activating a plasma to produce an activated $C_4H_2F_6$ and an activated CH_3I; and

allowing an etching reaction to proceed between the film uncovered by the patterned mask layer and the activated $C_4H_2F_6$ and the CH_3I to selectively etch the film from the patterned mask layer, thereby forming the HAR patterned structure. The disclosed methods may include one or more of the following aspects:

- further comprising the step of introducing an oxidizer into the reaction chamber, wherein the oxidizer is selected from O_2, O_3, CO, CO_2, NO, N_2O, NO_2, H_2O, H_2O_2, COS, SO_2 and combinations thereof;
- further comprising the step of introducing an inert gas into the reaction chamber, wherein the inert gas is selected from the group consisting of He, Ar, Xe, Kr, Ne and N_2;
- a high conductive sidewall passivation layer being formed on sidewalls of the HAR patterned structure;
- a conductivity of the high conductive sidewall passivation layer formed with the activated $C_4H_2F_6$ and the activated CH_3I being at least approximately 10% higher than the conductivity of the high conductive sidewall passivation layer formed with the activated $C_4H_2F_6$ without the addition of the activated CH_3I;
- the HAR patterned structure formed in the film having an aspect ratio between approximately 1:1 and approximately 200:1;
- further comprising introducing an additional etch gas into the reaction chamber, wherein the additional etch gas is selected from the group consisting of cC_4F_8, C_4F_8, cC_5F_8, C_5F_8, C_4F_6, CF_4, CH_3F, CF_3H, CH_2F_2, C_3HF_7, C_3F_6, $C_3H_2F_6$, $C_3H_2F_4$, $C_3H_3F_5$, C_4HF_7, C_5HF_9, C_3F_6, C_3F_8, CF_3I, C_2F_3I, C_2F_5I, C_3F_7I ,1-Iodoheptafluoropropane (1-C_3F_7I), 2-Iodoheptafluoropropane (2-C_3F_7I), C_3HF_7, COS, FNO, F-C≡N, CS_2, SO_2, SF_6, trans-1,1,1,4,4,4-hexafluoro-2-butene (*trans*-$C_4H_2F_6$), cis-1,1,1,4,4,4-hexafluoro-2-butene (*cis*-$C_4H_2F_6$), hexafluoroisobutene ($C_4H_2F_6$), trans-1,1,2,2,3,4-hexafluorocyclobutane (*trans*-$C_4H_2F_6$), 1,1,2,2,3-pentafluorocyclobutane ($C_4H_3F_5$), 1,1,2,2-tetrafluorocyclobutane ($C_4H_4F_4$), and cis-1,1,2,2,3,4-hexafluorocyclobutane (*cis*-$C_4H_2F_6$), and combinations thereof; and
- the film being a silicon-containing film that contains O and/or N and optionally contains dopants such as B, C, P, As Ga, In, Sn, Sb, Bi and/or Ge, and combinations thereof.

[0013a] In one aspect, there is provided a method for forming a high aspect ratio (HAR) structure during a HAR etch process in a substrate in a reaction chamber, the method comprising sequentially or simultaneously exposing the substrate to a vapor of an etchant including a

hydrofluorocarbon or fluorocarbon compound and an additive compound, the substrate having a film disposed thereon and a patterned mask layer disposed on the film; activating a plasma to produce an activated hydrofluorocarbon or fluorocarbon compound and an activated additive compound; and allowing an etching reaction to proceed between the film uncovered by the patterned mask layer and the activated hydrofluorocarbon or fluorocarbon compound and the activated additive compound to selectively etch the film from the patterned mask layer, thereby forming the HAR patterned structure, wherein a high conductive sidewall passivation layer is formed on sidewalls of the HAR patterned structure, wherein a conductivity of the high conductive sidewall passivation layer formed with the activated hydrofluorocarbon or fluorocarbon compound and the activated additive compound is at least 10% higher than the conductivity of the high conductive sidewall passivation layer formed with the activated hydrofluorocarbon or fluorocarbon compound without the addition of the activated additive compound.

