

the rotary chuck. A controller controls power supplied to each of the at least five individually controllable groups of radiant heating elements based on a position of the discharge point of the liquid dispenser.

5 In preferred embodiments of the apparatus according to the present invention, the at least five individually controllable groups of radiant heating elements comprises at least ten individually controllable groups of radiant heating elements.

10 In preferred embodiments of the apparatus according to the present invention, the at least five individually controllable groups of radiant heating elements comprises at least fifteen individually controllable groups of radiant heating elements.

15 In preferred embodiments of the apparatus according to the present invention, the at least five individually controllable groups of radiant heating elements comprises at least twenty individually controllable groups of radiant heating elements.

20 In preferred embodiments of the apparatus according to the present invention, the radiant heating elements are LED heating elements.

 In preferred embodiments of the apparatus according to the present invention, the LED heating elements emit

radiation having a maximum intensity in a wavelength range from 380 nm to 650 nm.

In preferred embodiments of the apparatus according to the present invention, the LED heating elements emit
5 radiation in a wavelength range from 380 nm to 650 nm.

In preferred embodiments of the apparatus according to the present invention, the heating assembly is positioned relative to the chuck so as to heat a wafer shaped article held on the chuck from one side only and without contacting
10 the wafer shaped article.

In preferred embodiments of the apparatus according to the present invention, the heating assembly overlies the rotary chuck and is positioned between the rotary chuck and a surface of a wafer-shaped article that faces the rotary
15 chuck when mounted on the rotary chuck.

In preferred embodiments of the apparatus according to the present invention, the liquid dispenser comprises an arm that is movable relative to the rotary chuck from a more central region of the rotary chuck to a more peripheral
20 region of the rotary chuck.

In preferred embodiments of the apparatus according to the present invention, a plate that is transparent to radiation emitted by the radiant heating elements is mounted for rotation with the rotary chuck and is positioned between
25 the heating assembly and a wafer-shaped article when

positioned on the rotary chuck.

In preferred embodiments of the apparatus according to the present invention, the plate is made of quartz or sapphire.

5 In preferred embodiments of the apparatus according to the present invention, each of the at least five individually controllable groups of radiant heating elements is capable of applying a power intensity of at least 2 W/cm² to a wafer-shaped article when positioned on
10 the rotary chuck.

In preferred embodiments of the apparatus according to the present invention, each of the at least five individually controllable groups of radiant heating elements is capable of applying a power intensity of at least 4 W/cm²
15 to a wafer-shaped article when positioned on the rotary chuck.

In preferred embodiments of the apparatus according to the present invention, the at least five individually controllable groups of radiant heating elements are arranged
20 concentrically to an axis of rotation of the rotary chuck.

In preferred embodiments of the apparatus according to the present invention, the controller is configured to supply full power to one of the at least five individually controllable groups in response to the discharge point of

impair or prevent the correct performance of the associated semiconductor device.

Conventional techniques for mitigating the phenomenon of pattern collapse include the use of a rinse liquid having lower surface tension than deionized water, with IPA being the predominant choice, and the use of such rinse liquid at elevated temperature; however, as noted above, such techniques have limited effect on reducing pattern collapse.

The present inventors have discovered that rapid localized heating of the wafer along a moving front can serve to evaporate the rinse liquid sufficiently quickly that a meniscus as shown in Fig. 1b is not formed, and the attendant pattern collapse shown in Fig. 1c is thereby avoided.

Fig. 2 shows a first embodiment of an apparatus designed to implement that discovery, in which a rotary chuck 10 is designed to hold and rotate a wafer W of a predetermined diameter, for example 300mm or 450mm. Wafer W is held by a circular series of gripping pins 16, which in this embodiment are six in number. Pins 16 pass through openings in a transparent plate 25 made of quartz or sapphire. Plate 25 is secured to chuck 10 by screws 26 and rotates with the chuck 10. When a wafer W is positioned on the chuck, it is held above the plate 25 so that the lower surface of the wafer is parallel to the plate 25 and spaced

therefrom by a small gap.

Beneath the transparent plate 25 is mounted a radiant heating assembly 50, which will be described in greater detail below.

5 Adjacent the chuck 10 a boom swing arm 30 is mounted for pivotal motion about its drive motor 34. Arm 30 is supplied with process and/or rinse liquid, which is discharged downwardly through its discharge nozzle 32. Boom swing arm 30 is movable between a standby position shown in
10 solid line in Fig. 2, and a central position shown in broken line. Discharge nozzle 32 can therefore scan across the full radius of a wafer W, and when a wafer W is rotated by chuck 10, thereby dispense liquid onto its entire upwardly-facing surface.

15 Turning now to Fig. 3, it can be seen that the rotary chuck 10 is made up of a lower chuck body 12 and an upper chuck body 14, which are secured to one another and are journaled for rotation about a stationary central post 20. The pins 16 and transparent plate 25 also rotate with the
20 chuck 10 in this embodiment, as does the ring gear 18 which is in continuous meshing engagement with each of the gripping pins 16 via gear teeth provided at the bases of these latter. Ring gear 18 can also rotate relative to the chuck 10 to a limit extent. thereby to rotate pins 16 about
25 their respective axes and move the uppermost eccentric

gripping portions between their open and closed positions,
in a manner well known *per se*.

