

CLAIMS

1. A method for etching features in a stack, comprising:
forming a combination hardmask, comprising:
forming a first hardmask layer comprising carbon or silicon oxide over the stack;
forming a second hardmask layer comprising metal over the first hardmask layer;
forming a third hardmask layer comprising carbon or silicon oxide over the second hardmask layer, and
forming a fourth hardmask layer comprising metal over the third hardmask layer;
etching the fourth hardmask layer, comprising:
flowing a fourth hardmask layer etch gas comprising a halogen component;
and
forming the fourth hardmask layer etch gas into a plasma; and
stopping the flow of the fourth; and
etching the third hardmask layer, comprising:
flowing a third hardmask layer etch gas comprising oxygen and at least one of COS or SO₂;
forming the first hardmask layer etch gas into a plasma; and
stopping the flow of the first hardmask layer etch gas;
patterning the first and second hardmask layers; and
etching the stack through the combination hardmask.
2. The method, as recited in claim 1, wherein the second hardmask comprises at least one of elemental metal, a metal alloy, a metal oxide, metal carbide, or a metal nitride.
3. The method, as recited in claim 1, wherein the stack is at least one of a silicon oxide layer, OPOP or ONON.
4. The method, as recited in claim 1, further comprising ashing the first hardmask layer.
5. The method, as recited in claim 1, wherein the patterning the first and second hardmask layers comprises:
forming a patterned mask over the hardmask layers;
etching the second hardmask layer; and
etching the first hardmask layer.
6. The method, as recited in claim 5, wherein the patterning the first and second hardmask layers comprises:
etching the second hardmask layer, comprising:
flowing a second hardmask layer etch gas comprising a halogen component;
forming the second hardmask layer etch gas into a plasma; and
stopping the flow of the second hardmask layer etch gas; and
etching the first hardmask layer, comprising:
flowing a first hardmask layer etch gas comprising oxygen and at least one of COS or SO₂;
forming the first hardmask layer etch gas into a plasma; and
stopping the flow of the first hardmask layer etch gas.

7. The method, as recited in claim 6, wherein the patterning the hardmask layers removes the patterned mask.
8. The method, as recited in claim 5, wherein the etching the second hardmask layer, comprises:
 - flowing a second hardmask layer etch gas comprising a halogen component;
 - forming the second hardmask layer etch gas into a plasma; and
 - stopping the flow of the second hardmask layer etch gas; and wherein etching the first hardmask layer, comprises:
 - flowing a first hardmask layer etch gas comprising oxygen and at least one of COS or SO₂;
 - forming the first hardmask layer etch gas into a plasma; and
 - stopping the flow of the first hardmask layer etch gas.
9. The method, as recited in claim 8, wherein the second hardmask comprises at least one of elemental metal, a metal alloy, a metal oxide, metal carbide, or a metal nitride.
10. The method, as recited in claim 9, wherein the stack is at least one of a silicon oxide layer, OPOP or ONON.
11. A method for etching features in a stack, wherein the stack is at least one of a silicon oxide layer, OPOP or ONON, comprising:
 - forming a combination hardmask, comprising:
 - forming a first hardmask layer comprising carbon or silicon oxide over the stack;
 - forming a second hardmask layer comprising metal over the first hardmask layer,
 wherein the second hardmask layer comprises at least one of elemental metal, a metal alloy, a metal oxide, metal carbide, or a metal nitride;
 - forming a third hardmask layer comprising carbon or silicon oxide over the second hardmask layer;
 - forming a fourth hardmask layer comprising metal over the third hardmask layer;
 - forming a patterned mask over the hardmask layers;
 - etching the fourth hardmask layer through the patterned mask, comprising:
 - flowing a fourth hardmask layer etch gas comprising a halogen component;
 - and
 - forming the fourth hardmask layer etch gas into a plasma, and
 - stopping the flow of the fourth; and
 - etching the third hardmask layer, comprising:
 - flowing a third hardmask layer etch gas comprising oxygen and at least one of COS or SO₂;
 - forming the first hardmask layer etch gas into a plasma; and
 - stopping the flow of the first hardmask layer etch gas; and
 - patterning the first and second hardmask layers, wherein the patterning the first and second hardmask layers comprises:
 - etching the second hardmask layer, comprising
 - flowing a second hardmask layer etch gas comprising a halogen component;
 - forming the second hardmask layer etch gas into a plasma; and
 - stopping the flow of the second hardmask layer etch gas; and
 - etching the first hardmask layer, comprising:
 - flowing a first hardmask layer etch gas comprising oxygen and at least one of COS or SO₂;
 - forming the first hardmask layer etch gas into a plasma; and
 - stopping the flow of the first hardmask layer etch gas;

etching the stack through the combination hardmask.