Notation and Nomenclature

[0014] The following detailed description and claims utilize a number of abbreviations,

What is claimed is:

1. A method for forming a high aspect ratio (HAR) structure during a HAR etch process in a substrate in a reaction chamber, the method comprising:

sequentially or simultaneously exposing the substrate to a vapor of an etchant including a hydrofluorocarbon or fluorocarbon compound and an additive compound, the substrate having a film disposed thereon and a patterned mask layer disposed on the film;

activating a plasma to produce an activated hydrofluorocarbon or fluorocarbon compound and an activated additive compound; and

allowing an etching reaction to proceed between the film uncovered by the patterned mask layer and the activated hydrofluorocarbon or fluorocarbon compound and the activated additive compound to selectively etch the film from the patterned mask layer, thereby forming the HAR patterned structure,

wherein a high conductive sidewall passivation layer is formed on sidewalls of the HAR patterned structure,

wherein a conductivity of the high conductive sidewall passivation layer formed with the activated hydrofluorocarbon or fluorocarbon compound and the activated additive compound is at least 10% higher than the conductivity of the high conductive sidewall passivation layer formed with the activated hydrofluorocarbon or fluorocarbon compound without the addition of the activated additive compound.

2. The method of claim 1, further comprising the step of introducing an oxidizer into the reaction chamber, wherein the oxidizer is selected from O_2, O_3, CO, CO_2, NO, N_2O, NO_2, H_2O, H_2O_2, COS, SO_2 and combinations thereof.

3. The method of claim 1, further comprising the step of introducing an inert gas into the reaction chamber, wherein the inert gas is selected from the group consisting of He, Ar, Xe, Kr, Ne and N_2.

4. The method of claim 1, wherein the hydrofluorocarbon or fluorocarbon compound include CF_4, CH_3F, C_2F_6, C_3F_8, C_2HF_5, C_5F_8, C_6F_6, C_4F_6, C_4F_8, C_1 to C_5 saturated or unsaturated linear, branched, cyclic hydrofluorocarbons, selected from $C_4H_2F_6$, CHF_3, CH_2F_2, or combinations thereof.

5. The method of claim 1, wherein the hydrofluorocarbon or fluorocarbon compound is $C_4H_2F_6$.

6. The method of claim 1, wherein the additive compound contains iodine, carbon and/or silicon elements having the following formula:

