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DEVICE FOR REMOVING VOID IN UNDERFILL MATERIAL

Abstract

A device for removing a void in an underfill material is described. The device includes a chamber configured to accept a substrate applied with an underfill material therein; a gas supply device connected to the chamber and configured to inject a heated gas into the chamber to create a heating atmosphere and a pressurizing atmosphere inside the chamber; and a vacuum device connected to the chamber and configured to exhaust a gas to the outside of the chamber to create a vacuum atmosphere inside the chamber. The vacuum device and the gas supply device are configured to alternately operate once during each cycle of one or more cycles to create the vacuum atmosphere and the pressurizing atmosphere inside the chamber, and during each cycle of the one or more cycles, the vacuum device and the gas supply device are configured to alternately operate once. Related methods are also described.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2024-0020612 filed at the Korean Intellectual Property Office on Feb. 13, 2024, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

(a) Field of the Invention

[0002] The present disclosure relates to a device for removing a void in an underfill material and related methods.

(b) Description of the Related Art

[0003] A capillary underfill (CUF) process is a process that fills a space between a substrate and an electronic component with an underfill solution using a capillary force. The CUF process is mainly carried out in an atmospheric pressure atmosphere, and the underfill solution moves forward by filling the space between the substrate and the electronic component with the capillary force. In this case, a speed difference for each position of the underfill solution may occur due to presence of a plurality of solder balls disposed between the substrate and the electronic component, and a void that is a pore surrounded by an underfill material may occur. The void may also be affected by a spraying position and a spraying amount of the underfill solution, a surface state of the substrate, positions of the solder balls, and the like.

[0004] As the electronic component becomes highly integrated, a size of the solder ball decreases and the number of the solder balls increases. This is a factor that increases a possibility of occurrence of voids. Because voids having the underfill material may affect reliability of a product, it may be advantageous to reduce or minimize voids.

SUMMARY OF THE INVENTION

[0005] An aspect of the present disclosure is to provide a device for removing a void in an underfill material.

[0006] A device for removing a void in an underfill material according to embodiments of the present disclosure includes a chamber configured to accept a substrate applied with an underfill material therein; a gas supply device connected to the chamber and configured to inject a heated gas into the chamber to create a heating atmosphere and a pressurizing atmosphere inside the chamber; and a vacuum device connected to the chamber and configured to exhaust a gas from the inside of the chamber to outside of the chamber to create a vacuum atmosphere inside the chamber. The vacuum device and the gas supply device are configured to alternately operate for one or more cycles to create the vacuum atmosphere and the pressurizing atmosphere inside the chamber, and during each cycle of the one or more cycles, the vacuum device and the gas supply device are configured to alternately operate once.

[0007] A device for removing a void in an underfill material according to embodiments of the present disclosure includes a chamber configured to accept a substrate applied with an underfill material therein; a gas supply device connected to the chamber and configured to inject a first gas into the chamber to create a pressurizing atmosphere inside the chamber; a vacuum device connected to the chamber and configured to exhaust a second gas from inside of the chamber to outside of the chamber to create a vacuum atmosphere inside the chamber; and a heating device disposed inside the chamber and configured to heat the substrate by irradiating light to the substrate. The vacuum device and the gas supply device are configured to alternately operate once during each cycle of one or more cycles to create the vacuum atmosphere and the pressurizing atmosphere inside the chamber.

[0008] A device for removing a void in an underfill material according to embodiments of the present disclosure includes a chamber configured to accept a substrate applied with an underfill material therein; a gas supply device configured to inject a first gas into the chamber to create a pressurizing atmosphere inside the chamber; and a vacuum device configured to exhaust a second gas from the inside of the chamber to outside of the chamber to create a vacuum atmosphere inside the chamber. The vacuum device and the gas supply device are configured to alternately operate once during each cycle of one or more cycles to create the vacuum atmosphere and the pressurizing atmosphere inside the chamber, and an internal pressure of the chamber in the vacuum atmosphere is 10 torr or less.

[0009] According to the aspect of the present disclosure, a device for removing a void in an underfill material capable of removing the void of the underfill material may be provided.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** and FIG. **2** are schematic views showing an exemplary underfill process.

[0011] FIG. **3** are images showing a size of an exemplary void in an underfill material according to a surrounding pressure.

[0012] FIG. **4** is a schematic diagram showing a device for removing a void in an underfill material according to an embodiment of the present invention.

[0013] FIG. **5** is a schematic diagram showing a device for removing a void in an underfill material according to an embodiment of the present invention.

[0014] FIG. **6** is a flowchart showing a method for removing a void in an underfill material according to an embodiment of the present invention.

[0015] FIGS. **7** to **15** are schematic views for describing the method for removing the void in the underfill material according to an embodiment of the present invention.

[0016] FIG. **16** are images showing an exemplary process in which the void is removed through the device for removing the void in the underfill material according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0017] Embodiments of the present disclosure will be described more fully hereinafter with reference to the accompanying drawings so that those skilled in the art easily implement the embodiments. The present disclosure may be modified in various different ways, all without departing from the spirit or scope of the present disclosure.

[0018] In order to clearly describe the present disclosure, parts or portions that are irrelevant to the description are omitted, and identical or similar constituent elements throughout the specification are denoted by the same reference numerals.

