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LIFT PIN ASSEMBLY FOR A SUSCEPTOR OF A PROCESSING CHAMBER

Abstract

Disclosed herewith are a lift pin assembly, a substrate support assembly having the lift pin assembly, and a method of handling a substrate. The lift pin assembly includes a pin head detachably coupled with a pin body. The elongated pin body includes a first material, and the pin head includes a second material different from the first material. The second material is softer than the first material and may have a thermal conductivity about four (4) to eight (8) times of the first material. The second material has a melting point or a sublimation point of at least 600° C.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application claims benefit of U.S. Provisional Application Ser. No. 63/553,565, filed Feb. 14, 2024 (Attorney Docket No. APPM/44023469US01), of which is incorporated by reference in its entirety.

BACKGROUND
Field
[0002] The present disclosure relates to a lift pin assembly for a susceptor of a processing chamber, and, more specifically, relates to a lift pin assembly having a pin head configured to reduce scratching a substrate.
Description of the Related Art
[0003] When a substrate, such as a silicon or a silicon carbide substrate, is processed in a processing chamber, a susceptor is used to support that substrate during processing. To load and unload the substrate from the susceptor, one or more lift pins are used to lift the substrate from or lower the substrate to the surface of the susceptor. Lift pin holes are provided in the susceptor to allow the lift pins to pass through.
[0004] During the processing of a substrate, the lift pin holes can involuntarily function as a heat sink due to convection. As a result, the lift pin holes dissipate heat at a faster rate than other area of the susceptor and has a lower temperature. The substrate area above the lift pin holes may also have a lower temperature than other areas, which causes the material deposited adjacent to the lift pin holes to be thinner than other areas. In addition, the lift pins, upon contact with the substrate, can scratch the backside of the substrate, which may affect subsequent processes of the substrate.
[0005] Thus, a need exists for an improved lift pin for processing a substrate.
SUMMARY
[0006] Disclosed herein are a lift pin assembly, a substrate support assembly including a lift pin assembly, and a method for handling a substrate. The lift pin assembly includes a pin head detachably coupled with a pin body. The elongated pin body includes a first material, and the pin head includes a second material different from the first material. The second material is softer than the first material and may have a thermal conductivity about four (4) to eight (8) times of the first material. The first material and the second material are capable of surviving a temperature range between 400° C. and 1200° C. In an example, the first material and the second material have a melting point or a sublimation point of at least 600° C. The second material may have a melting point or a sublimation point of at least 1200° C.
[0007] The substrate support assembly includes a susceptor having one or more pin holes. A lift pin assembly is disposed inside the one or more pin holes. The lift pin assembly is configured according to various embodiments of the present disclosure.
[0008] The method of handling a substrate in a processing chamber includes disposing a substrate on a surface of a susceptor, raising up a pin head by a pin body, raising up the substrate by the pin head, removing the substrate from the susceptor, and lowering the pin body and the pin head inside a pin hole of a susceptor. The pin body includes a first material, and the pin head includes a second material different from the first material. The second material is softer than the first material and may have a thermal conductivity about four (4) to eight (8) times of the first material. The first material and the second material are capable of surviving a temperature range between 400° C. and 1200° C. In an example, the first material and the second material have a melting point or a

sublimation point of at least 600° C. The second material may have a melting point or a sublimation point of at least 1200° C.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only exemplary embodiments and are therefore not to be considered limiting of its scope, may admit to other equally effective embodiments.

[0010] FIG. **1** illustrates a schematic top view of a processing system, according to an embodiment of the present disclosure.

[0011] FIG. **2** illustrates a schematic cross-sectional view of an EPI

[0012] processing chamber, according to an embodiment of the present disclosure.

[0013] FIG. **3** illustrates a schematic perspective view of a substrate support

[0014] assembly, according to an embodiment of the present disclosure.

[0015] FIG. **4***a* illustrates a schematic cross-sectional view of a susceptor having a pin hole, according to an embodiment of the present disclosure.

[0016] FIG. **4***b* illustrates a schematic cross-sectional view of a pin hole with a lift pin assembly, according to an embodiment of the present disclosure.

