

CLAIMS

1. An apparatus for providing photoresist films, the apparatus comprising:
 - a processing chamber,
 - a wafer support disposed within the processing chamber,
 - 5 a showerhead positioned above the wafer support and configured to distribute gases flowed therethrough across the wafer support, wherein the showerhead includes a first plenum that is fluidically connected with a plurality of first gas distribution ports leading to a reaction space between the wafer support and the showerhead,
 - one or more valve manifolds having, in aggregate, one or more valves, and
 - 10 a controller having one or more processors and one or more memory devices, wherein:
 - the one or more processors and the one or more memory devices are operably connected, and
 - the one or more memory devices store computer-executable instructions for
 - 15 controlling the one or more processors to:
 - a) cause at least a first valve of the one or more valves to be actuated to cause a vapor-phase of a first organometallic precursor to be flowed through the first plenum of the showerhead and into the reaction space via the first gas distribution ports, and
 - 20 b) cause at least a second valve of the one or more valves to be actuated to cause a vapor-phase of a first counter-reactant to be flowed through the second plenum of the showerhead and into the reaction space via the second gas distribution ports.
- 25 2. The apparatus of claim 1, wherein the photoresist films are extreme ultra-violet photoresist films.
3. The apparatus of claim 1, wherein:

the first organometallic precursor has a formula of $M_aR_bL_c$, where M is a metal with a high EUV absorption cross-section, R is alkyl, L is a ligand, ion, or other moiety that is reactant with the first counter-reactant, and a, b, and c are each greater than or equal to 1, and

5 the first counter-reactant is reactive with the first organometallic precursor so as to link two or more metal atoms of the first organometallic precursor via chemical bonding.

4. The apparatus of claim 1, wherein the metal of the first organometallic precursor has an EUV absorption cross-section absorption cross section equal to or greater than $1 \cdot 10^7 \text{ cm}^2/\text{mol}$.

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5. The apparatus of claim 3, wherein the first organometallic precursor contains a metal selected from the group consisting of: tin, bismuth, antimony, and tellurium.

15 6. The apparatus of claim 3, further comprising:
a first vaporizer that is fluidically connected with the first valve; and
a quantity of the first organometallic precursor located within the first vaporizer.

7. The apparatus of claim 6, further comprising:
20 a second vaporizer that is fluidically connected with the second valve; and
a quantity of the counter-reactant located within the second vaporizer, wherein the first counter-reactant contains a substance selected from the group consisting of: water, a peroxide, a dihydroxyl alcohol, a polyhydroxy alcohol, a fluorinated dihydroxyl alcohol, a fluorinated polyhydroxy alcohol, a fluorinated glycol, and a substance containing one or
25 more hydroxyl moieties.

8. The apparatus of claim 3, wherein the first counter-reactant contains a substance selected from the group consisting of: water, a peroxide, a dihydroxyl alcohol, a polyhydroxy alcohol, a fluorinated dihydroxyl alcohol, a fluorinated polyhydroxy alcohol, a fluorinated glycol, and a substance containing one or more hydroxyl moieties.

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9. The apparatus of claim 8, further comprising:
a second vaporizer that is fluidically connected with the second valve; and
a quantity of the counter-reactant located within the second vaporizer.

10 10. The apparatus of claim 1, wherein the one or more memory devices further store additional computer-executable instructions for further controlling the one or more processors to perform (a) and (b) simultaneously.

11 11. The apparatus of claim 1, wherein the one or more memory devices further store
15 additional computer-executable instructions for further controlling the one or more processors to perform (a) and (b) in an alternating fashion for one or more cycles of (a) and (b).

12 12. The apparatus of claim 1, wherein the one or more memory devices further store
20 additional computer-executable instructions for further controlling the one or more processors to:

c) cause at least a third valve of the one or more valves to be actuated to cause a vapor-phase of a second organometallic precursor to be flowed through the first plenum of the showerhead and into the reaction space via the first gas distribution ports, and

25 d) cause at least a fourth valve of the one or more valves to be actuated to cause a vapor-phase of a first counter-reactant to be flowed through the second plenum of the showerhead and into the reaction space via the second gas distribution ports, wherein the first organometallic precursor and the second organometallic precursor are different.

