513***b* and the outer peripheral surface of the solder ball **517**. In other words, in the state in which the solder ball **517** is pressurized and attached, the circular portion **513***a* is covered by the solder ball **517** and the slit portion **513***b* is not covered by the solder ball **517**.

[0083] The process of performing bonding by the solder ball by using the nozzle **503** having the above configuration is the same as the process of FIG. **2** described in the embodiment 1 except for the gas supply step of supplying a compressed gas (corresponding to the step S3 in FIG. **2**) and the step of emitting a laser beam (corresponding to the step S5 in FIG. **2**). In the embodiments described above, since the solder ball is pressurized and attached to the opening, an inner space **511** is in a sealed state. However, in the present embodiment, the slit portion **513***b* is provided. Therefore, when a compressed gas is supplied in the gas supply step (corresponding to the step S3 in FIG. **2**), the compressed gas passes through the slit portion **513***b* and is imparted to objects to be bonded **523** and **525**. Accordingly, it is possible to prevent the objects to be bonded **523** and **525** from being oxidized before the solder ball **517** adheres to the objects to be bonded **523** and **525**. A soldering failure caused by the oxidization of the objects to be bonded **523** and **525** can be thereby prevented.

[0084] Also, in the step of emitting a laser beam (corresponding to the step S5 in FIG. **2**), a portion of a laser beam **505***a* reaches the objects to be bonded **523** and **525** through the slit portion **513***b*. Accordingly, the objects to be bonded **523** and **525** are heated in advance before being soldered, and the wettability of the solder ball with respect to the objects to be bonded **523** and **525** can be improved. As a result, a good finish is obtained by the soldering operation.

(Soldering Apparatus)

[0085] One example of the entire configuration of the soldering apparatus to which the bonding apparatus of the present invention is applied will be described. FIG. **7** is a side schematic view of a soldering apparatus **1**. In the drawing, the x direction denotes the front-back direction of the drawing, the y direction denotes the lateral direction thereof, and the z direction denotes the vertical direction thereof.

[0086] The soldering apparatus **1** is an example in which the soldering apparatus of the embodiment 1 is incorporated. The soldering apparatus **1** mainly comprises a base **153**, the nozzle **103** and the laser beam emit unit **105** which are mounted above a top face **153***a* of the base **153** in a movable manner in the y and z directions, the work bench **118** on which the objects to be bonded **123** and **125** are placed, the reservoir **121** on which the solder ball is placed, and the control unit **109** for actuating each component.

[0087] The soldering apparatus **1** further comprises a y-direction drive unit **131** for moving the nozzle **103** in the y and z directions, a y-direction slider **135** mounted on the y-direction drive unit **131** and moved in the y direction, a z-direction drive unit **137** fixed to the y-direction slider **135**, and a z-direction slider **139** attached to the z-direction drive unit **137** and moved in the z direction.

[0088] A nozzle arm **141** and an emit unit arm **143** extending in the y direction are fixedly attached to the z-direction slider **139** in positions apart from each other in the z direction. The nozzle **103** and the laser beam emit unit **105** are respectively attached to the nozzle arm **141** and the emit unit arm **143**.

[0089] Also, the work bench **118** is mounted on an x-direction slider **147** movable in the x direction by an x-direction drive unit **145**. Accordingly, when the x-direction slider is moved by the x-direction drive unit **145**, the work bench **118** can be moved in the x direction.

[0090] A well known configuration is used for the y-direction drive unit **131**, the z-direction drive unit **137** and the x-direction drive unit **145**. For example, the y-direction drive unit **131** can be constituted by a motor, a y ball screw, and a y nut, which are not shown. The y nut having a female screw is fixed to the y-direction slider **135**. The y ball screw having a male screw provided on the periphery has the both ends supported by ball bearings in a rotatable manner in a housing of the y-direction drive unit. One of the ends of the y ball screw is coupled to the motor. When the motor is driven to rotate the y ball screw, the y-direction nut screwed with the y ball screw reciprocates along the y ball screw. By the reciprocation of the y-direction nut, the y-direction slider **135** is moved in the y direction. The other drive units can be similarly configured.

[0091] The reservoir **121** for storing the solder ball **117** is fixed to the top face **153***a* of the base **153** between the work bench **118** and the y-direction drive unit **131**. The solder ball is carried to the reservoir **121** by unshown carrying means.

[0092] The control unit **109** is electrically connected to the y-direction drive unit **131**, the z-direction drive unit **137**, the x-direction drive unit **145**, the laser beam emit unit **105** and the gas supply unit **107**, and the respective units are actuated by a command from the control unit **109**. Although not shown in the drawing, it is needless to say that a positioning camera, such as a CCD camera or the like, for performing positioning of the nozzle **103**, the objects to be bonded **123** and **125**, and the solder ball **117** in the reservoir **121** can be used to perform positioning control based on an image from the positioning camera.