[0017] FIG. **5** illustrates a schematic cross-sectional view of a lift pin assembly, according to an embodiment of the present disclosure.

[0018] FIG. **6** illustrates a method for handling a substrate, according to an embodiment of the present disclosure.

[0019] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0020] The disclosure contemplates that terms such as “couples,” “coupling,” “couple,” and “coupled” may include but are not limited to welding, fusing, melting together, interference fitting, and/or fastening such as by using bolts, threaded connections, pins, and/or screws. The disclosure contemplates that terms such as “couples,” “coupling,” “couple,” and “coupled” may include but are not limited to integrally forming. The disclosure contemplates that terms such as “couples,” “coupling,” “couple,” and “coupled” may include but are not limited to direct coupling and/or indirect coupling, such as indirect coupling through components such as links, blocks, and/or frames.

[0021] Disclosed herein is a lift pin assembly that includes a pin head detachably coupled with a pin body. In an embodiment, the pin head and the pin body are made of different materials. For example, the detachable pin head is made of a material configured to reduce scratching a substrate. The material of the pin head may include glassy carbon, graphite, or any other suitable materials. The detachable pin head may be replaced at a higher frequency than the pin body. The pin body is configured to support the pin head. The pin body may be made of a harder material, such as quartz, silicon carbide, or any other suitable materials. In an example, the material of the pin body may be the same or harder than the susceptor to avoid generating debris when the pin body moves inside the lift pin holes. The pin body functions as a sheath that protects the pin head from being scratched by the susceptor. The pin head is also configured to mitigate the heat sink effect. The conductivity of the pin head may be selected to be no greater than 10 times of the conductivity of the pin body.

[0022] In other embodiments, a top surface of the pin head may be further configured to reduce the chance of scratching a substrate. In an example, a center area of the top surface is configured to be higher than peripheral areas to reduce the size of a contact area between the pin head and the substrate. The pin head may include a leg inserted into a channel formed in the pin body. The leg is configured to have a predetermined heat capacity for mitigating the heat sink effect surrounding the lift pin holes. The lift pin includes a bulbous section configured to contact with the surfaces of the lift pin holes. The bulbous section can seal the lift pin holes, further reducing the heat sink effect. The lift pin assembly as set forth in the present disclosure can reduce scratching a substrate and increase the uniformity of deposited layers adjacent to the lift pin holes.

[0023] FIG. **1** illustrates a schematic top view of a processing system **100**, according to one or more embodiments. The processing system **100** includes one or more load lock chambers **122** (two are shown in FIG. **1**), a processing platform **104**, a factory interface **102**, and a controller **144**. In one or more embodiments, the processing system **100** is based on a CENTURA® integrated processing system, from Applied Materials, Inc., located in Santa Clara, California. It is contemplated that other processing systems (including those from other manufacturers) may be adapted to benefit from the disclosure. In one or more embodiments, the processing system includes a processing chamber having a lift pin assembly as set forth in the present disclosure.

[0024] The platform **104** includes a plurality of processing chambers **110**, **112**, **120**, **128**, and the one or more load lock chambers **122** that are coupled to a transfer chamber **136**. The plurality of processing chambers **110**, **112**, **120**, **128** may include an EPI chamber, a rapid thermal process chamber, an etch chamber, and any other suitable chambers. The transfer chamber **136** can be maintained under vacuum, or can be maintained at an ambient (e.g., atmospheric) pressure. Two load lock chambers **122** are shown in FIG. **1**. The factory interface **102** is coupled to the transfer chamber **136** through the load lock chambers **122**.

[0025] In one or more embodiments, the factory interface **102** includes at least one docking station **109** and at least one factory interface robot **114** to facilitate the transfer of substrates. The docking station **109** is configured to accept one or more front opening unified pods (FOUPs). Two FOUPS **106**A, **106**B are shown in the implementation of FIG. **1**. The factory interface robot **114** having a blade **116** disposed on one end of the robot **114** is configured to transfer one or more substrates from the FOUPS **106**A, **106**B, through the load lock chambers **122**, to the processing platform **104** for processing. Substrates being transferred can be stored at least temporarily in the load lock chambers **122**.