[0019] Further, in the drawings, a size of each element is arbitrarily illustrated for ease of description, and the present disclosure is not necessarily limited to those illustrated in the drawings. In the drawings, the thickness of layers, films, panels, regions, etc. are exaggerated for clarity. In the drawings, for better understanding and ease of description, thicknesses of some layers and areas are excessively displayed.

[0020] It will be understood that when an element such as a layer, film, region, or substrate is referred to as being “on” another element, it can be directly on the other element or intervening elements may also be present. In contrast, when an element is referred to as being “directly on” another element, there are no intervening elements present. Further, in the specification, the word “on” or “above” means positioned on or above the object portion, and does not necessarily mean positioned on the upper side of the object portion based on a gravitational direction.

[0021] In addition, throughout the specification, unless explicitly described to the contrary, the word “comprise” and variations such as “comprises” or “comprising” will be understood to imply the inclusion of stated elements but not the exclusion of any other elements.
[0022] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms “a”, “an”, and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising”, when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.
[0023] In addition, in the specification, when referring to “connected to”, this does not only mean that two or more constituent elements are directly connected, but also that two or more constituent elements are electrically connected through other constituent elements as well as being indirectly connected and being physically connected, or it may mean that they are referred to by different names according to a position or function, but are integrated.
[0024] Additionally, throughout the specification, a singular reference to a component includes references to a plurality of these components, unless specifically stated to the contrary.
[0025] Hereinafter, various embodiments and variations of the present invention will be described in detail with reference to the accompanying drawings.
[0026] FIG. **1** and FIG. **2** are schematic views showing an exemplary underfill process.
[0027] Referring to the drawings, an underfill material **40** is applied on a substrate **10**. In some embodiments, an electronic component **20** may be mounted on the substrate **10** through one or more conductive bumps **30** such as a solder ball.
[0028] In some embodiments, the substrate **10** may be a known substrate electrically connected to the electronic component **20** such as a printed circuit board (PCB) or a redistribution layer substrate.
[0029] The type of electronic component **20** is not particularly limited, and for example, in some embodiments, the electronic component **20** may be an active element such as a semiconductor chip or a transistor, or a passive element such as a capacitor. According to some embodiments of the present invention, the electronic component **20** may be mounted above the substrate **10** in a packaged form of one or more electronic components **20**.
[0030] In some embodiments, a conductive material may be used as a material of the conductive bump **30**, and for example, the conductive bump **30** may be a solder ball, but the present disclosure is not limited thereto. Additionally, in some embodiments, the conductive bump **30** may have various shapes such as a land, a pin, a ball, and the like.
[0031] In some embodiments, the underfill material **40** may include a thermosetting resin such as epoxy. Additionally, in some embodiments, the underfill material **40** may further include an inorganic filler such as silica (SiO.sub.2), a flux, or the like.
[0032] For example, in some embodiments, the underfill material **40** may be dispensed on one side of the substrate **10** through a dispenser **50**, and the dispensed underfill material **40** may fill a space residing between the substrate **10** and the electronic component **20** with a capillary force. In this case, as the underfill material **40** is being dispensed from the dispenser **50**, a speed difference for each position of the underfill material **40** may occur due to presence of a plurality of conductive bumps **30** (e.g., solder balls) disposed between the substrate **10** and the electronic component **20**, and a void **40**V may occur (see also FIG. **3**). In other words, the void **40**V is a pore surrounded by the underfill material **40**. In some embodiments, the void **40**V may also be affected by a spraying position and a spraying amount of the underfill material **40**, a surface state of the substrate **10**, positions of the conductive bumps **30** (e.g., solder balls), and the like.
[0033] As the electronic component **20** becomes highly integrated, a size of the solder ball

(conductive bump **30**) decreases and the number of the solder balls (conductive bumps **30**) increases. This is one factor that may increase the possibility of occurrence of voids **40**V in the underfill material **40**. Because having voids **40**V in the underfill material **40** may affect the reliability of a product, an effort is needed to minimize or eliminate the voids **40**V in the underfill material **40**.

[0034] FIG. **3** are images showing the size of exemplary voids **40**V in the underfill material **40** according to a surrounding pressure.

[0035] FIG. **3** (*a*) illustrates the size of the void **40**V at an atmospheric pressure, FIG. **3** (*b*) illustrates the size of the void **40**V at a pressure of **1000** torr, and FIG. **3** (*c*) illustrates the size of the void **40**V at a pressure of 50 torr. Referring to the drawings, it may be seen that the size of the void **40**V increases as the surrounding pressure decreases. According to embodiments of the present disclosure, the void **40**V in the underfill material **40** may be removed using a change in the size of the void **40**V according to the surrounding pressure.

[0036] FIG. **4** is a schematic diagram showing a device for removing voids **40**V in an underfill material **40** according to embodiments of the present invention.