$C_nR^1R^2R^3I$,

$SiR^1R^2R^3I$,

$SiR^1R^2I_xF_{(2-x)}$,

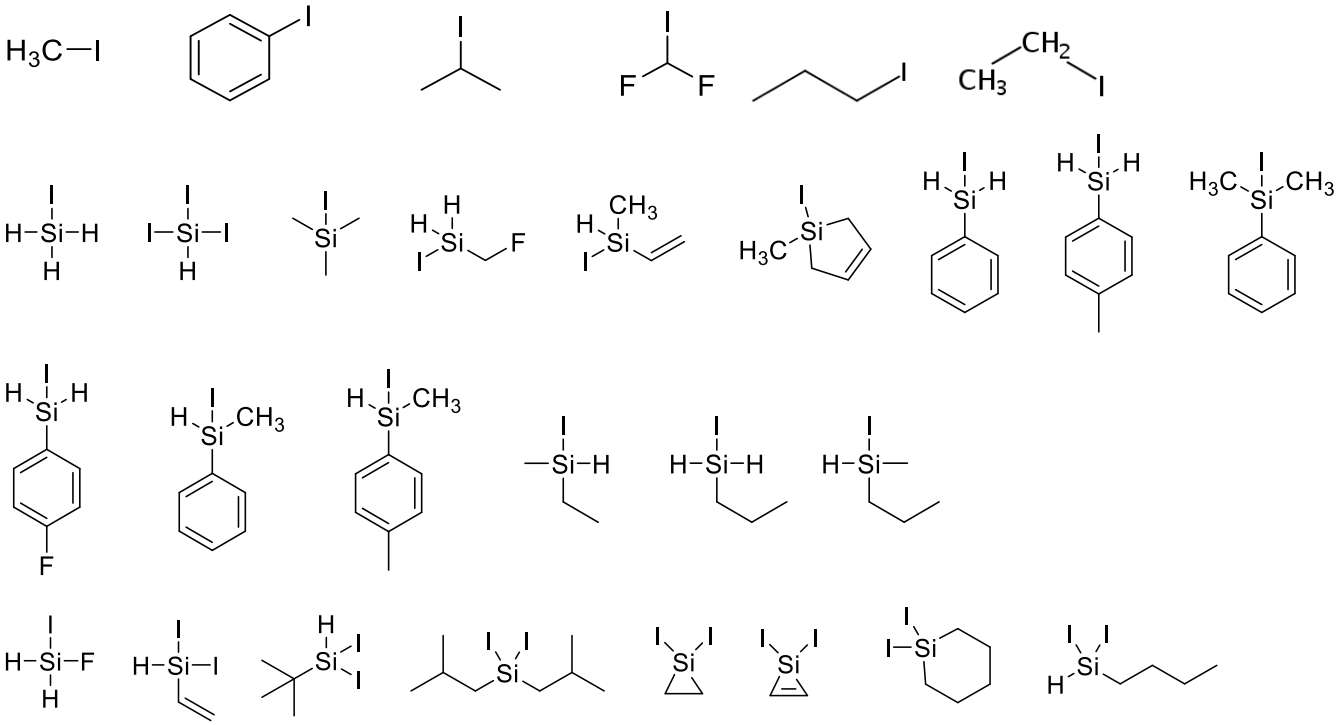
$SiRI_yF_{(3-y)}$,

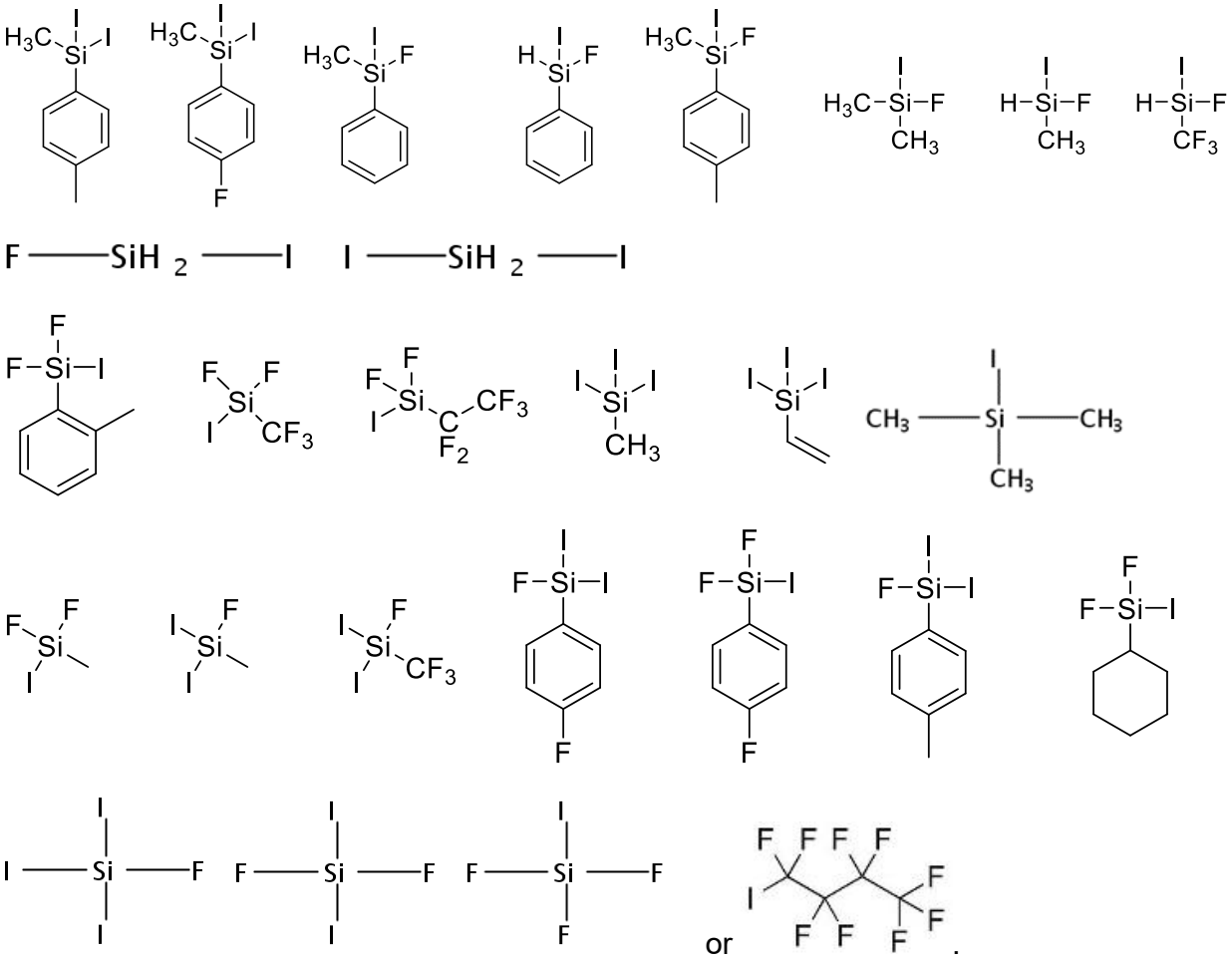
$SiI_zF_{(4-z)}$, or

$C_nF_{(2n+1)}I$

wherein n = 1 to 10; x = 1-2; y = 1-3; z = 1-3; R, R^1, R^2 and R^3 each are independently selected from H, C_1-C_{10} linear, branched or cyclic, saturated or unsaturated, aromatic, heterocyclic, partially or fully fluorinated, substituted or unsubstituted alkyl groups; R^1 and R^2, R^2 and R^3 or R^1 and R^3 may also be linked to form a cyclic group.

7. The method of any one of claims 1 to 6, wherein the additive compound is selected from





8. The method of any one of claims 1 to 6, wherein the film is a silicon-containing film that contains O and/or N and contains dopants selected from B, C, P, As Ga, In, Sn, Sb, Bi and/or Ge, and combinations thereof.

9. The method of any one of claims 1 to 6, wherein the patterned mask layer is an a-C layer, a doped a-C layer, a photoresist layer, an anti-reflective layer, an organic planarization layer, a poly-Si layer, a metal oxide layer and combinations thereof, wherein the metal oxide is selected from oxide of Ti, Al, Zr or Hf.

10. The method of any one of claims 1 to 6, wherein the HAR patterned structure formed in the film has an aspect ratio between 1:1 and 200:1.

11. The method of any one of claims 1 to 6, further comprising introducing an additional etch gas into the reaction chamber, wherein the additional etch gas is selected from the group consisting of cC_4F_8, C_4F_8, cC_5F_8, C_5F_8, C_4F_6, CF_4, CH_3F, CF_3H, CH_2F_2, C_3HF_7, C_3F_6, $C_3H_2F_6$, $C_3H_2F_4$, $C_3H_3F_5$, C_4HF_7, C_5HF_9, C_3F_6, C_3F_8, CF_3I, C_2F_3I, C_2F_5I, C_3F_7I