[0093] In the soldering apparatus having the above configuration, the solder ball **117** is pressurized and fitted into the opening **113** of the nozzle **103** by operating the above x-direction drive unit, the y-direction drive unit and the z-direction drive unit in the x, y and z directions to bring the nozzle **103** into abutment with the solder ball **117**. Accordingly, these drive units constitute the pressure and fit means.

[0094] The soldering operation using the above soldering apparatus **1** will be described. The y-direction drive unit **131** and the z-direction drive unit **137** receive a drive signal from the control unit **109**, and move the nozzle **103** toward the reservoir **121**. After the solder ball **117** is brought into abutment with the opening **113**, the nozzle **103** is further lowered to pressurize and fit the solder ball **117** into the opening **113**. After pressurizing and attaching the solder ball **117** to the opening **113**, the nozzle **103** is moved to a boding position of the objects to be bonded **123** and **125** placed on the work bench **118**. Positioning of the bonding position and the nozzle

103 is performed by operating the x-direction drive unit **145**, the y-direction drive unit **131** and the z-direction drive unit **137**.

[0095] The compressed gas is supplied into the inner space **111** (see FIG. **1**B) of the nozzle **103** from the gas supply unit **107**. When the inner space has a predetermined pressure, the laser beam emit unit **105** receives a drive signal from the control unit **109** and emits the laser beam to the solder ball **117** pressurized and attached to the opening **113**. When the solder ball **117** is heated, the pressure-attachment to the opening **113** is released by the compressed gas from the gas supply unit **107**, and the solder ball **117** lands on the bonding position. After the solder ball **117** lands on, the control unit **109** stops the gas supply unit **107**. Also, since the projecting direction of the solder ball **117** and the traveling direction of the laser beam correspond to each other, the laser beam emit unit **105** continues to emit the laser beam until the entire solder ball **117** is melted. After the solder ball **117** is melted, the control unit **109** stops the laser beam emit unit **105**. The molten solder is solidified and soldering of the objects to be bonded **123** and **125** is completed.

[0096] Although the laser beam continues to be emitted until after the solder ball is projected, moves away from the opening and lands on the bonding position in the above embodiments, it is needless to say that the entire solder ball may be melted before the solder ball reaches the bonding position.

[0097] Since the present invention is configured to project the solder ball in a solid phase state, the molten solder element does not adhere to the opening and the vicinity thereof by projecting the molten solder ball as in Japanese Patent Application Laid-Open No. 2002-25025. In the case of the configuration in which the molten solder element is projected, it is necessary to project the solder ball by setting the pressure in the inner space in consideration of the viscosity or the like of the solder element. However, according to the present invention, the pressure in the inner space can be set such that the solder ball is projected at a speed suitable for bonding, and the landing position accuracy of the solder element can be thereby improved.

[0098] Furthermore, a pressure value of the compressed gas suitable for causing the solder element to adhere to the objects to be bonded can be set. Accordingly, there is no adhesion failure of the solder element. Also, since the shutter for opening and closing the opening is not required, the influence of the shutter on the solder ball can be eliminated and the configuration of the soldering apparatus can be simplified.

EXAMPLE

[0099] An example in which the soldering operation was performed by using the soldering apparatus of the embodiment 2 (see FIG. **4**) will be described. An inner diameter D**1** of the opening **313** of the nozzle **303** was 0.095 mm and a diameter D**2** of the solder ball was 0.11 mm. The solder ball **317** was pressurized and attached to the opening **313** by the suction unit **325** with a suction pressure of −30.0 kPa, and the suction unit **325** was then stopped. The compressed gas was supplied from the gas supply unit **307** until the pressure in the inner space **311** reached 1.0 kPa. When the pressure in the inner space **311** reached 1.0 kPa, the laser beam emit unit **305** started to emit the laser beam to the solder ball **317**.

[0100] As a comparative example, the soldering apparatus described in Japanese Patent Application Laid-Open No. 2006-305625 having the configuration in which the solder ball is held by the shutter was used. The inner diameter of the nozzle was 0.125±0.003 mm and the diameter D**2** of the solder ball was 0.11 mm.

[0101] In the soldering apparatus in the present example and the comparative example, a nitrogen gas was used as the compressed gas. Also, a distance between the top end portion **313***b* of the nozzle and the landing position was 0.5 mm. A used laser was a YAG laser with a wavelength of 1064 nm and the spot diameter of the laser beam was ϕ200 μm at the landing position.

