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Subrahmanyan et al.

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(54) **APPARATUS AND METHOD FOR CHUCKING WARPED WAFERS**

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H01L 21/67 (2006.01)

(52) **U.S. Cl.**
CPC ***H01L 21/6838*** (2013.01); ***H01L 21/67288*** (2013.01)

(58) **Field of Classification Search**
CPC B25B 11/00; B25B 11/02; B25B 11/005
See application file for complete search history.

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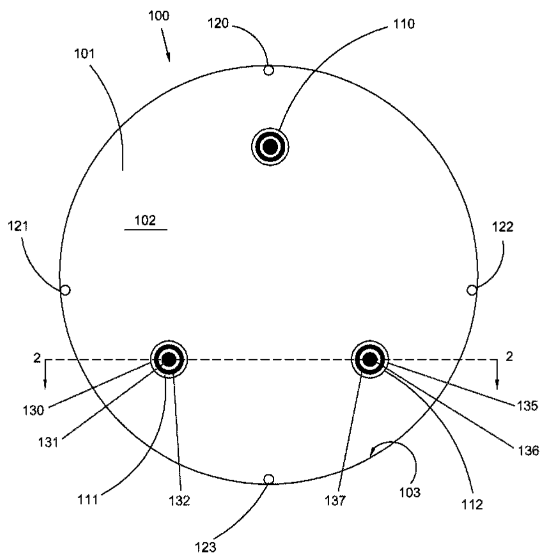
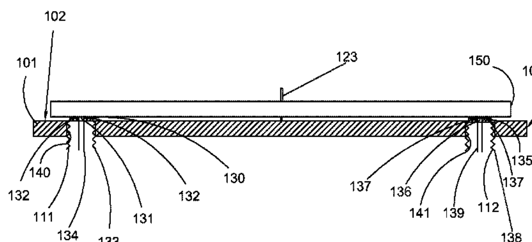
(57) **ABSTRACT**

An apparatus for fixing a wafer, including a chuck having a surface, a plurality of through bores in the chuck extending through the surface of the chuck, a fixed vacuum bellows, and a plurality of floating air bearings, wherein the fixed vacuum bellows and a respective floating air bearing of the plurality of floating air bearings are each individually arranged in separate through bores of the plurality of through bores and elevationally above the surface of the chuck.