[0037] Referring to the drawings, in some embodiments, the device **1000**A for removing the void **40**V in the underfill material **40** may include a chamber **100** in which the substrate **10** applied with the underfill material **40** is placed, a gas supply device **200** for injecting a gas G into the chamber **100**, and a vacuum device **300** for exhausting the gas G to the outside of the chamber **100**. In some embodiments, the device **1000**A may further include a cleaning device **400** that cleans the inside of the chamber **100**. In the drawings, the device **1000**A is shown as including two chambers **100**, two gas supply devices **200**, one vacuum device **300**, and two cleaning devices **400**, but the number of components included in the device **1000**A may be changed.

[0038] In some embodiments, the chamber **100** may have a support structure **110** for supporting the substrate **10**. In some embodiments, the support structure **110** may be a slot provided to insert the substrate **10** into the chamber **100**, but the present disclosure is not limited thereto. In some embodiments, the support structure **110** may be formed of a material with an excellent heat resistance and an excellent insulation characteristic. In some embodiments, the support structure **110** may be maintained at a constant temperature during operation of the device **1000**A for removing the void **40**V, and a heat loss of the substrate **10** may be prevented as heat is conducted to the support structure **110**.

[0039] In some embodiments, the gas supply device **200** may be connected to the chamber **100**, and may be configured to inject a heated gas G into the chamber **100** in order to create a heating atmosphere and a pressurizing atmosphere inside the chamber **100**. In the present specification, in some embodiments, the heated gas G may be a gas having a temperature higher than a room temperature. In some embodiments, the pressurizing atmosphere may be created inside the chamber **100** such that the void **40**V of the underfill material **40** is contracted, and the heating atmosphere may be created such that the underfill material **40** has appropriate fluidity. Additionally, in some embodiments, the gas supply device **200** may minimize a temperature change of the underfill material **40** according to a decrease in an internal temperature of the chamber **100** through operation of the vacuum device **300** by injecting the heated gas G. In other words, heated gas G may be injected into the chamber **100** to offset a decrease in internal temperature of the chamber **100** created by the vacuum device **300**, thereby minimizing a temperature change of the underfill material **40**.

[0040] In some embodiments, the gas supply device **200** may include a blower **210** for injecting the gas G into the chamber **100**. In some embodiments, the gas supply device **200** may also include a filter **220** for removing any contaminated particles of the gas G. Additionally, in some embodiments, the gas supply device **200** may further include a heating portion (not shown) for heating the gas G. In some embodiments, the gas G injected into the chamber **100** through the gas supply device **200** may be an inert gas such as nitrogen or air.

[0041] In some embodiments, to contract the void **40**V in the underfill material **40**, an internal pressure of the chamber **100** in the pressurizing atmosphere may be greater than or equal to an atmospheric pressure. In the present disclosure, in some embodiments, the pressurizing atmosphere may include an atmospheric pressure environment. However, for sufficient contraction of the void **40**V, in some embodiments, the pressurizing atmosphere may be an environment higher than the atmospheric pressure.
[0042] For example, in some embodiments, an internal temperature of the chamber **100** in the heating atmosphere may be about 30° C. to about 80° C., about 40° C. to about 70° C., or about 50° C. to about 60° C. If the internal temperature of the chamber **100** is too low, it may be difficult to secure fluidity of the underfill material **40**, and if the internal temperature of the chamber **100** is too high, the underfill material **40** may be cured (or hardened). Thus, in some embodiments, the internal temperature of the chamber **100** may be controlled within the above-described temperature ranges.
[0043] In some embodiments, in the heating atmosphere, the substrate **10** and the underfill material **40** may be heated through convective heat transfer, and temperatures of the substrate **10** and the underfill material **40** may be substantially the same as the internal temperature of the chamber **100**.
[0044] In some embodiments, a viscosity of the underfill material **40** in the heating atmosphere may be about 0.25 Pa.Math.s to about 0.8 Pa.Math.s. If the viscosity of the underfill material **40** is too low, it may be difficult to uniformly fill the underfill material **40**, and if the viscosity of the underfill material **40** is too high, it may be difficult to secure fluidity of the underfill material **40**. Thus, in some embodiments, the viscosity of the underfill material **40** may be controlled within the above-described range.
[0045] In some embodiments, an operating time required for the gas supply device **200** to create the heating atmosphere and/or the pressurizing atmosphere inside the chamber **100** may be about 5 minutes or less, about 4 minutes or less, about 3 minutes or less, about 2 minutes or less, about 1 minute or less, or about 30 seconds or less. According to the present disclosure, in some embodiments, the gas G may be injected from the outside of the chamber **100** to the inside of the chamber **100**, so that the heating atmosphere and/or the pressurizing atmosphere is created inside the chamber **100** at a high speed.
[0046] In some embodiments, the vacuum device **300** may be connected to the chamber **100**, and may create a vacuum atmosphere inside the chamber **100** by exhausting the gas G to the outside of the chamber **100**. In some embodiments, the vacuum atmosphere may be created inside the chamber **100** so that the void **40**V of the underfill material **40** is expanded and the void **40**V is removed by moving to an outer direction of the underfill material **40** (i.e., moving toward an outer edge of the underfill material **40**) (see also FIG. **11**). Additionally, in some embodiments, the vacuum atmosphere may be created inside the chamber **100** so that the gas G with an appropriate pressure range is introduced from the gas supply device **200**. In some embodiments, the vacuum device **300** may include a pump.
[0047] In some embodiments, the internal pressure inside the chamber **100** in the vacuum atmosphere may be about 10 torr or less, about 9 torr or less, about 8 torr or less, about 7 torr or less, about 6 torr or less, about 5 torr or less, about 4 torr or less, about 3 torr or less, about 2 torr or less, or about 1 torr or less. For sufficient expansion and movement of the void **40**V in the underfill material **40**, in some embodiments, the internal pressure of the chamber **100** in the vacuum atmosphere may be about 1 torr. For example, in some embodiments, the internal pressure of the chamber **100** in the vacuum atmosphere may be about 0.1 torr to about 1.9 torr, about 0.2 torr to about 1.8 torr, about 0.3 torr to about 1.7 torr, about 0.4 torr to about 1.6 torr, about 0.5 torr to about 1.5 torr, about 0.6 torr to about 1.4 torr, about 0.7 torr to about 1.3 torr, about 0.8 torr to about 1.2 torr, about 0.9 torr to about 1.1 torr, or about 1 torr.
[0048] In some embodiments, an operating time required for the vacuum device **300** to create the vacuum atmosphere inside the chamber **100** may be about 5 minutes or less, about 4 minutes or