[0026] The transfer chamber **136** has a vacuum robot **130** disposed therein. The vacuum robot **130** has one or more blades **134** (two are shown in FIG. **1**) capable of transferring the substrates **124** between the load lock chambers **122** and the processing chambers **110**, **112**, **120**, **128**.

[0027] The controller **144** is coupled to the processing system **100** and is used to control processes and methods, such as the operations of the methods described herein (for example the operations of the method **1000** and/or the method **1050** described below). The controller **144** includes a central processing unit (CPU) **138**, a memory **140** containing instructions, and support circuits **142** for the CPU. The controller **144** controls various items directly, or via other computers and/or controllers.

[0028] FIG. **2** illustrates a schematic cross-sectional view of an EPI processing chamber **200** according to an embodiment. The EPI processing chamber **200** is a deposition chamber to grow an EPI layer on a substrate **202** and includes one or more lift pin assemblies **232** as set forth in the present disclosure. The EPI chamber may be operated at elevated temperatures, such as between 400° C. and 1600° C. or between 600° C. and 1200° C. The elevated temperatures are maintained to process a variety of semiconductor substrates. Common polymeric materials used in components for handling substrates at lower temperature ranges may not survive these elevated temperatures. The lift pin assembly comprises a plurality of materials, which have a melting point or sublimation point of at least 600° C. or at least 1200° C. such that the lift pin assembly can survive the elevated operating temperatures. The processing chamber **200** can be used as one or more of the processing chambers **110**, **112**, **128** shown in FIG. **1**.

[0029] The processing chamber **200** includes an upper body **256**, a lower body **248** disposed below the upper body **256**, and a flow module **212** disposed between the upper body **256** and the lower body **248**. The upper body **256**, the flow module **212**, and the lower body **248** form a chamber body. Disposed within the chamber body is a substrate support assembly **206**, an upper window **208** (such as an upper dome), a lower window **210** (such as a lower dome), a plurality of upper heat sources **241**, and a plurality of lower heat sources **243**. As shown, the controller **144** is in communication with the processing chamber **200** and is used to control processes and methods of at least the processing chamber **200**.

[0030] The plurality of upper heat sources **241** are disposed between the upper window **208** and a lid **254**. The plurality of upper heat sources **241** form a portion of the upper heating module **255**. The plurality of lower heat sources **243** are disposed between the lower window **210** and a chamber floor **252**. The plurality of lower heat sources **243** form a portion of a lower heating module **245**. The upper window **208** is an upper dome and is formed at least partially of an energy transmissive material, such as quartz. The lower window **210** is a lower dome and is formed at least partially of an energy transmissive material, such as quartz.

[0031] According to an embodiment, the heat sources **241**, **243** are lamps that are capable of generating infrared radiation. Other heat sources that are capable of generating infrared radiation are contemplated, such as resistive heaters, light emitting diodes (LEDs), and/or lasers.

[0032] The processing chamber **200** includes one or more thermal sensors **271** configured to detect a thermal condition of the processing chamber **200**. The one or more thermal sensors **271** may include one or more cameras, one or more pyrometers, one or more thermoelectric sensors, and/or one or more thermal labels. The one or more thermal sensors **271** can be mounted, for example, below the lower window **210** (as shown in FIG. **2**), or above the upper window **208** (such as on or in the lid **254**), or any other suitable place in the processing chamber **200**. In one example, a pyrometer is mounted above the upper window **208** and is configured to remotely measure temperature of the substrate **202** and the substrate support assembly **206** during the growth process of an EPI layer.