10 Claims, 3 Drawing Sheets





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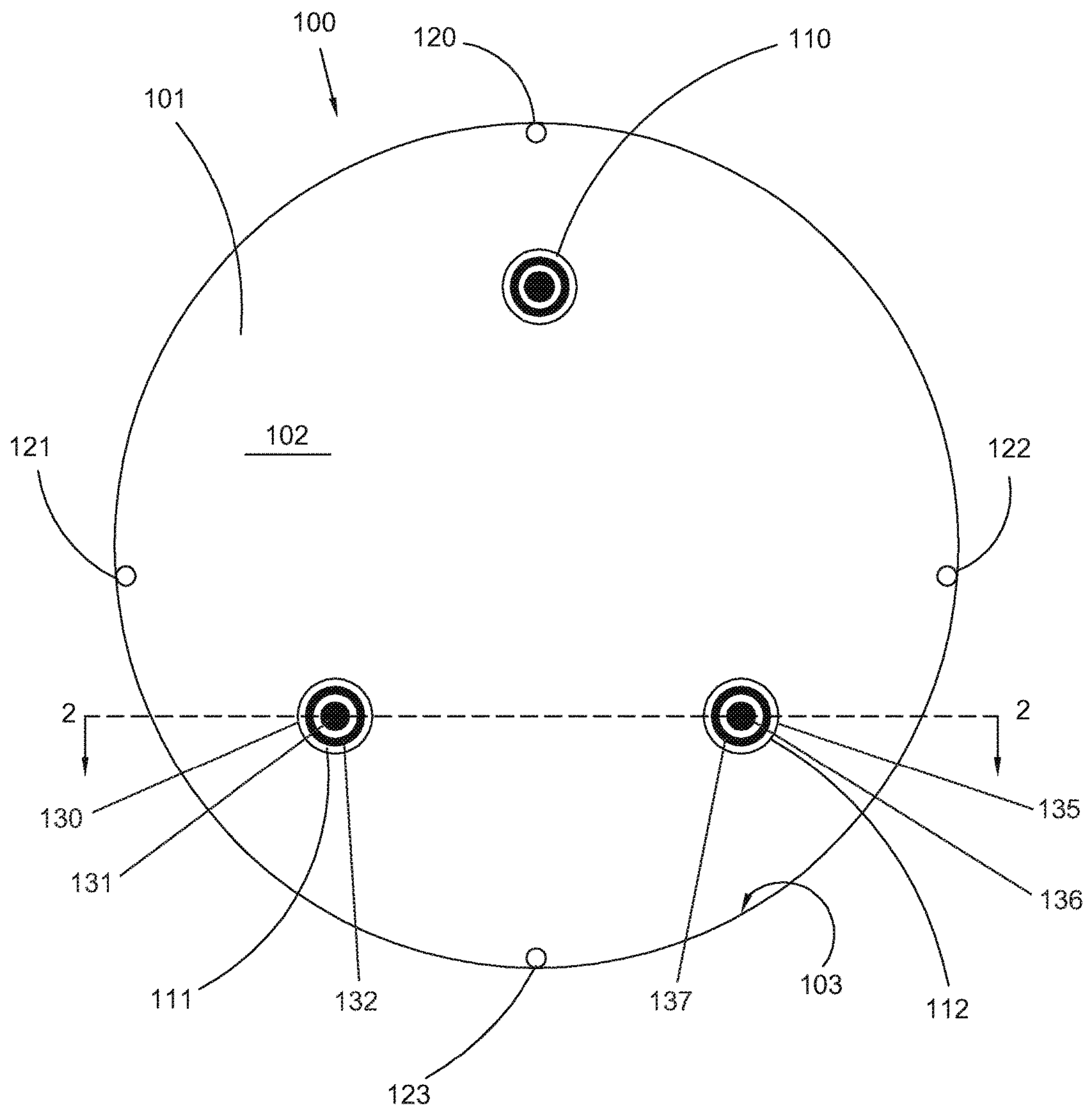