less, about 3 minutes or less, about 2 minutes or less, about 1 minute or less, or about 30 seconds or less. According to the present disclosure, in some embodiments, the gas G may be exhausted from the inside of the chamber **100** to the outside of the chamber **100**, so that the vacuum atmosphere is created at a high speed and the internal pressure of the chamber **100** is significantly lowered.

[0049] Because the vacuum device **300** and the gas supply device **200** operate for one or more cycles, in some embodiments, the vacuum atmosphere and the pressurizing atmosphere may be alternately created inside the chamber **100**. Here, in some embodiments, in the one cycle, the vacuum device **300** and the gas supply device **200** may be alternately operated once. In some embodiments, the vacuum device **300** and the gas supply device **200** may operate for one or more cycles after the substrate **10** is placed into the chamber **100**, and as described later, in some embodiments, may operate for one or more cycles before the substrate **10** is placed into the chamber **100**. In some embodiments, in the cycle, the vacuum device **300** may operate first, and the gas supply device **200** may operate later, but an order of their operations is not particularly limited. Additionally, in some embodiments, after the cycle ends, one of the vacuum device **300** and the gas supply device **200** may be additionally operated. For example, in some embodiments, after the substrate **10** is placed into the chamber **100**, the vacuum device **300** and the gas supply device **200** may operate for one cycle, and the vacuum device **300** may additionally operate. According to the present disclosure, in some embodiments, the void **40**V in the underfill material **40** may be removed by alternately creating the vacuum atmosphere and the pressurizing atmosphere inside the chamber **100** to repeat expansion and contraction of the void **40**V in the underfill material **40**. In addition, according to the present disclosure, in some embodiments, the internal pressure of the chamber **100** may be significantly and quickly changed through injection and exhaust of the gas G into and out of the chamber **100**. Accordingly, it is possible to efficiently remove the void **40**V in the underfill material **40** by quickly inducing a change in volume and motion of the void **40**V.

[0050] On the other hand, in some embodiments, in order to create the heating atmosphere inside the chamber **100**, the gas supply device **200** may be operated even before the substrate **10** is placed into the chamber **100**. In order to create a sufficient heating atmosphere inside the chamber **100**, in some embodiments, an operating time of the gas supply device **200** before the substrate **10** is placed inside the chamber **100** may be longer than an operating time of the gas supply device **200** after the substrate **10** is placed into the chamber **100**. For example, in some embodiments, the operating time of the gas supply device **200** before the substrate **10** is placed into the chamber **100** may be about 5 minutes or less, but the present disclosure is not limited thereto.

[0051] For injection of the gas G through the gas supply device **200**, in some embodiments, an operation of the vacuum device **300** may be preceded. In some embodiments, an operating time of the vacuum device **300** before the substrate **10** is placed into the chamber **100** and the gas supply device **200** is operated may be about 5 minutes or less, about 4 minutes or less, about 3 minutes or less, about 2 minutes or less, about 1 minute or less, or about 30 seconds or less. In addition, in some embodiments, an internal pressure of the chamber **100** in the vacuum atmosphere created by the vacuum device **300** may be about **10** torr or less, about 9 torr or less, about 8 torr or less, about 7 torr or less, about 6 torr or less, about 5 torr or less, about 4 torr or less, about 3 torr or less, about 2 torr or less, about 1 torr or less, or about 1 torr. For example, the internal pressure of the chamber **100** in the vacuum atmosphere may be about 0.1 torr to about 1.9 torr, about 0.2 torr to about 1.8 torr, about 0.3 torr to about 1.7 torr, about 0.4 torr to about 1.6 torr, about 0.5 torr to about 1.5 torr, about 0.6 torr to about 1.4 torr, about 0.7 torr to about 1.3 torr, about 0.8 torr to about 1.2 torr, about 0.9 torr to about 1.1 torr, or about 1 torr.

