

CLAIMS

1. A composition for atomic layer deposition of a silicon doped hafnium oxide film comprising:

at least one organoaminosilane precursor selected from the group consisting of tetrakis(dimethylamino)silane, and tetrakis(ethylmethylamino)silane; and

at least one organoaminohafnium precursor selected from the group consisting of tetrakis(dimethylamino)hafnium, and tetrakis(ethylmethylamino)hafnium;

wherein

at least one of the at least one organoaminosilane precursor and at least one of the at least one organoaminohafnium precursor have a same organoamino ligand;

less than 5 ppm of halide impurities; and

less than 5 ppm of metal impurities.
2. The composition of Claim 1, wherein the composition comprises tetrakis(dimethylamino)silane and tetrakis(dimethylamino)hafnium.
3. The composition of Claim 1, wherein the composition comprises tetrakis(ethylmethylamino)silane and tetrakis(ethylmethylamino)hafnium.
4. The composition of Claim 1, wherein

the at least one organoaminosilane precursor ranges about 9.00 to about 11.00 wt. %; about 9.50 to about 10.50 wt. %, about 9.75% to about 10.25 wt. %, or about 9.90% to about 10.10 wt. %; and

the at least one organoaminohafnium precursor ranges about 89.00 to about 91.00 wt. %; about 89.50 to about 90.50 wt. %, about 89.75 to about 90.25 wt. %, or about 89.90 to about 90.90 wt. %.

5. The composition of Claim 1, wherein the composition comprises 9.89 (± 1) wt. % tetrakis(dimethylamino)silane and 90.11(± 1) wt. % tetrakis(dimethylamino)hafnium; or the composition comprises 10 (± 1) wt. % tetrakis(dimethylamino)silane and 90 wt. % (± 1 wt. %) tetrakis(dimethylamino)hafnium.
6. The composition of Claim 1, wherein the composition comprises 9.89 (± 1) wt. % tetrakis(ethylmethylamino)silane and 90.11(± 1) wt. % tetrakis(ethylmethylamino)hafnium or the composition comprises 10 (± 1) wt. % tetrakis(ethylmethylamino)silane and 90 wt. % (± 1 wt. %) tetrakis(ethylmethylamino)hafnium.
7. The composition of Claim 1, wherein the composition comprises 10 ppm or less, or 5 ppm or less of chloride ions.
8. The composition of Claim 1 further comprises (c) a solvent selected from the group consisting of ether, tertiary amine, alkyl hydrocarbon, aromatic hydrocarbon, siloxanes, tertiary aminoether, and combinations thereof.
9. The composition of Claim 1 further comprises (c) a solvent selected from the group consisting of ether, tertiary amine, alkyl hydrocarbon, aromatic hydrocarbon, siloxanes, tertiary aminoether, and combinations thereof; and total weight percent of the at least one organoaminosilane precursor and the at least one organoaminohafnium precursor is from 0.01 to 90.99 wt. %, 10.00 to 90.00 wt. %, 20.00 to 80.00 wt. %, 30.00 to 70.00 wt. %, or 40.00 to 60.00 wt. %.
10. The composition of Claim 1, wherein the at least one organoaminosilane precursor comprises tetrakis(dimethylamino)silane, the at least one organoaminohafnium precursor comprises tetrakis(dimethylamino)hafnium and weight percent (wt. %) ratio of

tetrakis(dimethylamino)hafnium to tetrakis(dimethylamino)silane ranges from 7 to 13, 8 to 12, or 9 to 11.

11. A method to deposit a film comprising silicon, hafnium, and oxygen onto a substrate, comprising:

- a) providing the substrate in a reactor;
- b) introducing into the reactor the composition of any one of claims 1 to 10;
- c) purging the reactor with a purge gas;
- d) introducing an oxygen-containing source into the reactor; and
- e) purging the reactor with the purge gas;

wherein

the oxygen-containing source is selected from the group consisting of an oxygen plasma, ozone, hydrogen peroxide, a water vapor, water vapor plasma, nitrogen oxide plasma, a carbon oxide plasma, and combinations thereof;

the purge gas selected from the group consisting of argon (Ar), nitrogen (N₂), helium (He), neon, hydrogen (H₂), and combinations thereof;

deposition process is selected from the group consisting of a thermal atomic layer deposition (ALD), plasma enhanced atomic layer deposition (PEALD) process, cyclic chemical vapor deposition, plasma enhanced cyclic chemical vapor deposition, and combination thereof;

the method is conducted at a temperature ranging from 100°C to 350°C, 125°C to 325°C, 150°C to 325°C, 200°C to 300°C, 220°C to 300°C, or 230°C to 300°C; and

b) through e) are repeated until a desired thickness of film is deposited.

12. The method of Claim 11, wherein the composition is delivered into the reactor via vaporization through direct liquid injection apparatus.

13. The method of Claim 11, wherein the oxygen-containing source further comprises an inert gas selected from the group consisting of argon, helium, nitrogen, hydrogen, and combinations thereof.

14. A system to deposit a film comprising silicon, hafnium, and oxygen onto a substrate, comprising:
the substrate in a reactor; and
the composition of any one of claims 1 to 10;
wherein
the system is at a temperature ranging from 100°C to 350°C, 125°C to 325°C, 150°C to 325°C, 200°C to 300°C, 220°C to 300°C, or 230°C to 300°C.
15. A silicon doped hafnium oxide film suitable as ferroelectric materials deposited by using the composition of any one of claims 1 to 10 or the method of any one of claims 11 to 13.
16. The silicon doped hafnium oxide film of claim 15, wherein the silicon doped hafnium oxide film has a silicon doping level ranging from 2 to 6 mol. %, or 3.00 to 5.00 mol. %.
17. The silicon doped hafnium oxide film of claim 15, wherein the silicon doped hafnium oxide film has a silicon doping level ranging from 3.00 to 5.00 mol. %.
18. A vessel employing the composition of any one of claims 1 to 10.