13. The apparatus of claim 12, further comprising:
- a first vaporizer that is fluidically connected with the first valve,
 - a second vaporizer that is fluidically connected with the second valve,
 - 5 a third vaporizer that is fluidically connected with the third valve,
 - a fourth vaporizer that is fluidically connected with the second valve,
 - a quantity of the first organometallic precursor located within the first vaporizer,
 - a quantity of the first counter-reactant located within the second vaporizer,
 - a quantity of the second organometallic precursor located within the third vaporizer,
 - 10 and
 - a quantity of the second counter-reactant located within the fourth vaporizer.
14. The apparatus of claim 13, wherein the one or more memory devices further store additional computer-executable instructions for further controlling the one or more processors to:
- 15 e) perform (a) and (b) to form a first sub-layer on a substrate supported by the wafer support, and
 - f) perform, subsequent to (e), (c) and (d) to form a second sub-layer on top of the first sub-layer, wherein:
 - the first sub-layer is a first metal oxide having a first EUV absorption cross-section,
 - 20 the second sub-layer is a second metal oxide having a second EUV absorption cross-section, and
 - the second EUV absorption cross-section is lower than the first EUV absorption cross-section.
- 25 15. The apparatus of claim 13, wherein the one or more memory devices further store additional computer-executable instructions for further controlling the one or more processors to:

e) perform (a) and (b) multiple times and in an alternating fashion to form a first sub-layer on a substrate supported by the wafer support, and

f) perform, subsequent to (e), (c) and (d) simultaneously to form a second sub-layer on top of the first sub-layer.

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16. The apparatus of claim 1, further comprising:

a first heater system for heating the showerhead;

a second heater system for heating the processing chamber; and

a top plate that is part of the wafer support and which includes a third heater system
10 embedded therewithin, wherein the one or more memory devices further store additional computer-executable instructions for further controlling the one or more processors to control the first heater system, the second heater system, and the third heater system to cause an interior wall surface of the processing chamber to be at least 95°C higher than the average temperature of the top plate during (a) and (b).

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17. The apparatus of claim 16, wherein the one or more memory devices further store additional computer-executable instructions for further controlling the one or more processors to control the first heater system, the second heater system, and the third heater system to cause, during (a) and (b), an interior wall surface of the processing
20 chamber to be at least 95°C and the average temperature of the top plate to be at or below 100°C.

18. The apparatus of claim 16, wherein:

the top plate includes a plurality of mesas that protrude from a wafer support region
25 in the top surface thereof,

the mesas are configured to support a substrate placed thereupon such that a back side gap exists between the top surface and the substrate,

the wafer support includes a plurality of gas ports within the wafer support region that are fluidically connected with the top surface, and

the one or more memory devices further store additional computer-executable instructions for further controlling the one or more processors to cause a backside cooling
5 gas to be directed through the gas ports during (a) and (b).

19. The apparatus of claim 16, wherein:

the third heater system includes a plurality of concentric zones,

each zone has one or more resistance heater traces located therewithin, and

10 the one or more resistance heater traces of each zone are configured to be independently controllable by the controller.

20. The apparatus of claim 1, further comprising:

a vacuum foreline fluidically connected with the processing chamber, wherein the
15 wafer support is fluidically interposed between the vacuum foreline and the showerhead;

a first bypass line; and

a second bypass line, wherein:

the first bypass line is fluidically connected with the vacuum foreline and with
a first bypass valve of the one or more valves,

20 the second bypass line is fluidically connected with the vacuum foreline and with a second bypass valve of the one or more valves, and

the one or more memory devices further store additional computer-executable instructions for further controlling the one or more processors to:

25 actuate the one or more valves to cause the first organometallic precursor to flow through the first bypass line to the vacuum foreline prior to performing (a), and

actuate the one or more valves to cause the first counter-reactant to flow through the second bypass line to the vacuum foreline prior to performing (b).