[0052] In some embodiments, the cleaning device **400** may be connected to the chamber **100**, and may clean the inside of the chamber **100** with plasma P. In some embodiments, the cleaning device **400** may be an in-situ cleaning device that generates the plasma P inside the chamber **100**, and in some embodiments, may be a remote cleaning device that generates the plasma P from a remote plasma source (RPS) that is a supply source distinguished from the chamber **100** to supply the plasma P to the inside of the chamber **100**.

[0053] FIG. **5** is a schematic diagram showing a device for removing a void **40**V in an underfill material **40** according to embodiments of the present invention.

[0054] As shown in FIG. **5**, the device **1000**B of removing the void **40**V in the underfill material **40** further includes a heating device **500** compared with the device **1000**A for removing the void **40**V in the underfill material **40**.

[0055] In some embodiments, the heating device **500** may be disposed inside the chamber **100**, and may directly heat the substrate **10** placed into the chamber **100**. In some embodiments, the heating device **500** may heat the substrate **10** by irradiating light to the substrate **10**, and for example, the heating device **500** may be an infrared (IR) lamp, but the present disclosure is not limited thereto.

[0056] In some embodiments, the heating device **500** may heat the substrate **10** applied with the underfill material **40** through radiant heat transfer, and for example, may heat the substrate **10** applied with the underfill material **40** to about 30° C. to about 80° C., about 40° C. to about 70° C., or about 50° C. to about 60° C.

[0057] In some embodiments, the gas supply device **200** may create the pressurizing atmosphere inside the chamber **100** by injecting the gas G into the chamber **100**. In some embodiments, the pressurizing atmosphere may be created inside the chamber **100** so that the void **40**V of the underfill material **40** is contracted.

[0058] In some embodiments, the gas G injected into the chamber **100** through the gas supply device **200** may be in a heated state. In some embodiments, the heating device **500** may heat the substrate **10** together with the gas supply device **200**. For example, if it is difficult to sufficiently heat the substrate **10** with the gas supply device **200**, in some embodiments, the heating device **500** may further heat the substrate **10** together with the gas supply device **200**. As another example, in some embodiments, the heating device **500** may prevent a decrease in a temperature of the substrate **10** if an internal temperature inside of the chamber **100** decreases due to operation of the vacuum device **300**.

[0059] In some embodiments, the gas G injected into the chamber **100** through the gas supply device **200** may be in an unheated state. In some embodiments, the heating device **500** may heat the substrate **10** so that the underfill material **40** has appropriate fluidity.

[0060] Descriptions of other components may be identically applied to the description of the device **1000**A for removing the void **40**V in the underfill material **40** and duplicate discussion thereof may be omitted herein.

[0061] FIG. **6** is a flowchart showing a method for removing a void **40**V in an underfill **40** material according to embodiments of the present invention.

[0062] FIGS. **7** to **15** are schematic views illustrating the method for removing the void **40**V in the underfill material **40** according to embodiments of the present invention.

[0063] First, referring to FIG. **6**, in some embodiments, the method for removing the void **40**V in the underfill material **40** may include a step S**1** of creating a vacuum atmosphere inside the chamber **100**, a step S**2** of creating a heating atmosphere and a pressurizing atmosphere inside the chamber **100**, a step S**3** of placing the substrate **10** applied with the underfill material **40** into the chamber **100**, a step S**4** of creating the vacuum atmosphere inside the chamber **100** again, a step S**5** of creating the heating atmosphere and the pressurizing atmosphere inside the chamber **100**, a gas purge step S**6**, a step S**7** of recovering the substrate **10** from the chamber **100**, and a step S**8** of cleaning the inside of the chamber **100**.

[0064] In some embodiments, the step S**1** of creating the vacuum atmosphere inside the chamber **100** and the step S**2** of creating the heating atmosphere and the pressurizing atmosphere inside the chamber **100** may create the heating atmosphere before the substrate **10** is placed into the chamber **100**, such that the heating atmosphere and pressurizing atmosphere heat the substrate **10** placed into the chamber **100**.

[0065] In some embodiments, the step S**1** of creating the vacuum atmosphere inside the chamber

100 may be performed by exhausting the gas G to the outside of the chamber **100** using a pump or the like. In some embodiments, the step S**1** of creating the vacuum atmosphere inside the chamber **100** may be a preceding step for the step S**2** of creating the heating atmosphere and the pressurizing atmosphere inside the chamber **100**. The vacuum atmosphere may be created inside the chamber **100** so that the gas G with an appropriate pressure range is introduced from the gas supply device **200** into the chamber **100**. However, if necessary, in some embodiments, the step S**1** of creating the vacuum atmosphere may be omitted.

[0066] In some embodiments, an internal pressure of the chamber **100** in the vacuum atmosphere may be about 10 torr or less, about 9 torr or less, about 8 torr or less, about 7 torr or less, about 6 torr or less, about 5 torr or less, about 4 torr or less, about 3 torr or less, about 2 torr or less, or about 1 torr or less. For sufficient expansion and movement of the void **40**V in the underfill material **40**, in some embodiments, the internal pressure of the chamber **100** in the vacuum atmosphere may be about 1 torr. For example, in some embodiments, the internal pressure of the chamber **100** in the vacuum atmosphere may be about 0.1 torr to about 1.9 torr, about 0.2 torr to about 1.8 torr, about 0.3 torr to about 1.7 torr, about 0.4 torr to about 1.6 torr, about 0.5 torr to about 1.5 torr, about 0.6 torr to about 1.4 torr, about 0.7 torr to about 1.3 torr, about 0.8 torr to about 1.2 torr, about 0.9 torr to about 1.1 torr, or about 1 torr.

