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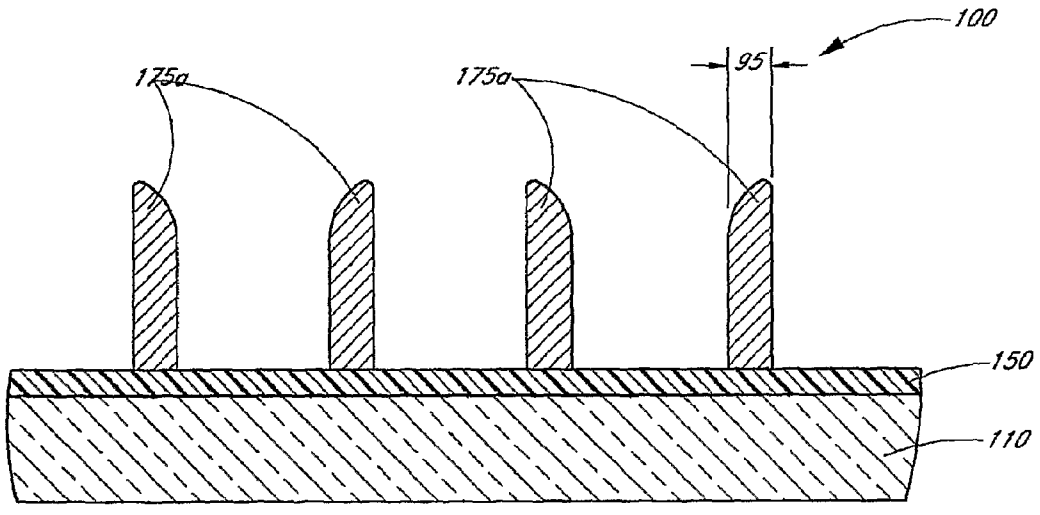
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[Continued on next page]

(54) Title: MASK MATERIAL CONVERSION



(57) Abstract: The dimensions of mask patterns, such as pitch-multiplied spacers, are controlled by controlled growth of features in the patterns after they are formed. To form a pattern of pitch-multiplied spacers 175a, a pattern of mandrels is first formed overlying a semiconductor substrate 110. Spacers are then formed on sidewalls of the mandrels by depositing a blanket layer of material over the mandrels and preferentially removing spacer material from horizontal surfaces. The mandrels are then selectively removed, leaving behind a pattern of freestanding spacers. The spacers comprise a material, such as polysilicon and amorphous silicon, known to increase in size upon being oxidized. The spacers are oxidized to grow them to a desired width 95. After reaching the desired width, the spacers 175a can be used as a mask to pattern underlying layers 150 and the substrate 110. Advantageously, because the spacers 175a are grown by oxidation, thinner blanket layers can be deposited over the mandrels, thereby allowing the deposition of more conformal blanket layers and widening the process window for spacer formation.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

AMENDED CLAIMS

[received by the International Bureau on 18 APRIL 2006 (18.04.06); original claims 1 to 75 have been replaced by amended claims 1 to 45.

1. A method of semiconductor processing, comprising:

providing a substrate, wherein a temporary layer overlies the substrate and a photodefinable layer overlies the temporary layer;

forming a pattern in the photodefinable layer;

transferring the pattern to the temporary layer to form a plurality of placeholders in the temporary layer;

depositing a blanket layer of spacer material over the plurality of placeholders;

selectively removing the spacer material from horizontal surfaces;

selectively removing the placeholders relative to the spacer material; and

expanding the spacer material to a desired size.

2. The method of Claim 1, wherein selectively removing the placeholders forms a pattern of free-standing spacers and wherein expanding the spacer material is performed after selectively removing the placeholders.

3. The method of Claim 1, wherein expanding the spacer material is performed before selectively removing the spacer material from horizontal surfaces.

4. The method of Claim 1, wherein expanding the spacer material is performed after selectively removing the spacer material from horizontal surfaces and before selectively removing the placeholders.

5. The method of Claim 1, wherein the temporary layer comprises amorphous carbon.

6. The method of Claim 5, wherein the photodefinable layer comprises photoresist.

7. The method of Claim 6, wherein forming a pattern in the photodefinable layer comprises performing photolithography and subsequently isotropically etching the photodefinable layer.

8. The method of Claim 6, wherein a hard mask layer separates the temporary layer and the photodefinable layer.

9. The method of Claim 8, wherein the hard mask layer comprises a dielectric antireflective coating.

10. The method of Claim 9, wherein the dielectric antireflective coating comprises silicon oxynitride.

11. The method of Claim 9, wherein selectively removing the placeholders comprises:

depositing a filler material over and around the spacer material;

simultaneously etching the filler material and the hard mask layer; and

subsequently simultaneously etching the filler material and the temporary layer.