Fig. 1

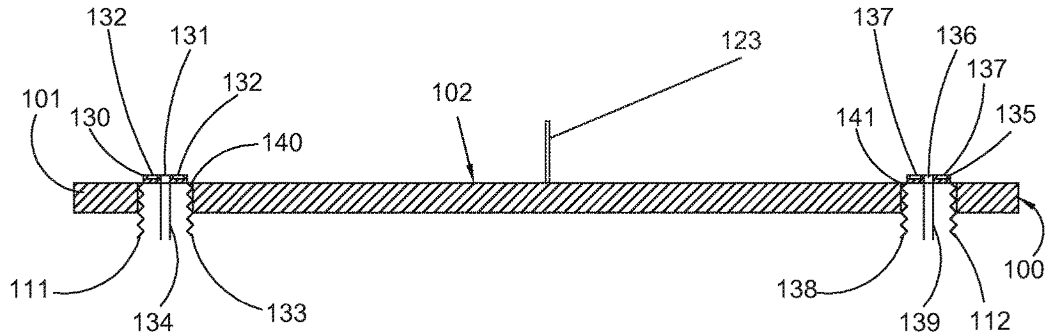

Fig. 2

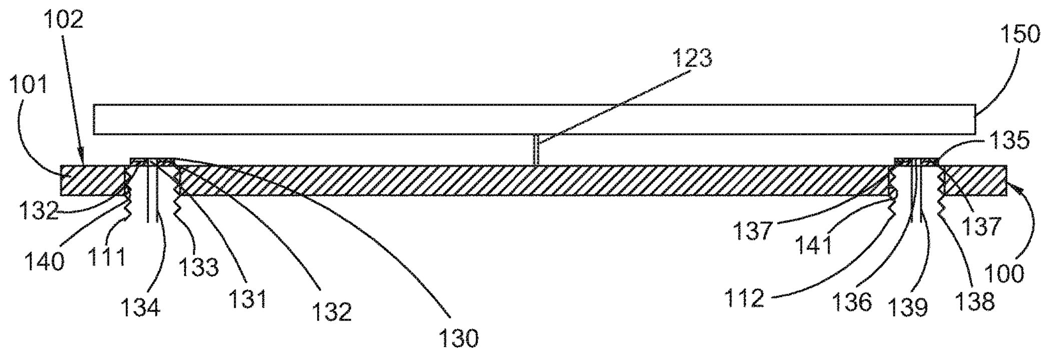

Fig. 3

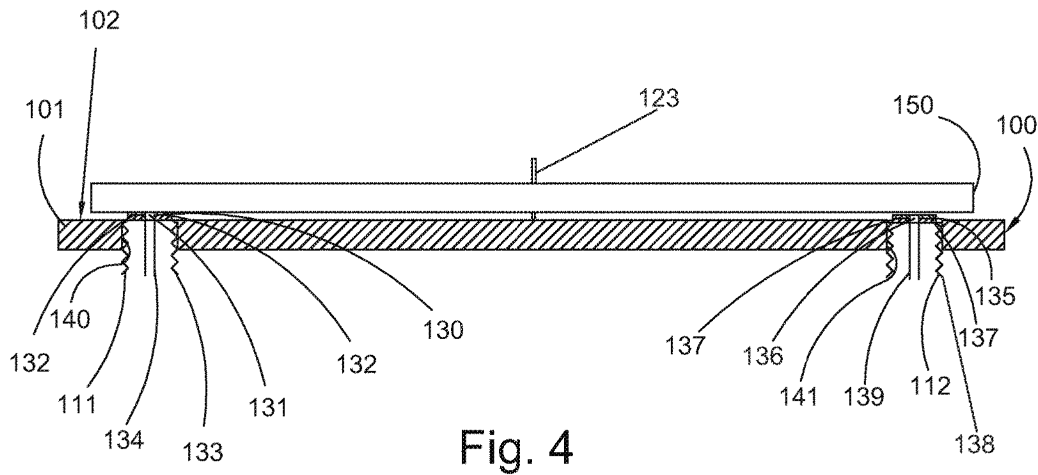

Fig. 4

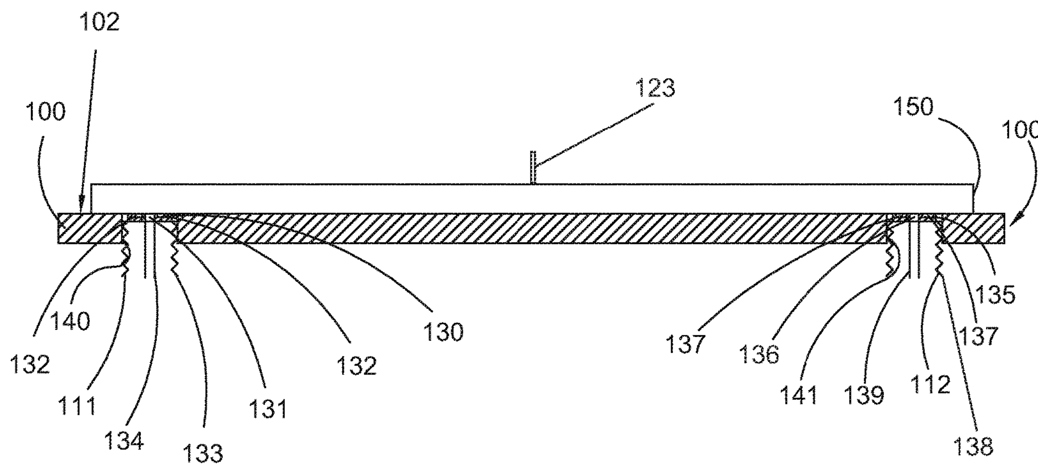

Fig. 5

APPARATUS AND METHOD FOR CHUCKING WARPED WAFERS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Patent Application No. 62/132,473, filed Mar. 12, 2015, which application is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present invention relates to an apparatus and method for fixing wafers used in the manufacture of semiconductors to a chuck.

BACKGROUND

Wafers used for Advanced Wafer Level Packaging (aWLP) come in a variety of sizes and formats. For example, the thicknesses of aWLP wafers range from tens of microns to a few millimeters. Additionally, the wafers may be mounted on film frames, bonded to carrier wafers, or reconstituted onto packaging materials or other wafers. This diversity results in significant variation in wafer stiffness and warp, both of which adversely affect the ability of wafers to be fixed to a conventional chuck.

