

WHAT IS CLAIMED IS:

1. A method of dechucking a substrate from an electrostatic chuck in a plasma processing chamber, the method comprising:

- supplying process gas into the chamber;
- energizing the process gas into a plasma state;
- maintaining the plasma chamber at a vacuum pressure and low RF power to produce a plasma sheath above the substrate of 2 mm or greater thickness;
- lifting the substrate above a support surface of the electrostatic chuck to a mid-lift position within the plasma sheath which does not induce plasma instability and maintaining the substrate at the mid-lift position;
- extinguishing the plasma; and
- lifting the substrate above the mid-lift position to an upper position at which the substrate can be removed from the plasma chamber.

2. The method of Claim 1, wherein:

- (a) the process gas is argon, nitrogen, or a mixture thereof;
- (b) the substrate is held in the mid-lift position for 2 to 30 seconds; and/or
- (c) the substrate is lifted 0.5 to 3 mm above the support surface of the electrostatic chuck when in the mid-lift position.

3. The method of Claim 1, wherein the substrate is lifted by lift pins made of electrically insulating material while dechucking and a voltage is applied to the electrostatic chuck.

4. The method of Claim 1, wherein:

- (a) the substrate is a silicon wafer bonded to a glass carrier, the method further comprising plasma etching the silicon material;
- (b) the substrate is a semiconductor wafer, the method further comprising etching a silicon layer in the wafer; or
- (c) the substrate is a semiconductor wafer having at least one layer of dielectric material, the method further comprising plasma etching openings into the dielectric material.

5. The method of Claim 5, wherein He gas is supplied to the underside of the substrate while plasma etching the openings in the dielectric material, the method further comprising terminating supply of the He gas before the substrate is raised to the mid-lift position.

6. The method of Claim 1, wherein He gas is supplied to the underside of the substrate and, before the substrate is released from the electrostatic chuck, supplying of He gas to the underside of the substrate is terminated.

7. The method of Claim 1, wherein He gas is supplied to the underside of the substrate, and further comprising applying a backpressure of He at 1 to 5 Torr to an underside of the wafer while the process gas is in a plasma state.

8. The method of Claim 1, wherein voltage to the electrostatic chuck is set to a value prior to lifting the substrate sufficient to reduce a spike in substrate voltage potential to below 25V in magnitude.

9. The method of Claim 1, wherein the substrate is lifted to at least 5 mm above the support surface of the electrostatic chuck during the lifting to the upper position.

10. The method of Claim 1, wherein:

(a) the plasma processing chamber is a capacitively coupled plasma processing chamber wherein an upper showerhead electrode is located opposite a lower electrode on which the substrate is supported, and the energizing comprises supplying radio frequency power to the lower electrode; or

(b) the plasma processing chamber is an inductively coupled plasma processing chamber comprising a coil, and the energizing comprises supplying RF power to the coil.

11. The method of Claim 10, wherein the chamber is the capacitively coupled plasma processing chamber and a gap between the upper electrode and the lower electrode is at least 20 mm and pressure in the chamber is at 15 to 500 mTorr.

12. The method of Claim 1, further comprising applying a dechucking voltage prior to extinguishing the plasma.

13. The method of Claim 12, wherein the dechucking voltage is set to a value within 50V or within 200V of a plasma-induced bias on the substrate.

14. The method of Claim 1, further comprising processing the substrate prior to lifting the substrate, wherein the processing comprises (a) forming a layer on an upper surface of the substrate or (b) stripping photoresist from the substrate.

15. The method of Claim 1, wherein the lifting to the mid-lift position and the lifting above the mid-lift position both comprise lifting with a pneumatic actuator, and wherein gas flow through a shuttle valve contributes to a low lifting force.

1 16. A pneumatic lift mechanism for a plasma reactor wherein lift pins raise and lower a substrate in at least three positions with respect to an upper surface of an electrostatic chuck, the lift mechanism comprising:

a housing having an upper chamber and a lower chamber;
an upper piston slidably mounted to move up and down in the upper chamber;
a lower piston slidably mounted to move up and down in the lower chamber, the lower chamber comprising a hard stop defining an upper limit of travel of the lower piston;
the at least three positions comprising (1) a lower position at which the upper piston positions the lift pins below the upper surface of the electrostatic chuck, (2) a mid-lift position at which the lower piston is in contact with the hard stop and a shaft of the lower piston raises the upper piston, and (3) an up position at which the upper piston positions the lift pins so the substrate can be removed from the plasma chamber; and
wherein the upper piston and the lower piston are independently pneumatically operated.

472. The lift mechanism of claim-16_1, further comprising a lift pin yoke operably connected to a shaft extending upward from the upper piston.

483. The lift mechanism of claim-16_1, wherein:

the housing includes gas inlets operably connected to pressurized gas sources, the gas inlets including a first gas inlet in fluid communication with a portion of the upper chamber above the upper piston, a second gas inlet in fluid communication with a portion of the upper chamber below the upper piston, a third gas inlet in fluid communication with a portion of the lower chamber above the lower piston, and a fourth gas inlet in fluid communication with a portion of the lower chamber below the lower piston; and

an up force on the upper piston is limited by an opposing pneumatic pressure provided by pressurized gas supplied to the first inlet.

494. The lift mechanism of claim-18_3, wherein: the first gas inlet is in fluid communication with a first gas source supplying gas at a pressure of 25 to 65 psig and the second, third, and fourth gas inlets are in fluid communication with a second gas source supplying gas at a pressure of 70 to 120 psig, and the lift mechanism further comprises a controller operable to selectively supply gas from the first and second gas sources to the gas inlets.

205. The lift mechanism of claim-19_4, further comprising a valve operating to place the first gas inlet in fluid communication with either the first gas source or the second gas source.