[0033] The substrate support assembly **206** is disposed between the upper window **208** and the lower window **210**. The substrate support assembly **206** supports the substrate **202** and has a plurality of pin holes **207**. The substrate support assembly **206** is supported by an inner shaft **218** coupled with a motion assembly **221**. The motion assembly **221** includes one or more actuators and/or adjustment devices that provide movement and/or adjustment for the inner shaft **218**, which, in turn, moves the substrate support assembly **206** and the substrate **202**. The substrate support assembly **206** is coupled to the inner shaft **218** through one or more arms **219**. The lift pin holes **207** of the substrate support assembly **206** are each sized to accommodate a lift pin assembly **232** that is used to lift the substrate **202** from the substrate support assembly **206** or lower the same to the substrate support assembly **206**. The lift pin assembly **232** is coupled with the actuator **221** via an outer shaft **220**. The outer shaft **220** includes a plurality of pedestals **222** configured to support the lift pin assembly **232**. According to an embodiment, the lift pin assembly **232** includes a pin head detachably coupled with a lift body. Details of the lift pin assembly **232** will be described in other sections of the present disclosure.

[0034] The flow module **212** includes a plurality of gas inlets **214**, a plurality of purge gas inlets **264**, and one or more gas exhaust outlets **216**. The gas inlets **214** are connected with a plurality of process gas sources **251**, **253** and provides a cross-flow of precursors across a top surface **250** of the substrate **202**. The purge gas inlets **264** are connected to a purge gas source **262** and provide purge gas to the EPI chamber **200**. The plurality of gas inlets **214** and the plurality of purge gas inlets **264** are disposed on the opposite side of the flow module **212** from the one or more gas exhaust outlets **216**. The one or more gas exhaust outlets **216** are connected to or include an exhaust system **278**. The exhaust system **278** fluidly connects the one or more gas exhaust outlets **216** and the exhaust pump **257**. The exhaust system **278** is disposed on an opposite side of the processing chamber **200** relative to the flow module **212**.

[0035] FIG. **3** illustrates a schematic perspective view of a substrate support assembly **206**, according to an embodiment of the present disclosure. The substrate support assembly **206** includes a susceptor **302** supporting a substrate **310**. The susceptor **302** includes a top surface **304** having one or more pin holes **306**, such as three pin holes **306** shown in FIG. **3**. The susceptor **302** is not limited to have three pin holes and may have any suitable number of pin holes, such as four, five, or even a greater number of pin holes. In some embodiments, one or more through holes **308** may be provided through the susceptor **302** to facilitate providing a backside gas to the backside region of the substrate or providing a vacuum to retain the substrate **310** on the substrate support. The susceptor **302** may be made of any suitable materials that have adequate chemical resistance to the chemistry in the processing chamber. The material of the susceptor **302** may include aluminum, alumina, quartz, silicon carbide, graphite, stainless steel, or any other suitable materials.

[0036] FIG. **4***a* illustrates a schematic cross-sectional view of the pin hole pin hole **306** along the lines **312** of FIG. **3** without a lift pin assembly, according to an embodiment. The susceptor **302** includes the lift pin hole **306**. The lift pin hole **306** functions as a through hole that extends through the thickness of the susceptor **302**, such as from a top surface **304** to a bottom surface **416** of the susceptor **302**. According to an embodiment, the lift pin hole **306** is funnel shaped to support a lift pin assembly disposed inside the lift pin hole **306**. For example, the lift pin hole **306** includes a first cylindrical portion **410**, a second cylindrical portion **412**, and a transition portion **406** connecting the first cylindrical portion **410** and the second cylindrical portion **412**. The first cylindrical portion **410** is shallow and disposed adjacent to the surface **304**. The second cylindrical portion **412** is long and extends through the susceptor **302**. The first cylindrical portion **410** has a larger diameter than the second cylindrical portion **412**. The transition portion **406** forms a connection between the first cylindrical portion **410** and the second cylindrical portion **412**. In an embodiment, the transition portion **406** has a frustum shape having an upward facing surface **418** configured to support a lift pin assembly resting in the lift pin hole **306**.