Conventional chucks use a vacuum to fix a wafer to the chuck. This method of fixation tends to preserve any warping in the wafer, as the wafer is drawn to the surface of the chuck without having an opportunity to flatten out through transverse extension of the warped portion of the wafer. Thus, a wafer fixed to a chuck in this way may not conform to the surface geometry of the chuck. Physical edge clamps which clamp the wafer directly to the chuck can improve the fixation of the wafer to the chuck by forcing the wafer to conform to the surface geometry of the chuck, however, physically clamping a wafer may generate debris particles or other contaminants.

As the optical inspection of wafers requires establishing a focus plane with high precision, warping in the wafer can cause portions of the wafer to be outside the desired focus plane. Further, the debris particles generated by physical clamping can contaminate the die, which in turn may negatively affect yield.

SUMMARY

According to aspects illustrated herein, there is provided an apparatus for fixing a wafer, including a chuck having a surface, a plurality of through bores in the chuck extending through the surface of the chuck, a fixed vacuum bellows, and a plurality of floating air bearings, wherein the fixed vacuum bellows and a respective floating air bearing of the plurality of floating air bearings are each individually arranged in separate through bores of the plurality of through bores and elevationally above the surface of the chuck.

According to aspects illustrated herein, there is provided a method for fixing a wafer to a chuck, including lowering the wafer to a position adjacent a surface of the chuck, coupling the wafer using a first negative air pressure to a fixed vacuum bellows arranged within a vacuum through bore in the surface of the chuck and elevationally above the surface of the chuck, suspending the wafer using a positive air pressure provided by a plurality of floating air bearings, wherein respective floating air bearings of the plurality of floating air bearings are arranged elevationally above the surface of the chuck and each individually arranged in separate through bores of a plurality of through bores in the chuck, coupling the wafer using a second negative air pressure to the plurality of floating air bearings, and clamping the wafer to the surface of the chuck by retracting the fixed vacuum bellows and the plurality of floating air bearings inside the chuck.

According to aspects illustrated herein, there is provided an apparatus for fixing a wafer, including a chuck having a surface, a plurality of through bores in the chuck extending through the surface of the chuck, at least two location pins arranged around an edge of the surface of the chuck in at least one direction substantially orthogonal to the surface of the chuck, a first floating air bearing arranged within a first through bore of the plurality of through bores, a second floating air bearing arranged within a second through bore of the plurality of through bores, and a fixed vacuum bellows arranged within a third through bore of the plurality of through bores.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments are disclosed, by way of example only, with reference to the accompanying schematic drawing in which:

FIG. **1** is a top plan view of an apparatus for chucking wafers;

FIG. **2** is a cross-sectional view of the apparatus shown in FIG. **1** taken along line **2-2**;

FIG. **3** is a cross-sectional view of e apparatus shown in FIG. **1** taken along line **2-2** including a wafer;

FIG. **4** is a cross-sectional view of the apparatus shown in FIG. **1** taken along line **2-2** including a wafer partially secured to the apparatus, i.e., secured at a single location; and,

FIG. **5** is a cross-sectional view of the apparatus shown in FIG. **1** taken along line **2-2** with a wafer fixed to the surface of the chuck.

DETAILED DESCRIPTION

At the outset, it should be understood that the disclosure as claimed is not limited to the disclosed aspects.

Furthermore, it is understood that this disclosure is not limited to the particular methodologies, materials and modifications described and as such may, of course, vary. It is also understood that the terminology used herein is for the purpose of describing particular aspects only, and is not intended to limit the scope of the present disclosure.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this disclosure belongs. It should be understood that any methods, devices or materials similar or equivalent to those described herein can be used in the practice or testing of the disclosure. As used herein, by "vacuum" it is generally meant a region or state of negative air pressure, for example, a region or state having a lower air pressure than an adjacent environment.