[0102] In the case of using the bonding apparatus according to the embodiment 2, the landing accuracy could be improved 25% to 30% in comparison with the bonding apparatus in the comparative example.

[0103] In the embodiments 1 to 3, the modifications and the example described above, heat is imparted to the solder ball, namely, the conductive element pressurized and attached to the opening to release the pressure-attachment. However, the present invention may be configured not only to reduce the frictional force by imparting the heat to the conductive element, but to release the pressure-attachment of the conductive element by using only the urging force by the compressed gas.

[0104] A method for projecting the solder ball by imparting an urging force P by the compressed gas, which is greater than the frictional force (μF**1** shown in FIG. **1**F), in order to release the pressure-attachment by using the soldering apparatus having the configuration shown in FIG. **1** can be cited as another example of the embodiment 1. FIG. **10** is a flowchart illustrating the soldering method for projecting the solder ball only by the compressed gas. As shown in the flowchart, the solder ball **117** is pressurized and attached to the opening **113** (the step S**11**, corresponding to FIG. **1**A), and the nozzle **103** is positioned (the step S**12**). The gas supply unit **107** supplies the compressed gas into the inner space **111** (the step S**13**). When the urging force P against the solder ball **117** by the compressed gas is greater than the frictional force μF**1** (corresponding to FIG. **1**F), the solder ball **117** is projected in a solid phase state (the step S**14**). At this time, the laser beam is not emitted to the solder ball **117** unlike the embodiment 1. After that, the laser beam is emitted to the flying solder ball **117** (the step S**15**) to melt and cause the solder ball to land on a predetermined position. Subsequently, the emission of the laser beam and the supply of the compressed gas are stopped (the step S**17**), and the soldering process is terminated. As described above, the method of projecting the pressurized and attached solder ball without emitting the laser beam thereto may be also employed.

[0105] Furthermore, although the laser beam emit unit is formed separately from the nozzle, the nozzle and the laser beam emit unit may be integrally formed. FIG. **8** is a partial cross-sectional view of a soldering apparatus in which a laser beam emit unit **605** is fixed to a nozzle **603**. The laser beam emit unit **605** is fixed to a top plate **615** of the nozzle **603**. A laser beam **605***a* from the laser beam emit unit **605** enters an inner space **611** via a laser transmission unit **615***a* formed of glass or the like which is provided in the nozzle top plate **615**, and reaches a solder ball **617**. It is needless to say that, after the laser beam **605***a* from the laser beam emit unit reaches the solder ball **617** through the inner space **611** as described above and the solder ball **617** is projected, any change may be made as long as the projecting direction and the traveling direction of the laser beam can be aligned. The laser beam emit unit **605**, a gas supply unit **607**, a control unit **609**, and a drive unit **618** have the same operations as the corresponding units described in the above embodiments, and therefore, the descriptions thereof are omitted here.

[0106] Although the laser beam emit unit is formed separately from the nozzle in the embodiments 1 to 3, the modifications and the example, the nozzle and the laser beam emit unit may be integrally formed. FIG. **8** is a partial cross-sectional view of a soldering apparatus in which a laser beam emit unit **605** is fixed to a nozzle **603**. The laser beam emit unit **605** is fixed to a top plate **615** of the nozzle **603**. A laser beam **605***a* from the laser beam emit unit **605** enters an inner space **611** via a laser transmission unit **615***a* formed of glass or the like which is provided in the nozzle top plate **615**, and reaches a solder ball **617**. It is needless to say that, after the laser beam **605***a* from the laser beam emit unit reaches the solder ball **617** through the inner space **611** as described above and the solder ball **617** is projected, any change may be made as long as the projecting direction and the traveling direction of the laser beam can be aligned.

[0107] Although the laser apparatus is used in the embodiments 1 to 3 and the modifications, the solder ball, namely, the solder element may be heated and melted by using halogen light or hot air. Also, the spherical solder ball is used as the solder element. However, it is needless to say that a solder element having a cube shape, a rectangular solid shape or the like may be used as needed.

[0108] In the embodiments 1 to 3, the modifications and the example, the solder ball is projected onto the objects to be bonded constituted by at least two members which are arranged in a planar shape, and the two members are bonded. However, the objects to be bonded of the present invention are not limited to the objects to be bonded arranged in a planar shape. For example, the objects to be bonded may be constituted by two members forming an angle of about 90 degrees with each other as an electrode of a substrate and a side electrode of an electronic component placed on the substrate shown in FIG. **10** or FIG. **11** referred to as the related background art.