12. The method, as recited in claim 11, wherein the patterning the hardmask layers removes the patterned mask.
13. The method, as recited in claim 12, further comprising ashing the first hardmask layer.
14. A method for etching features in a stack, comprising:
 - forming a combination hardmask, comprising:
 - forming a first hardmask layer comprising carbon or silicon oxide over the stack;
 - forming a second hardmask layer comprising metal over the first hardmask layer; and
 - forming a patterned mask over the second hardmask layer;
 - etching the second hardmask layer through the patterned mask, comprising:
 - flowing a second hardmask layer etch gas comprising a halogen component;
 - forming the second hardmask layer etch gas into a plasma; and
 - stopping the flow of the second hardmask layer etch gas;
 - etching the first hardmask layer, comprising:
 - flowing a first hardmask layer etch gas comprising oxygen and at least one of COS or SO₂;
 - forming the first hardmask layer etch gas into a plasma; and
 - stopping the flow of the first hardmask layer etch gas; and
 - etching the stack through the combination hardmask.
15. The method, as recited in claim 14, further comprising patterning the first and second hardmask layers by the steps of etching the second hardmask layer and etching the first hardmask layer.
16. The method, as recited in claim 15, wherein the patterning the first and second hardmask layers removes the patterned mask.
17. The method, as recited in claim 15, wherein the stack is at least one of a silicon oxide layer, OPOP or ONON.
18. The method, as recited in claim 15, further comprising ashing the first hardmask layer.
19. The method, as recited in claim 15 wherein the stack is at least one of silicon oxide or polysilicon.
20. The method, as recited in claim 15, wherein the forming the combination hardmask further comprises forming a third hardmask layer comprising carbon or silicon oxide over the second hardmask layer, and forming a fourth hardmask layer comprising metal over the third hardmask layer, wherein the forming the patterned mask over the second hardmask layer forms the patterned mask over the fourth hardmask layer.
21. The method, as recited in claim 20, further comprising:
 - etching the fourth hardmask layer, comprising:
 - flowing a fourth hardmask layer etch gas comprising a halogen component;
 - forming the fourth hardmask layer etch gas into a plasma; and
 - stopping the flow of the fourth hardmask layer etch gas; and
 - etching the third hardmask layer, comprising:

- flowing a third hardmask layer etch gas comprising oxygen and at least one of COS or SO₂;
forming the third hardmask layer etch gas into a plasma; and
stopping the flow of the third hardmask layer etch gas.
22. The method, as recited in claim 15, wherein the first hardmask layer is of amorphous carbon.
23. The method, as recited in claim 22, wherein the second hardmask layer is of titanium nitride.
24. The method, as recited in claim 23, wherein the patterned mask is of silicon nitride.
25. The method, as recited in claim 15, wherein the second hardmask layer comprises at least one of elemental metal, a metal alloy, a metal oxide, metal carbide, or a metal nitride.
26. The method, as recited in claim 25, wherein the stack is at least one of a silicon oxide layer, OPOP or ONON.
27. The method, as recited in claim 26, wherein the forming the combination hardmask further comprises forming a third hardmask layer comprising carbon or silicon oxide over the second hardmask layer, and forming a fourth hardmask layer comprising metal over the third hardmask layer.
28. The method, as recited in claim 27, further comprising:
etching the fourth hardmask layer, comprising:
flowing a fourth hardmask layer etch gas comprising a halogen component;
forming the fourth hardmask layer etch gas into a plasma; and
stopping the flow of the fourth hardmask layer etch gas; and
etching the third hardmask layer, comprising:
flowing a third hardmask layer etch gas comprising oxygen and at least one of COS or SO₂;
forming the third hardmask layer etch gas into a plasma; and
stopping the flow of the third hardmask layer etch gas.
29. The method, as recited in claim 28, wherein the patterning the first and second hardmask layers removes the patterned mask.
30. The method, as recited in claim 29, further comprising ashing the first hardmask layer.
31. The method, as recited in claim 14, wherein the second hardmask comprises at least one of elemental metal, a metal alloy, a metal oxide, metal carbide, or a metal nitride.
32. The method, as recited in claim 14, wherein the stack is at least one of a silicon oxide layer, OPOP or ONON.