FIG. **1** is a top plan view of an apparatus **100** for chucking wafers. Apparatus **100** includes chuck **101**, which has surface **102**. In an example embodiment, chuck **101** has a surface geometry equivalent to a circular plane. Edge **103** is the outer edge of surface **102**, and in an example embodiment, edge **103** is the circular boundary of surface **102**,

while surface **102** is a planar surface. Location pins **120**, **121**, **122**, and **123** are arranged around and adjacent edge **103** in at least one direction substantially orthogonal to surface **102**, for example, parallel with the surface normal of surface **102**. In an example embodiment, there are at least two location pins arranged around edge **103** of surface **102** of chuck **101**, and these at least two location pins are arranged in at least one direction substantially orthogonal to surface **102** of chuck **101**.

Apparatus **100** includes floating air bearings **110** and **112** and fixed vacuum bellows **111**. Floating air bearings **110** and **112** and fixed vacuum bellows **111** are each individually arranged in separate through bores in chuck **101**. These through bores extend through surface **102**. Further, floating air bearings **110** and **112** and fixed vacuum bellows **111** are initially arranged elevationally above surface **102**. The function and movement of floating air bearings **110** and **112** and fixed vacuum bellows **111** are discussed in greater detail below. In some example embodiments, apparatus **100** includes more than two floating air bearings.

FIG. **2** is a cross-sectional view of apparatus **100** shown in FIG. **1** taken along line **2-2**. Chuck **101** includes through bores **140** and **141**, in which are arranged fixed vacuum bellows **111** and floating air bearing **112**, respectively. Fixed vacuum bellows **111** includes vacuum pad **130** including through bore **131**, bellows **133** connected to vacuum pad **130**, and vacuum line **134** arranged within bellows **133** and connected to vacuum pad **130**, such that vacuum line **134** is in fluid communication with through bore **131** in vacuum pad **130**. In an example embodiment, bellows **133**, and thus, fixed vacuum bellows **111** as an assembly, are both extendable and retractable in directions orthogonal to surface **102** of chuck **101**, i.e., coaxial with the longitudinal axis of through bore **140**.

Floating air bearing **112** includes air bearing pad **135** including through bore **136**, bellows **138** connected to air bearing pad **135**, at least one air bearing opening **137** in a surface of air bearing pad **135**, an air line in fluid communication with at least one air bearing opening **137**, and vacuum line **139** arranged within bellows **138** and connected to air bearing pad **135**, wherein vacuum line **139** is in fluid communication with through bore **136** in air bearing pad **135**. In an example embodiment, bellows **138**, and thus floating air bearing **112** as an assembly, are both extendable and retractable in directions orthogonal to surface **102** of chuck **101**, i.e., coaxial with the longitudinal axis of through bore **141**. In an example embodiment, bellows **138** serves as the air line in fluid communication with at least one air hearing opening **137**. In an example embodiment, the surface of air bearing pad **135** in which at least one air bearing opening **137** is arranged is a surface parallel to surface **102** of chuck **101**. In an example embodiment, at least one air bearing opening **137** is an annular opening in the surface of air bearing pad **135**. In on example embodiment, at least one air bearing opening **137** is a porous medium, e.g., porous metal or sintered metal particles.

In an example embodiment, fixed vacuum bellows **111** includes the same components as floating air bearing **112**, i.e., fixed vacuum bellows **111** is one of the plurality of floating air bearings. This similarity in structure between vacuum bellows **111** and the floating air bearings, such as floating air bearing **112**, reduces the complexity of apparatus **100** and the need to maintain separate sets of replacement parts.

FIG. **3** is a cross-sectional view of apparatus **100** as shown in FIG. **2** including wafer **150** partially secured to apparatus **100**. Wafer **150** is lowered to a position adjacent surface **102** of chuck **101**. In an example embodiment, wafer **150** is lowered within a perimeter defined by the at least two location pins arranged around edge **103** of surface **102** of chuck **101**.