[0067] In some embodiments, in the step S**1** of creating the vacuum atmosphere inside the chamber **100**, a time required to create the vacuum atmosphere inside the chamber **100** may be about 5 minutes or less, about 4 minutes or less, about 3 minutes or less, about 2 minutes or less, about 1 minute or less, or about 30 seconds or less. According to the present disclosure, in some embodiments, the gas G may be exhausted from the inside and the outside of the chamber **100**, so that the vacuum atmosphere is created at a high speed and the internal pressure of the chamber **100** is significantly lowered.

[0068] In some embodiments, the step S**2** of creating the heating atmosphere and the pressurizing atmosphere inside the chamber **100** may be performed by injecting a heated gas G into the chamber **100**. In some embodiments, the gas G injected into the chamber **100** may be an inert gas such as nitrogen or air.

[0069] In some embodiments, to contract the void **40**V, an internal pressure of the chamber **100** in the pressurizing atmosphere may be greater than or equal to an atmospheric pressure. In the present disclosure, in some embodiments, the pressurizing atmosphere may mean an environment greater than or equal to the atmospheric pressure.

[0070] For example, in some embodiments, an internal temperature of the chamber **100** in the heating atmosphere may be about 30° C. to about 80° C., about 40° C. to about 70° C., or about 50° C. to about 60° C. If the internal temperature of the chamber **100** is too low, it may be difficult to secure fluidity of the underfill material **40**, and if the internal temperature of the chamber **100** is too high, the underfill material **40** may be cured (or hardened). Thus, in some embodiments, the internal temperature of the chamber **100** may be controlled within the above-described temperature ranges.

[0071] In some embodiments, in the heating atmosphere, the substrate **10** and the underfill material **40** may be heated through convective heat transfer, and temperatures of the substrate **10** and the underfill material **40** may be substantially the same as the internal temperature of the chamber **100**.

[0072] In some embodiments, a viscosity of the underfill material **40** in the heating atmosphere may be about 0.25 Pa.Math.s to about 0.8 Pa.Math.s. If the viscosity of the underfill material **40** is too low, it may be difficult to uniformly fill the underfill material **40**, and if the viscosity of the underfill material **40** is too high, it may be difficult to secure fluidity of the underfill material **40**. Thus, in some embodiments, the viscosity of the underfill material **40** may be controlled within the above-described range.

[0073] In some embodiments, in the step S**2** of creating the heating atmosphere and the pressurizing atmosphere inside the chamber **100**, a time required to create the heating atmosphere and/or the pressurizing atmosphere inside the chamber **100** may be about 5 minutes or less, about 4 minutes or less, about 3 minutes or less, about 2 minutes or less, about 1 minute or less, or about 30 seconds or less. According to the present disclosure, in some embodiments, the gas G may be injected from the outside of the chamber **100** to the inside of the chamber **100**, so that the heating atmosphere and/or the pressurizing atmosphere is created inside the chamber **100** at a high speed.

[0074] On the other hand, in some embodiments in which the substrate **10** is heated using only the heating device **500**, the step S**1** of creating the vacuum atmosphere inside the chamber **100** and the step S**2** of creating the heating atmosphere and the pressurizing atmosphere may be omitted, and the substrate **10** placed into the chamber **100** may be heated by light. For example, in some embodiments, the substrate **10** placed into the chamber **100** may be heated to about 30° C. to about 80° C., about 40° C. to about 70° C., or about 50° C. to about 60° C. by light irradiation.

[0075] Referring to FIG. **7** and FIG. **8**, in some embodiments, the step S**3** of placing the substrate **10** applied with the underfill material **40** into the chamber **100** may be performed by disposing the substrate **10** on the support structure **110** of the chamber **100**. In some embodiments, before the step S**3** of putting the substrate **10** is performed, the step S**1** of creating the vacuum atmosphere inside the chamber **100** and the step S**2** of creating the heating atmosphere and the pressurizing atmosphere inside the chamber **100** may be preceded, so that the substrate **10** may be placed into the chamber **100** already having the heating atmosphere.

[0076] Referring to FIG. **9**, in some embodiments, the step S**4** of creating the vacuum atmosphere inside the chamber **100** may be performed by exhausting the gas G to the outside of the chamber **100** using a pump or the like. In some embodiments, the void **40**V of the underfill material **40** may be expanded through the step S**4** of creating the vacuum atmosphere inside the chamber **100**, and the void **40**V may be removed by moving to an outer direction (dm) of the underfill material **40** (i.e., moving toward an outer edge of the underfill material **40**). Additionally, in some embodiments, the vacuum atmosphere may be created inside the chamber **100** so that the gas G with an appropriate pressure range is introduced from the gas supply device **200** into the chamber **100**.

[0077] In addition to the above description, in some embodiments, a description of the step S**4** of creating the vacuum atmosphere inside the chamber **100** may be equally applied to a description of the step S**1** of creating the vacuum atmosphere inside the chamber **100** unless there is a particularly contradictory description.