[0037] FIG. **4***b* illustrates a schematic cross-sectional view of the susceptor **302** with a lift pin assembly **402** resting in the lift pin hole **306**, according to an embodiment. The lift pin assembly **402** has a shape that generally conforms with the shape of the lift pin hole **306**. For example, the lift pin assembly **402** is generally funnel-shaped. The lift pin assembly **402** has a downward facing surface **420** configured to contact the upward facing surface **418** of the lift pin hole **306**, thus sealing the lift pin hole **306** and reducing heat loss by convection. In an embodiment, the lift pin assembly **402** includes a pin head **408** detachably coupled with an elongated pin body **414**. The pin head **408** is supported by the pin body **414** and can be lifted up or lowered down by the pin body **414**. FIG. **4***b* shows a resting position of the lift pin assembly **402**, in which position the pin head **408** is substantially disposed inside the lift pin hole **306**. As a result, the top surface **411** of the pin head **408** is below the surface **304** of the susceptor **302**. In an embodiment, the top surface **411** of the pin head **408** is about 0.5 mm, or 1.0 mm below the surface **304** of the susceptor **302**.

[0038] The pin head **408** is configured to reduce substrate scratching and heat-sink effect. A material for the pin head **408** may be selected to be softer than the pin body **414** and the substrate. The material for the pin head **408** may also have a thermal conductivity a few times higher than that of the pin body. In an embodiment, the thermal conductivity of the material for the pin head may be no greater than 10 times of the pin body or about four (4) to eight (8) times of the pin body When a pin head has a much higher conductivity than the pin body, it can cause large temperature variations across the pin hole area. In an embodiment, the material for the pin head **408** may include glassy carbon, graphite, or any other suitable materials. The pin head **408** may be made of the material or have the material deposited as a thin layer on the top surface **411**.

[0039] In an example, the pin head **408** includes a cap **422** and a leg **424**. The cap **422** is disposed

substantially within the first cylindrical portion **410**. The cap **422** may have a cylindrical shape whose diameter is slightly shorter than that of the first cylindrical portion **410**. The leg **424** extends into the pin body **414**. When the pin body **414** includes a through channel **430**, the leg **424** has a length configured to have sufficient heat capacity to mitigate the heat sink effect. In an example, the length of the leg **424** may be about half the thickness of the susceptor **302**.
[0040] The pin body **414** may have a bulbous portion **426** supported by a cylindrical portion **428**. The bulbous portion **426** is disposed at an upper end of the pin body **414** and supports the cap **422** of the pin head **408**. The bulbous portion **426** is configured to have a similar shape with the connecting portion **406**. The downward facing surface **420** is disposed on the bulbous portion **426** and contacts with the upward facing surface **418** to seal the lift pin hole **306** when the lift pin assembly **402** is at a resting position, thus reducing heat loss by convection. The cylindrical portion **428** of the pin body **414** extends through the susceptor **302** and is configured to couple with a lift pedestal **222** (shown in FIG. **2**) below the susceptor **302**. Thus, the cylindrical portion **428** of the pin body **414** is longer than the thickness of the susceptor **302**. The cylindrical portion **428** includes a channel **430**, which may be a blind channel or a through channel.
[0041] The pin head **408** is detachably coupled with the pin body **414**. Any suitable mechanisms may be used to couple the pin head **408** to the pin body **414**, including threads, fitting, and sleeves.
[0042] FIG. **5** illustrates a schematic cross-sectional view of a lift pin assembly **402**, according to an embodiment. The lift pin assembly **402** includes the pin head **408** and the pin body **414**. The pin head **408** includes a top surface **411**, in which a center portion **508** is higher than a peripheral portion **510**. When the pin assembly **402** lifts up a substrate, the center portion **508** is configured to contact the substrate while the peripheral portion **510** does not contact the substrate because the peripheral portion **510** is lower than the center portion **508**. The reduced contact area with the substrate also reduces the chances to scratch the substrate. The pin head **408** has a cap **422** which has a bottom surface **502** that is configured to contact with a top surface **504** of the pin body **414**. The pin head **408** also has a leg **424** coupled with the cap **422**. The leg has a smaller diameter than that of the cap **422**. The leg **424** can be inserted into a channel **506** formed inside the pin body **414**. The channel **506** may extend through the entire pin body **414** (a through channel) or only a partial portion of the pin body **414** (a blind channel).
[0043] FIG. **6** illustrates a method **600** for handling a substrate in a processing chamber, according to an embodiment. At operation **602**, a substrate is disposed on the surface of a susceptor. The susceptor includes a plurality of pin holes, each of which contains a lift pin assembly. At operation **604**, the lift pin assembly is raised up by an actuator. The lift pin assembly includes a pin body and a pin head. The actuator is configured to lift the pin body, which, in turn, raises up the pin head. At operation **606**, the pin head contacts the substrate disposed on the surface of the susceptor and raises up the substrate. To reduce scratching, the pin head comprises a softer material than the pin body. At operation **608**, the substrate is removed from the pin head by a robotic arm. At operation **610**, the lift pin assembly is lowered to the inside of the lift pin hole.
[0044] It is contemplated that one or more aspects disclosed herein may be combined. Moreover, it is contemplated that one or more aspects disclosed herein may include some or all of the aforementioned benefits. While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