,1-Iodoheptafluoropropane (1-C_3F_7I), 2-Iodoheptafluoropropane (2-C_3F_7I), C_3HF_7, COS, FNO, F-C≡N, CS_2, SO_2, SF_6, trans-1,1,1,4,4,4-hexafluoro-2-butene (*trans*-$C_4H_2F_6$), cis-1,1,1,4,4,4-hexafluoro-2-butene (*cis*-$C_4H_2F_6$), hexafluoroisobutene ($C_4H_2F_6$), trans-1,1,2,2,3,4-hexafluorocyclobutane (*trans*-$C_4H_2F_6$), 1,1,2,2,3-pentafluorocyclobutane ($C_4H_3F_5$), 1,1,2,2-tetrafluorocyclobutane ($C_4H_4F_4$), and cis-1,1,2,2,3,4-hexafluorocyclobutane (*cis*-$C_4H_2F_6$), and combinations thereof.

12. A method for forming a HAR patterned structure, the method comprising the steps:

sequentially or simultaneously exposing the substrate to a vapor of $C_4H_2F_6$ and CH_3I, the substrate having a film disposed thereon and a patterned mask layer disposed on the film;

activating a plasma to produce an activated $C_4H_2F_6$ and an activated CH_3I; and

allowing an etching reaction to proceed between the film uncovered by the patterned mask layer and the activated $C_4H_2F_6$ and the CH_3I to selectively etch the film from the patterned mask layer, thereby forming the HAR patterned structure.

13. The method of claim 12, further comprising the step of introducing an oxidizer into the reaction chamber, wherein the oxidizer is selected from O_2, O_3, CO, CO_2, NO, N_2O, NO_2, H_2O, H_2O_2, COS, SO_2 and combinations thereof.

14. The method of claim 12, further comprising the step of introducing an inert gas into the reaction chamber, wherein the inert gas is selected from the group consisting of He, Ar, Xe, Kr, Ne and N_2.

15. The method of claim 12, wherein a high conductive sidewall passivation layer is formed on sidewalls of the HAR patterned structure.

16. The method any one of claims 12 to 15, wherein a conductivity of the high conductive sidewall passivation layer formed with the activated $C_4H_2F_6$ and the activated CH_3I is at least 10% higher than the conductivity of the high conductive sidewall passivation layer formed with the activated $C_4H_2F_6$ without the addition of the activated CH_3I.

17. The method of any one of claims 12 to 15, wherein the HAR patterned structure formed in the film has an aspect ratio between 1:1 and 200:1.

18. The method of any one of claims 12 to 15, further comprising introducing an additional etch gas into the reaction chamber, wherein the additional etch gas is selected from the group consisting of cC_4F_8, C_4F_8, cC_5F_8, C_5F_8, C_4F_6, CF_4, CH_3F, CF_3H, CH_2F_2, C_3HF_7, C_3F_6, $C_3H_2F_6$, $C_3H_2F_4$, $C_3H_3F_5$, C_4HF_7, C_5HF_9, C_3F_6, C_3F_8, CF_3I, C_2F_3I, C_2F_5I, C_3F_7I ,1-Iodoheptafluoropropane (1-C_3F_7I), 2-Iodoheptafluoropropane (2-C_3F_7I), C_3HF_7, COS, FNO, F-C≡N, CS_2, SO_2, SF_6, trans-1,1,1,4,4,4-hexafluoro-2-butene (*trans*-$C_4H_2F_6$), cis-1,1,1,4,4,4-hexafluoro-2-butene (*cis*-$C_4H_2F_6$), hexafluoroisobutene ($C_4H_2F_6$), trans-1,1,2,2,3,4-hexafluorocyclobutane (*trans*-$C_4H_2F_6$), 1,1,2,2,3-pentafluorocyclobutane ($C_4H_3F_5$), 1,1,2,2-tetrafluorocyclobutane ($C_4H_4F_4$), and cis-1,1,2,2,3,4-hexafluorocyclobutane (*cis*-$C_4H_2F_6$), and combinations thereof.