[0078] Referring to FIG. **10**, in some embodiments, the step S**5** of creating the heating atmosphere and the pressurizing atmosphere inside the chamber **100** may be performed by injecting a heated gas G into the chamber **100**. In some embodiments, the underfill material **40** may maintain appropriate fluidity through the step S**5** of creating the heating atmosphere and the pressurizing atmosphere inside the chamber **100**, and the void **40**V of the underfill material **40** may be contracted. In addition, in some embodiments, the step S**5** of creating the heating atmosphere and the pressurizing atmosphere inside the chamber **100** may minimize a temperature change of the underfill material **40** according to a decrease in an internal temperature of the chamber **100** due to the step S**4** of creating the vacuum atmosphere.

[0079] On the other hand, in some embodiments in which the substrate **10** is heated using only the heating device **500**, the step S**5** of creating the heating atmosphere and the pressurizing atmosphere inside the chamber **100** may be replaced by a step of creating only the pressurizing atmosphere without creating the heating atmosphere. In some embodiments, the step of creating the pressurizing atmosphere may be performed by injecting an unheated gas G into the chamber **100**.

[0080] In addition to the above description, in some embodiments, a description of the step S**5** of creating the heating atmosphere and the pressurizing atmosphere inside the chamber **100** may be equally applied to a description of the step S**2** of creating the heating atmosphere and the pressurizing atmosphere inside the chamber **100** unless there is a particularly contradictory description.

[0081] In some embodiments, the step S**4** of creating the vacuum atmosphere inside the chamber **100** and the step S**5** of creating the heating atmosphere and the pressurizing atmosphere may be performed for one or more cycles so that the vacuum atmosphere, the heating atmosphere, and the pressurizing atmosphere are alternately created inside the chamber **100** after the substrate **10** is placed into the chamber **100**. Here, in some embodiments, in the one cycle, the step S**4** of creating the vacuum atmosphere inside the chamber **100** and the step S**5** of creating the heating atmosphere and the pressurizing atmosphere may be alternately performed once. Therefore, in some embodiments, the vacuum atmosphere and the pressurizing atmosphere may be alternately created inside the chamber **100**. In some embodiments, in the cycle, the step S**4** of creating the vacuum atmosphere may be performed first, and the step S**5** of creating the heating atmosphere and the pressurizing atmosphere may be performed later, but their order is not particularly limited. In addition, in some embodiments, after the cycle ends, one of the step S**4** of creating the vacuum atmosphere and the step S**5** of creating the heating atmosphere and the pressurizing atmosphere may be additionally performed. For example, as shown in FIGS. **9** to **11**, in some embodiments, after the substrate **10** is placed into the chamber **100**, the step S**4** of creating the vacuum atmosphere and the step S**5** of creating the heating atmosphere and the pressurizing atmosphere may be performed for one cycle, and the step S**4** of creating the vacuum atmosphere may be additionally performed. According to the present disclosure, in some embodiments, the void **40**V may be removed by alternately creating the vacuum atmosphere and the pressurizing atmosphere inside the chamber **100** to repeat expansion and contraction of the void **40**V of the underfill material **40** (see FIG. **12**). In addition, according to the present disclosure, in some embodiments, an internal pressure of the chamber **100** may be significantly and quickly changed through injection and exhaust of the gas G. Accordingly, it is possible to efficiently remove the void **40**V by quickly inducing a change in volume and motion of the void **40**V.
[0082] In some embodiments, the gas purge step S**6** may be performed by injecting a purge gas such as nitrogen or the like into the chamber **100**. In some embodiments, the gas purge step S**6** may be performed to restore an atmospheric pressure condition in the chamber **100** and remove a chemical reaction from the chamber **100**. In some embodiments, the gas purge step S**6** may be replaced by the step S**5** of creating the pressurizing atmosphere.
[0083] In some embodiments, after the step S**7** of recovering the substrate **10** from the chamber **100**, a curing step for curing the underfill material **40** may be performed. In some embodiments, the curing step for curing the underfill material **40** may be performed inside the chamber **100** before the step S**7** of recovering the substrate **10** from the chamber **100** is performed.
[0084] Referring to FIGS. **13** to **15**, because the gas G is supplied into the chamber **100**, in some embodiments, a wall surface or the like of the chamber **100** may be contaminated with a contaminated particle (CP) caused by the underfill material **40** or the like, and the step S**8** of cleaning the inside of the chamber **100** may be additionally performed to remove the contaminated particle CP. In some embodiments, in the step S**8** of cleaning the inside of the chamber **100**, an in-situ cleaning method in which plasma P is generated inside the chamber **100** may be used, or a remote cleaning method in which plasma P is generated from a remote plasma source (RPS) that is a supply source distinguished from the chamber **100** to supply the plasma P into the chamber **100** may be used.
[0085] FIG. **16** are images illustrating a process in which the void **40**V is removed through the device for removing the void **40**V in the underfill material **40** according to embodiments of the present invention.
[0086] In some embodiments, in an atmospheric pressure condition, the void **40**V of the underfill material **40** may be created (see FIG. **16** (*a*)). According to embodiments of the present invention, the void **40**V may be expanded in the vacuum atmosphere (see FIG. **16** (*b*)) and may be contracted in the pressurizing atmosphere (see FIG. **16** (*c*)) so that the void **40**V may be completely removed from the underfill material **40** by moving the void **40**V in an outer direction of the underfill

material **40** when the atmospheric pressure condition is finally restored (i.e., moving the void **40**V toward an outer edge of the underfill material **40**).