Claims

1. A lift pin assembly for a substrate support assembly, comprising: an elongated pin body comprising a first material; and a pin head detachably coupled with the elongated pin body and comprising a second material different from the first material, wherein the second material is softer than the first material, and the second material has a melting point or a sublimation point of at least

600° C.
2. The lift pin assembly of claim 1, wherein the second material has a melting point or a sublimation point of at least 1200° C.
3. The lift pin assembly of claim 2, wherein the second material of the pin head has a thermal conductivity of about four (4) to eight (8) times of the first material of the pin body.
4. The lift pin assembly of claim 1, wherein the pin head comprises a cap coupled with a leg, and a bottom surface of the cap is supported by a top surface of the pin body.
5. The lift pin assembly of claim 4, wherein the leg is disposed inside a channel of the elongated pin body.
6. The lift pin assembly of claim 5, wherein the cap comprises glassy carbon.
7. The lift pin assembly of claim 6, wherein a length of the leg is about half of a thickness of a susceptor of the substrate support assembly.
8. The lift pin assembly of claim 4, wherein the pin head comprises a top surface that is uneven.
9. The lift pin assembly of claim 8, wherein the top surface comprises a layer of glassy carbon, and the leg comprises quartz.
10. The lift pin assembly of claim 1, wherein the elongated pin body comprises a bulbous portion disposed at an upper end and a cylindrical portion below the bulbous portion.
11. The lift pin assembly of claim 10, wherein the elongated pin body comprises a channel that extends through the bulbous portion.
12. The lift pin assembly of claim 11, wherein the first material is selected from quartz, aluminum, silicon carbide, or stainless steel.
13. A substrate support assembly for an epitaxy chamber, comprising: a susceptor comprising a lift pin hole; and a lift pin assembly disposed within the lift pin hole and comprising: an elongated body comprising a first material; and a pin head detachably coupled with the elongated body and comprising a second material different from the second material, wherein the second material is softer than the first material, and the second material has a melting point or a sublimation point of at least 600° C.
14. The substrate support assembly of claim 13, wherein the lift pin hole has a funnel shape comprising a frustum portion connecting a first cylindrical portion and a second cylindrical portion.
15. The substrate support assembly of claim 14, wherein the lift pin assembly generally conforms to the funnel shape of the lift pin hole.
16. The substrate support assembly of claim 15, wherein the lift pin assembly includes a downward facing surface configured to contact with an upward facing surface of the frustum portion of the lift pin hole.
17. The substrate support assembly of claim 16, wherein the first material is harder than the second material of the susceptor, and the second material has a thermal conductivity of about four (4) to eight (8) times of the first material.
18. The substrate support assembly of claim 13, wherein the pin head comprises a top surface disposed below a top surface of the susceptor.
19. The substrate support assembly of claim 18, wherein the pin head comprises glassy carbon.
20. A method of handling a substrate in a processing chamber, comprising: raising up a pin head by a pin body, the pin body disposed in a lift pin hole formed through a susceptor; raising a substrate by the pin head, wherein the pin body comprises a first material different from a second material comprised by the pin head, wherein the second material is softer than the first material and the second material has a melting point or a sublimation point of at least 600° C.; and removing the substrate from the susceptor.