12. The method of Claim 11, wherein depositing a filler material comprises depositing photoresist.

13. The method of Claim 12, wherein depositing photoresist comprises performing a spin-on process.

14. The method of Claim 11, wherein simultaneously etching the filler material and the hard mask layer comprises performing a CF_4/He plasma etch.

15. The method of Claim 11, wherein subsequently simultaneously etching the filler material and the temporary layer comprises performing an O_2 plasma etch.

16. The method of Claim 1, wherein depositing a blanket layer of spacer material comprises depositing a layer of silicon by chemical vapor deposition.

17. The method of Claim 16, wherein expanding the spacer material comprises forming silicon oxide.

18. The method of Claim 16, wherein selectively removing the spacer material from horizontal surfaces comprises anisotropically etching the silicon layer.

19. The method of Claim 18, wherein anisotropically etching the silicon layer comprises etching the silicon layer with HBr/Cl_2 plasma.

20. The method of Claim 1, wherein the spacer material is selected from the group consisting of titanium, tantalum and tungsten.

21. A process for forming a memory device, comprising:

forming a plurality of mask lines by performing pitch multiplication, wherein performing pitch multiplication comprises:

forming a plurality of mandrels;

depositing a blanket layer of spacer material over the mandrels; and

anisotropically etching the blanket layer of spacer material to form the mask lines on sidewalls of the mandrels, wherein neighboring mask lines are separated from one another by an open space; and

narrowing the open space between neighboring mask lines.

22. The process of Claim 21, wherein the mask lines comprise polysilicon or amorphous silicon.

23. The process of Claim 21, wherein narrowing the open space comprises reacting the mask lines to form a different chemical compound or alloy.

24. The process of Claim 23, wherein reacting the mask lines comprises expanding the mask lines by oxidation.

25. The process of Claim 24, wherein reacting the mask lines comprises completely oxidizing the mask lines.

26. The process of Claim 21, further comprising transferring a pattern formed by the mask lines to an underlying layer.

27. The process of Claim 26, wherein the underlying layer comprises amorphous carbon.

28. The process of Claim 27, wherein transferring the pattern to the amorphous carbon layer comprises transferring the pattern to a hard mask layer and then transferring the pattern from the hard mask layer to the amorphous carbon layer.

29. The process of Claim 28, wherein transferring the pattern to a hard mask layer comprises etching the hard mask layer with a BCl_3/Cl_2 plasma.

30. The process of Claim 28, wherein transferring the pattern from the hard mask layer to the amorphous carbon layer comprises exposing the amorphous carbon layer to SO_2-containing plasma.

31. The process of Claim 28, wherein the hard mask layer comprises aluminum oxide.

32. A method for semiconductor processing, comprising:

forming a plurality of mask lines by performing pitch multiplication, wherein performing pitch multiplication comprises:

forming a plurality of mandrels;

depositing a blanket layer of spacer material over the mandrels; and

anisotropically etching the blanket layer of spacer material to form the mask lines on sidewalls of the mandrels; and

expanding a volume of material forming the mask lines to a desired width by converting the material to an other material.

33. The method of Claim 32, wherein expanding a volume of material forming the mask lines comprises expanding the blanket layer of spacer material during forming a plurality of mask lines pitch multiplication.

34. The method of Claim 33, comprising:

expanding the volume of material forming the mask lines before anisotropically etching the blanket layer of spacer material.

35. The method of Claim 33, comprising:

expanding the volume of material forming the mask lines after anisotropically etching the blanket layer of spacer material; and

subsequently preferentially removing the mandrels relative to the spacer material after expanding the volume of material forming the mask lines.

36. The method of Claim 32, wherein expanding the volume of material forming the mask lines comprises expanding a pattern of spacers after pitch multiplication.

37. The method of Claim 32, wherein converting the material to an other material comprises oxidizing the material forming the mask lines.

38. The method of Claim 32, wherein converting the material to an other material comprises nitriding the material forming the mask lines.

39. The method of Claim 32, further comprising exposing an underlying layer to reactants through openings between the mask lines.

40. The method of Claim 39, wherein the reactants are etchants.

41. The method of Claim 40, wherein exposing an underlying layer comprises etching amorphous carbon.

42. The method of Claim 40, wherein exposing an underlying layer comprises etching a conductive substrate.

43. The method of Claim 32, further comprising trimming the mask lines after expanding a volume of material forming the mask lines.