FIG. **4** is a cross-sectional view of apparatus **100** as shown in FIG. **2** including wafer **150**. A first negative air pressure is provided between wafer **150** and vacuum pad **130**. In an example embodiment, this first negative air pressure is created by a vacuum pump (not shown) in fluid communication with vacuum line **134** and through bore **131**. This first negative air pressure tends to draw air into through bore **131** and through vacuum line **134** towards the vacuum pump. This first negative air pressure draws objects towards through bore **131** and thus, vacuum pad **130**. Wafer **150** is brought into contact with vacuum pad **130** as a result of the first negative air pressure between wafer **150** and vacuum pad **130**. Once wafer **150** is in contact with vacuum pad **130**, the first negative air pressure between wafer **150** and vacuum pad **130** couples wafer **150** to vacuum pad **130** and thus, to fixed vacuum bellows **111** as an assembly. As fixed vacuum bellows **111** is arranged within through bore **140**, fixed vacuum bellows **111** cannot move transversely relative to surface **102** of chuck **101**. Thus, after coupling to fixed vacuum bellows **111**, wafer **150** cannot move transversely relative to surface **102** of chuck **101**.

A positive air pressure is provided between wafer **150** and air bearing pad **135**. In an example embodiment, this positive air pressure is created by an air pump (not shown) in fluid communication with an air line and at least one air bearing opening **137**. This positive air pressure tends to vent air from at least one air bearing opening **137**. In an example embodiment, air vented from floating air bearing **112** and other floating air bearings in the plurality of air bearings vents directly to an atmospheric environment. The positive air pressure tends to repel objects away from at least one air bearing opening **137** and thus, away from air bearing pad **135**. In this way, floating air bearing **112** serves as an air bearing, namely, an apparatus for providing a low-friction, load-bearing interface between two surfaces using positive air pressure. As wafer **150** is repelled from floating air bearing **112**, but coupled to fixed vacuum bellows **111**, the portion of wafer **150** generally above floating air bearing **112** is suspended elevationally above floating air bearing **112** by the positive air pressure.

In an example embodiment, a second negative air pressure is provided between wafer **150** and air bearing pad **135**. This second negative air pressure is created by a vacuum pump (not shown) in fluid communication with vacuum line **139** and through bore **136**. This second negative air pressure tends to draw air into through bore **136** and through vacuum line **139** towards the vacuum pump. This second negative air pressure draws objects towards through bore **136** and thus, air bearing pad **135**. In an example embodiment, the effects of the positive air pressure and second negative air pressure created between wafer **150** and floating air bearing **112** are balanced, such that wafer **150** is drawn towards floating air bearing **112**, but wafer **150** is not able to contact floating air bearing **112**, i.e. the portion of wafer **150** immediately elevationally above floating air bearing **112** remains suspended by the positive air pressure.

The combined effects of the positive air pressure and second negative air pressure provided by floating air bearing **112** draw wafer **150** towards floating air bearing **112** while providing a low-friction interface between floating air bearing **112** and wafer **150**. As wafer **150** is drawn towards floating air bearing **112**, its natural tendency is to flatten out, removing any warping in wafer **150**. As the warping in wafer

150 is removed, the dimensions of wafer 150 will change. In an example embodiment, these dimensional changes are generally in the nature of a decrease in the height and increase in the length and width of wafer 150. The tow-friction interface between wafer 150 and floating air bearing 112 permits the portions of wafer 150 generally devotionally above floating air bearing 112 to move transversely, relative to surface 102 of chuck 101, while suspended devotionally over floating air bearing 112. The ability of floating air bearing 112 and other floating air hearings in the plurality of floating air hearings to flatten wafer 150 is enhanced by the coupling of wafer 150 to fixed vacuum bellows 111, which coupling acts to securely anchor wafer 150 at a single point. This anchoring effect permits floating air bearing 112 and other floating air bearings in the plurality of floating air bearings to more effectively flatten the warping in wafer 150 while preventing wafer 150 as a whole from moving transversely relative to surface 102 of chuck 101.

After the warping in wafer 150 has been removed by the desired amount, the balance of the positive air pressure and second negative air pressure created between wafer 150 and floating air bearing 112 can be adjusted to couple wafer 150 to air bearing pad 135 and thus, to floating air bearing 112 as an assembly. In an example embodiment, wafer 150 is coupled to all floating air bearings in the plurality of floating air bearings. Such coupling may occur simultaneously at all floating air bearings or may occur individually in a serial or random order.

