

CLAIMS

~~What is claimed is:~~

1. A method of forming low dielectric-constant (low- κ) films, the method comprising:
depositing, by atomic-layer deposition (ALD) techniques, a film-deposition layer;
doping the deposited film layer with fluorine;
depositing, by atomic-layer deposition techniques, a subsequent film-deposition layer; ~~and~~
repeating the deposition operations and the doping operations as needed to obtain a final film thickness of a film having a low dielectric constant; and
selecting at least one variable from variables comprising a level of fluorine doping and a deposited film thickness per deposition layer, such that the resulting formed film has a low dielectric constant in a range of 3.15 to 3.4.
2. The method of claim 1, wherein the resulting formed film has a low dielectric constant in a range of 3.2 to 3.4.
- ~~23.~~ 3. The method of claim 1, where the formed low- κ films are silicon-based materials.
- ~~34.~~ 4. The method of claim ~~23~~, further comprising selecting a silane precursor.
- ~~45.~~ 5. The method of claim 1, wherein the low- κ films comprise at least one material selected from materials including fluorine-doped silicon oxide (SiOF), carbonofluoridoysilicon (SiOCF), and fluorinated silicon oxynitride (SiONF).

~~56.~~ The method of claim 1, further comprising selecting a density of the fluorine dopant is within a range of ~~about~~ 1×10^{18} atoms per cm^3 to ~~about~~ 1×10^{21} atoms per cm^3 .

~~67.~~ The method of claim ~~56~~, wherein the stated range of the density of the fluorine dopant is within a silicon oxide (SiO_x) matrix.

~~7.~~ The method of claim 1, further comprising selecting at least one variable from variables comprising a level of fluorine doping and a deposited film thickness per deposition layer.

~~8.~~ The method of claim 7, further comprising selecting the at least one variable such that a resulting formed film has a low dielectric constant in a range of about 3.2 to about 3.4.

~~98.~~ A method of forming a low dielectric-constant (low- κ) film, the method comprising:

introducing a silane precursor into a reaction chamber;

depositing, by an atomic-layer deposition (ALD) process, at least a first layer of film;

oxidizing and cleaning the first layer of film; and

doping the first layer of film with a fluorine-based dopant material; and

repeating the deposition operations and the doping operations as needed

to obtain a final desired film thickness of a film having a low

dielectric constant in a range of 3.15 to 3.4.

~~109.~~ The method of claim ~~98~~, further comprising ~~repeating the deposition operations and the doping operations as needed to obtain a final desired film thickness of a~~ wherein the film having a low dielectric constant in a range of ~~about~~ 3.2 to ~~about~~ 3.4.

~~11~~10. The method of claim ~~9~~8, further comprising adding an anneal operation.

~~12~~11. The method of claim ~~9~~8, further comprising forming the film at least partially within a high-aspect feature thereby providing a substantially void-free gap-fill of the high-aspect ratio feature.

~~13~~12. The method of claim ~~9~~8, further comprising selecting a profile of the fluorine-dopant profile to have a gradient profile in at least one spatial direction.

~~14. The method of claim 9, further comprising selecting a profile of the fluorine dopant profile to have a gradient profile in at least one spatial direction.~~

~~15~~13. A method of forming a low dielectric-constant (low- κ) silicon oxide (SiO_x) film, the method comprising:
depositing, by atomic-layer deposition (ALD) techniques, a film-deposition layer;
doping the deposited film layer with a halide;
depositing, by atomic-layer deposition (ALD) techniques, a subsequent film-deposition layer of SiO_x ; and
repeating the deposition operations and the doping operations as needed to obtain a final film thickness of the SiO_x film having a low dielectric constant in a range of ~~about 3.2~~3.23.15 to ~~about 3.4~~.

14. The method of claim 13, wherein the SiO_x film has a low dielectric constant in a range of 3.2 to 3.4.

~~16~~15. The method of claim ~~15~~13, further comprising selecting the halide to comprise at least one material selected from materials including

iodine and bromine.

~~1716~~. A method of forming a low dielectric-constant (low- κ) film, the method comprising:
modulating a film thickness by atomic-layer deposition (ALD) techniques, in a layer-by-layer film-deposition process;
doping each deposited film layer with dopant material selected from at least one dopant material comprising fluorine and a halide;
depositing, by atomic-layer deposition (ALD) techniques, a subsequent film-deposition layer; and
repeating the deposition operations and the doping operations as needed to obtain a final film thickness of the low- κ film, such that the resulting formed film has a low dielectric constant in a range of 3.15 to 3.4.

17. The method of claim 16, wherein the resulting formed film has a low dielectric constant in a range of 3.2 to 3.4.

18. The method of claim ~~1716~~, further comprising selecting a type of dielectric material to be deposited.

19. The method of claim ~~1716~~, wherein the low- κ film comprises at least one material selected from materials including fluorine-doped silicon oxide (SiOF), carbonofluoridoysilicon (SiOCF), and fluorinated silicon oxynitride (SiONF).

20. The method of claim ~~1716~~, wherein the low- κ film comprises at least one material selected from materials including carbonofluoridoylgermanium (GeOCF) and fluorine-doped germanium oxide (GeOF) materials.