[0087] While this disclosure has been described in connection with what is presently considered to be practical embodiments, it is to be understood that the disclosure is not limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims. The above-disclosed subject matter is to be considered illustrative, and not restrictive, and the appended claims are intended to cover all such modifications, enhancements, and other embodiments, which fall within the scope of the present inventive concept. Thus, to the maximum extent allowed by law, the scope it to be determined by the broadest permissible interpretation of the following claims and their equivalents, and shall not be restricted or limited by the foregoing detailed description.

Claims

1. A device for removing a void in an underfill material, the device comprising: a chamber configured to accept a substrate applied with an underfill material therein; a gas supply device connected to the chamber and configured to inject a heated gas into the chamber to create a heating atmosphere and a pressurizing atmosphere inside the chamber; and a vacuum device connected to the chamber and configured to exhaust a gas from the inside of the chamber to outside of the chamber to create a vacuum atmosphere inside the chamber, wherein the vacuum device and the gas supply device are configured to alternately operate for one or more cycles to create the vacuum atmosphere and the pressurizing atmosphere inside the chamber, and during each cycle of the one or more cycles, the vacuum device and the gas supply device are configured to alternately operate once.

2. The device of claim 1, wherein an internal pressure of the chamber in the vacuum atmosphere is 10 torr or less, and an internal pressure of the chamber in the pressurizing atmosphere is greater than or equal to an atmospheric pressure.

3. The device of claim 2, wherein the internal pressure of the chamber in the vacuum atmosphere is 1 torr or less.

4. The device of claim 1, wherein the vacuum device and the gas supply device are configured to operate for one or more cycles before and after the substrate is placed into the chamber.

5. The device of claim 1, wherein an operating time required for the vacuum device to create the vacuum atmosphere inside the chamber is 5 minutes or less.

6. The device of claim 1, wherein the gas supply device comprises a blower and a filter.

7. The device of claim 1, wherein the heated gas to be injected into the chamber through the gas supply device is nitrogen or air.

8. The device of claim 1, wherein an internal temperature of the chamber in the heating atmosphere is 30° C. to 80° C.

9. The device of claim 1, wherein a viscosity of the underfill material in the heating atmosphere is 0.25 Pas to 0.8 Pa.Math.s.

10. The device of claim 1, wherein an operating time required for the gas supply device to create the heating atmosphere and the pressurizing atmosphere inside the chamber is 5 minutes or less.

11. The device of claim 1, further comprising a heating device disposed inside the chamber and configured to heat the substrate by irradiating light to the substrate.

12. The device of claim 1, further comprising a cleaning device connected to the chamber and configured to clean the inside of the chamber with a plasma.

13. A device for removing a void in an underfill material, comprising: a chamber configured to accept a substrate applied with an underfill material therein; a gas supply device connected to the chamber and configured to inject a first gas into the chamber to create a pressurizing atmosphere inside the chamber; a vacuum device connected to the chamber and configured to exhaust a second gas from the inside of the chamber to outside of the chamber to create a vacuum atmosphere inside the chamber; and a heating device disposed inside the chamber and configured to heat the substrate by irradiating light to the substrate, wherein the vacuum device and the gas supply device are configured to alternately operate once during each cycle of one or more cycles to create the vacuum atmosphere and the pressurizing atmosphere inside the chamber, and during each cycle.

14. The device of claim 13, wherein the heating device is an infrared (IR) lamp.

15. The device of claim 13, wherein an internal pressure of the chamber in the vacuum atmosphere is 10 torr or less, and an internal pressure of the chamber in the pressurizing atmosphere is greater than or equal to an atmospheric pressure.

16. The device of claim 13, wherein an operating time required for the vacuum device to create the vacuum atmosphere inside the chamber is 5 minutes or less.

17. The device of claim 13, wherein an operating time required for the gas supply device to create the pressurizing atmosphere inside the chamber is 5 minutes or less.

18. A device for removing a void in an underfill material, comprising: a chamber configured to accept a substrate applied with an underfill material therein; a gas supply device connected to the chamber and configured to inject a first gas into the chamber to create a pressurizing atmosphere inside the chamber; and a vacuum device connected to the chamber and configured to exhaust a second gas from the inside of the chamber to outside of the chamber to create a vacuum atmosphere inside the chamber, wherein the vacuum device and the gas supply device are configured to alternately operate once during each cycle of one or more cycles to create the vacuum atmosphere and the pressurizing atmosphere inside the chamber, and wherein an internal pressure of the chamber in the vacuum atmosphere is 10 torr or less.

19. The device of claim 18, wherein the first gas to be injected into the gas supply device is a heated gas.

20. The device of claim 18, further comprising a heating device disposed inside the chamber and configured to heat the substrate.