The stationary post 20 is mounted on a machine frame 40
of the apparatus, as is a stator 44, whereas rotor 42 is
5 secured to the lower chuck body 12, with the stator 44 and
rotor 42 constituting a magnetic motor that drives the chuck
10 in rotation. Further particulars of the overall chuck
structure are described for example in commonly-owned U.S.
Patent No. 9,245,777.

10 Radiant heating assembly 50 in this embodiment is
mounted on the stationary post 20, and therefore does not
rotate, whereas it is enveloped by the rotating structure of
the chuck comprising elements 25, 14, 16. Radiant heating
assembly 50 in this embodiment comprises a multiplicity of
15 blue LEDs 51 mounted facing the transparent plate 25, and a
controller 52 (e.g. an on-board controller (not shown)
mounted on the underside of heating assembly 50).
Controller 52 controls the turning on and off, as well as
the power, of the blue LEDs 51, and also communicates
20 wirelessly with the motor 34 of the boom swing arm 30.

As shown in Fig. 4, the radiant heating assembly 50 is
composed of an aluminum substrate made up of upper and lower
pieces 54 and 55 that are brazed together, the aluminum
substrate serving as a heat sink to prevent excessive
25 heating of the structure beneath the blue LED elements 51. A

printed circuit board 53 is mounted on top of upper piece 54, on which the traces for the LED elements are formed and on which the LED elements 51 are mounted.

Onboard chips 56 are mounted on a printed circuit board 60 secured to the underside of lower piece 55. Wires 58 interconnecting the output pins of onboard chips 56 and the input terminals of the traces formed on PCB 53 are accommodated in pockets 57 that pass through the aluminum substrate 53, 54.

As shown in Fig. 5, the PCB 53 of this embodiment is formed in four quadrants, which are joined together by connectors 59. The LED elements 51 are formed in groups of sixteen, i.e., the arrangement of onboard chips 56 and the connections from those chips to PCB 53, along with the onboard controller 52, permit the LEDs to be powered individually in groups as small as sixteen.

It will be seen in Fig. 5 that the LEDs 51 are arranged in twenty concentric circles, and that the number of LEDs in each circle is a multiple of sixteen. Thus, each concentric circle can be individually controlled as a separate heating zone, by virtue of the arrangement described above.

The blue LED lamps 51 have a maximum intensity at a wavelength of about 450 nm. Other sources of radiation could be used, but it is preferred to use sources emitting radiation having a maximum intensity in a wavelength range

2. The apparatus according to claim 1, wherein said at least five individually controllable groups of radiant heating elements comprises at least ten individually controllable groups of radiant heating elements.

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3. The apparatus according to claim 1, wherein said at least five individually controllable groups of radiant heating elements comprises at least fifteen individually controllable groups of radiant heating elements.

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4. The apparatus according to claim 1, wherein said at least five individually controllable groups of radiant heating elements comprises at least twenty individually controllable groups of radiant heating elements.

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5. The apparatus according to claim 1, wherein said radiant heating elements are LED heating elements.

6. The apparatus according to claim 5, wherein the LED heating elements emit radiation having a maximum intensity in a wavelength range from 380 nm to 650 nm.

7. The apparatus according to claim 5, wherein the LED heating elements emit radiation in a wavelength range from 380 nm to 650 nm.

8. The apparatus according to claim 1, wherein said heating assembly is positioned relative to said chuck so as to heat a wafer shaped article held on said chuck from one side only and without contacting the wafer shaped article.

9. The apparatus according to claim 1, wherein said heating assembly overlies said rotary chuck and is positioned between said rotary chuck and a surface of a wafer-shaped article that faces the rotary chuck when mounted on the rotary chuck

10. The apparatus according to claim 9, wherein said liquid dispenser comprises an arm that is movable relative to said rotary chuck from a more central region of said rotary chuck to a more peripheral region of said rotary chuck.

11. The apparatus according to claim 1, further comprising a plate that is transparent to radiation emitted by said radiant heating elements, said plate being mounted for rotation with said rotary chuck and being positioned between said at least heating assembly and a wafer-shaped article when positioned on said rotary chuck.

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12. The apparatus according to claim 11, wherein said plate is made of quartz or sapphire.

13. The apparatus according to claim 1, wherein each
5 of said at least five individually controllable groups of radiant heating elements is capable of applying a power intensity of at least 2 W/cm² to a wafer-shaped article when positioned on said rotary chuck.

10 14. The apparatus according to claim 1, wherein each of said at least five individually controllable groups of radiant heating elements is capable of applying a power intensity of at least 4 W/cm² to a wafer-shaped article when positioned on said rotary chuck.

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15. The apparatus according to claim 1, wherein said at least five individually controllable groups of radiant heating elements are arranged concentrically to an axis of rotation of said rotary chuck.

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16. The apparatus according to claim 1, wherein said controller is configured to supply full power to one of said