[0109] Also, a single member may be used as the object to be bonded. FIG. **9** illustrates the state in which the solder ball is projected onto the object to be bonded constituted by the single member and a solder bump is formed. In FIG. **9**, the soldering apparatus **101** in FIG. **1** is used to cause a solder ball **917** to land on a flat-plate conductor **924** and form a solder bump **916**.

[0110] In the embodiments 1 to 3, the modifications and the example, the conductive element pressurized and attached to the opening of the nozzle is located outside of the nozzle. However, it is needless to say that one portion of the conductive element may extend to the inside of the nozzle. For example, if the length of the opening in the longitudinal direction is relatively shorter than the outer diameter of the solder ball, one portion of the solder ball extends to the inside of the inner space.

[0111] Also, the optical axis of the laser beam, the central axis of the inner space, and the central axis of the opening correspond to each other in the same direction. However, as long as a laser beam can be scanned along the track of the solder ball projected from the opening, any laser apparatus may be used. It goes without saying that it is not necessary to align the optical axis of the laser beam and the projection route after the solder ball is projected.

[0112] From the perspective of prevention of oxidization of the solder ball, an inert gas (compressed gas) such as nitrogen or the like can be applied as the compressed gas in the above embodiments.

[0113] In the present invention, heat radiation is applied to the conductive element to release the pressure-attachment to the nozzle and start melting the conductive element. Therefore, the residue of the conductive element does not adhere to the nozzle opening and the vicinity thereof.

[0114] The present invention can be embodied in various forms without departing from the spirit thereof. Accordingly, it is needless to say that the above embodiments are only for describing the present invention, but not for limiting the scope of the present invention.

[0115] This application claims priority from Japanese Patent Application Nos. 2007-167258 filed on Jun. 26, 2007, and 2008-4358 filed on Jan. 11, 2008, which are hereby incorporated by reference herein in their entirety.

What is claimed is:

1. A bonding method for projecting a conductive element from a nozzle onto an object to be bonded and electrically bonding the object to be bonded and the conductive element, comprising the steps of:

preparing the conductive element having an outer diameter with a curvature radius larger than a curvature radius of a portion of an opening of the nozzle which is in contact with the conductive element;

pressurizing and attaching the conductive element to the opening of the nozzle; and

supplying a compressed gas into an inner space of the nozzle and projecting the conductive element in a solid phase state onto the object to be bonded.

2. A bonding method according to claim **1**, further comprising the step of emitting heat radiation to the conductive element pressurized and attached to the opening when a pressure inside the inner space is at a predetermined value.

3. The bonding method according to claim **1**, wherein the conductive element is pressurized and attached to the opening by pressing the nozzle against the conductive element.

4. The bonding method according to claim **1**, wherein the conductive element is pressurized and attached to the opening by a suction force imparted to the opening via the inner space.

5. The bonding method according to claim **4**, wherein the conductive element is pressurized and attached to the opening by pushing the conductive element in abutment with the opening by the suction force into the opening by a pressure and fit unit.

6. The bonding method according to claim **2**, wherein, after the conductive element is projected, the heat radiation continues to be emitted to the conductive element.

7. A bonding apparatus for disposing a conductive element on an object to be bonded and electrically bonding the object to be bonded and the conductive element, comprising:

a nozzle having an opening with a curvature radius smaller than a curvature radius of an outer diameter of the conductive element, and an inner space in communication with an outside via the opening;

gas supply means for supplying a compressed gas into the inner space;

pressure and fit means for pressurizing and fitting the conductive element into the opening of the nozzle and pressurizing and attaching the conductive element to the opening; and a control unit for controlling the gas supply means such that, with the conductive element being pressurized and attached to the opening, the compressed gas is supplied into the inner space and the conductive element is projected in a solid phase state.

8. The bonding apparatus according to claim **7**, further comprising heat radiation emit means for emitting heat radiation to the conductive element pressurized and attached to the opening, wherein the control unit controls the heat radiation emit means such that the heat radiation is emitted to the conductive element when the inner space has the predetermined pressure.

9. The bonding apparatus according to claim **7**, wherein the pressure and fit means pressurizes and fits the conductive element into the opening such that the conductive element is pressurized and attached with a portion of the conductive element having a larger dimension than an inner diameter of the opening being located outside of the nozzle.

10. The bonding apparatus according to claim **7**, wherein the pressure and fit means has drive means for moving the opening and the conductive element in directions toward and away from each other.

11. The bonding apparatus according to claim **7**, wherein the pressure and fit means has suction means for imparting a suction force to the opening via the inner space and assisting the pressure-attachment of the conductive element to the opening.

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