Also disclosed are plasma etching compounds selected from trans-1,1,1,4,4,4-hexafluoro-2-butene; cis-1,1,1,4,4,4-hexafluoro-2-butene; hexafluoroisobutene; hexafluorocyclobutane (trans-1,1,2,2,3,4); pentafluorocyclobutane (1,1,2,2,3-); tetrafluorocyclobutane (1,1,2,2-); or hexafluorocyclobutane (cis-1,1,2,2,3,4). The plasma etching compound has a purity of at least 99.9% by volume and less than 0.1% by volume trace gas impurities. A total content of nitrogen-containing and oxygen-containing gas contained in said trace gaseous impurities is less than 150 ppm by volume. The disclosed plasma etching compounds may include one or more of the following aspects:

- the etching compound being trans-1,1,1,4,4,4-hexafluoro-2-butene;
- the etching compound being cis-1,1,1,4,4,4-hexafluoro-2-butene;
- the etching compound being hexafluoroisobutene;
- the etching compound being hexafluorocyclobutane (trans-1,1,2,2,3,4);
- the etching compound being pentafluorocyclobutane (1,1,2,2,3-);
- the etching compound being tetrafluorocyclobutane (1,1,2,2-);
- the etching compound being hexafluorocyclobutane (cis-1,1,2,2,3,4);
- the oxygen-containing gas being water;
- the oxygen-containing gas being CO_2;
- the nitrogen-containing gas being N_2; and
- the plasma etching compound having a water content of less than 20 ppm by weight.

In one aspect, there is provided a method for fabricating a 3D NAND flash memory having alternating layers of a first etching layer and a second etching layer on a substrate and a hardmask layer on the alternating layers, the method comprising the steps of forming a hardmask pattern on the hardmask layer; and using the hardmask pattern to form apertures in the alternating layers by selectively plasma etching the alternating layers of the first etching layer and the second etching layer versus the hardmask layer in a plasma reaction chamber using a hydrofluorocarbon etching gas selected from the group consisting of hexafluoroisobutene (CAS No. 382-10-5); and tetrafluorocyclobutane (1,1,2,2-); wherein the first etching layer comprises a material different from that of the second etching layer.

In another aspect, the present disclosure provides a method for fabricating a 3D NAND flash memory having alternating layers of a first etching layer and a second etching layer on a substrate and a hardmask layer on the alternating layers, the method comprising the steps of forming a hardmask pattern on the hardmask layer; and using the hardmask pattern to form apertures in the alternating layers by selectively plasma etching the alternating layers of the first etching layer and the second etching layer versus the hardmask layer using an etching gas hexafluoroisobutene, wherein the first etching layer comprises a material different from that of the second etching layer.

Brief Description of the Drawings

For a further understanding of the nature and objects of the present invention, reference should be made to the following detailed description, taken in conjunction with the accompanying drawings, in which like elements are given the same or analogous reference numbers and wherein:

FIG 1 is the structural formula for trans-1,1,1,4,4,4-hexafluoro-2-butene;

FIG 2 is the structural formula for cis-1,1,1,4,4,4-hexafluoro-2-butene;

FIG 3 is the structural formula for trans-1,1,2,2,3,4-hexafluorocyclobutane;

FIG 4 is the structural formula for cis-1,1,2,2,3,4-hexafluorocyclobutane;

FIG 5 is the structural formula for hexafluoroisobutene;

What is claimed is:

1. A method for fabricating a 3D NAND flash memory having alternating layers of a first etching layer and a second etching layer on a substrate and a hardmask layer on the alternating layers, the method comprising the steps of:

forming a hardmask pattern on the hardmask layer; and

using the hardmask pattern to form apertures in the alternating layers by selectively plasma etching the alternating layers of the first etching layer and the second etching layer versus the hardmask layer in a plasma reaction chamber using a hydrofluorocarbon etching gas selected from the group consisting of hexafluoroisobutene (CAS No. 382-10-5); and tetrafluorocyclobutane (1,1,2,2-);

wherein the first etching layer comprises a material different from that of the second etching layer.

2. The method of claim 1, wherein the alternating layers comprises a layer of silicon oxide, silicon nitride, poly-Si, silicon oxynitride, silica, SiCOH, or combinations thereof.

3. The method of claim 1, wherein the first etching layer comprises a silicon oxide layer and the second etching layer comprises a silicon nitride layer, and vice versa.

4. The method of claim 1, wherein the hardmask layer is composed of carbon and metals.

5. The method of claim 4, wherein the alternating layers are selectively plasma etched from the hardmask layer composed of carbon and metals.

6. The method of claim 1, wherein the hydrofluorocarbon etching gas is hexafluoroisobutene.

7. The method of any one of claims 1 to 6, wherein the hydrofluorocarbon etching gas plasma etches the alternating layers of the first etching layer and the second etching layer versus the hardmask layer with an improved selectivity.

8. The method of any one of claims 1 to 6, wherein the apertures have an aspect ratio between approximately 10:1 and approximately 100:1.

9. The method of any one of claims 1 to 6, further comprising introducing an oxidizer into the plasma reaction chamber.

10. The method of claim 9, wherein the oxygen-containing gas is selected from the group consisting of O_2, O_3, CO, CO_2, NO, N_2O, NO_2 and combinations thereof.

11. The method of any one of claims 1 to 6, further comprising introducing an inert gas into the plasma reaction chamber.

12. The method of any one of claims 1 to 6, further comprising introducing a second etch gas, wherein the second etch gas is selected from the group consisting of cC_4F_8, C_4F_8, cC_5F_8, C_4F_6, CF_4, CHF_3, CFH_3, CH_2F_2, COS, CS_2, CF_3I, C_2F_3I, C_2F_5I, and SO_2.

13. A method for fabricating a 3D NAND flash memory having alternating layers of a first etching layer and a second etching layer on a substrate and a hardmask layer on the alternating layers, the method comprising the steps of:

forming a hardmask pattern on the hardmask layer; and

using the hardmask pattern to form apertures in the alternating layers by selectively plasma etching the alternating layers of the first etching layer and the second etching layer versus the hardmask layer using an etching gas hexafluoroisobutene,

wherein the first etching layer comprises a material different from that of the second etching layer.