FIG. 5 is a cross-sectional view of apparatus 100 as shown in FIG. 2 with wafer 150 fixed to surface 102 of chuck 101. After wafer 150 has coupled to fixed vacuum bellows 111, floating air bearing 112, and other floating air bearings in the plurality of floating air bearings, bellows 133 and 138 and the bellows associated with other floating air hearings in the plurality of floating air bearings retract orthogonally into chuck 101, also retracting respective connected fixed vacuum bellows 111, floating air bearing 112, and other floating air bearings in the plurality of floating air bearings orthogonally into chuck 101. This retraction of fixed vacuum bellows 111, floating air bearing 112, and other floating air bearings in the plurality of floating air bearings clamps wafer 150 to surface 102 of chuck 101, as wafer 150 is coupled with the retracted fixed vacuum bellows ill and the plurality of floating air bearings. By flattening the warping in wafer 150 and clamping it to surface 102 of chuck 101, the surface geometry of chuck 101 is imparted to wafer 150. In an example embodiment, after this clamping occurs, the positive air pressure provided by floating air bearing 112 and other floating air bearings in the plurality of floating air bearings can be ceased.

It will be appreciated that various of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations, or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

What is claimed is:

1. An apparatus for fixing a wafer, comprising:
- a chuck comprising a surface;
- a plurality of through bores in the chuck extending through the surface of the chuck;
- a fixed vacuum bellows; and,
- a plurality of floating air bearings, wherein the fixed vacuum bellows and a respective floating air bearing of the plurality of floating air bearings are each individually arranged in separate through bores of the plurality of through bores, each is configured for reciprocating movement within a respective through bore, and each includes a pad surface disposable from a position that is flush with the surface of the chuck and to a position that is above the surface of the chuck.

2. The apparatus of claim 1, wherein the plurality of floating air bearings comprises:
- a first floating air bearing arranged within a first through bore of the plurality of through bores; and,
- a second floating air bearing arranged within a second through bore of the plurality of through bores, wherein the fixed vacuum bellows is arranged within a third through bore of the plurality of through bores.

3. The apparatus of claim 1, wherein the fixed vacuum bellows comprises:
- a vacuum pad comprising a through bore;
- a bellows connected to the vacuum pad which is both extendable and retractable in directions orthogonal to the surface of the chuck; and,
- a vacuum line arranged within the bellows and connected to the vacuum pad, wherein the vacuum line is in fluid communication with the through bore in the vacuum pad.

4. The apparatus of claim 1, wherein a respective floating air bearing of the plurality of floating air bearings comprises:
- an air bearing pad comprising a through bore;
- a bellows connected to the air bearing pad which is both extendable and retractable in directions orthogonal to the surface of the chuck;
- at least one air bearing opening in a surface of the air bearing pad;
- an air line in fluid communication with the at least one air bearing opening; and,
- a vacuum line arranged within the bellows and connected to the air bearing pad, wherein the vacuum line is in fluid communication with the through bore in the air bearing pad.

5. The apparatus of claim 4, wherein the at least one air bearing opening is an annular opening in the surface of the air bearing pad.

6. The apparatus of claim 4, wherein the at least one air bearing opening is a porous medium.

7. The apparatus of claim 1, further comprising:
- at least two location pins arranged around an edge of the surface of the chuck in at least one direction substantially orthogonal to the surface of the chuck.

8. The apparatus of claim 1, wherein the plurality of floating air bearings vent directly to an atmospheric environment.

9. The apparatus of claim 1, wherein the fixed vacuum bellows comprises one of the plurality of floating air bearings.

10. An apparatus for fixing a wafer, comprising:
- a chuck comprising a surface;
- a plurality of through bores in the chuck extending through the surface of the chuck;
- at least two location pins each arranged proximate an edge of the surface of the chuck and extending above the surface of the chuck in a direction substantially orthogonal to the surface of the chuck;
- a first floating air bearing arranged within a first through bore of the plurality of through bores;
- a second floating air bearing arranged within a second through bore of the plurality of through bores; and,
- a fixed vacuum bellows arranged within a third through bore of the plurality of through bores, wherein

one or more of the first floating air bearing, the second floating air bearing, and fixed vacuum bellows include a pad surface configured for reciprocating movement between a position that is flush with the surface of the chuck and to a position that is above the surface of the 5 chuck.

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