CLAIMS

1. A patterning structure, comprising:

an organo metal oxide EUV-sensitive imaging layer disposed over a substrate; and

an underlayer disposed below the organo metal oxide EUV-sensitive imagine layer, wherein the underlayer comprises an amorphous hydrogenated carbon film with sp2 carbons, sp carbons, and/or unsaturated carbon-containing bonds, wherein the underlayer comprises at least 30 atomic % hydrogen, and wherein the underlayer has a density of 0.7 g/cm^3 to 1.4 g/cm^3.

2. The patterning structure of claim 1, further comprising a hard mask disposed below the underlayer.

3. The patterning structure of claim 1, wherein the underlayer comprises a thickness of no more than 25 nm.

4. The patterning structure of any one of claims 1-3, wherein the amorphous hydrogenated carbon film of the underlayer is doped with oxygen (O), silicon (Si), nitrogen (N), tungsten (W), boron (B), iodine (I), chlorine (Cl), or a combination of two or more of any of these; and optionally wherein the amorphous hydrogenated carbon film of the underlayer is doped with iodine and is configured to improve generation of secondary electrons upon exposure to radiation.

5. The patterning structure of any one of claims 1-3, wherein the underlayer comprises 1 atomic % to 30 atomic % oxygen (O) .

6. The patterning structure of any one of claims 1-3, wherein the underlayer provides increased etch selectivity; and optionally wherein the underlayer provides decreased line edge and line width roughness and/or decreased dose to size.

7. The patterning structure of any one of claims 1-3, wherein the underlayer comprises beta hydrogen atoms configured to be released upon exposure to radiation.

8. The patterning structure of claim 1, wherein the underlayer comprises oxygen atoms configured to form metal-oxygen bonds in the organo metal oxide EUV-sensitive imaging layer during or after a post exposure bake (PEB).

9. The patterning structure of claim 1, wherein the underlayer is configured to increase adhesion between the substrate and the organo metal oxide EUV-sensitive imaging layer and reduce a radiation dose for effective photoresist exposure of the organo metal oxide EUV-sensitive imaging layer.

10. A patterning structure, comprising:

a substrate comprising a partially fabricated semiconductor device film stack;

a radiation-sensitive imaging layer disposed over the substrate; and

an underlayer disposed between the substrate and the imaging layer,

wherein the underlayer comprises a vapor deposited film of hydronated carbon doped with oxygen (O), silicon (Si), nitrogen (N), tungsten (W), boron (B), iodine (I), chlorine (Cl), or a combination of two or more of any of these, and

wherein the film has a thickness of no more than 25 nm or a thickness of 2 to 20 nm.

11. The patterning structure of claim 10, wherein the substrate further comprises an optionally doped amorphous carbon hardmask disposed thereon.

12. The patterning structure of claim 10, wherein the underlayer comprises 0 atomic % to 30 atomic % oxygen (O) and/or 20 atomic % to 50 atomic % hydrogen (H); and/or wherein a surface of the underlayer comprises hydroxyl groups, carboxyl groups, peroxy groups, sp^2 carbons, sp carbons, and/or unsaturated carbon-containing bonds.

13. The patterning structure of claim 10, wherein the hydronated carbon doped with iodine is configured to improve generation of secondary electrons upon exposure to radiation.

14. The patterning structure of claim 10, wherein the underlayer comprises a density of 0.7 g/cm^3 to 2.9 g/cm^3; optionally wherein the underlayer further provides increased etch selectivity; and optionally wherein the underlayer further provides decreased line edge and line width roughness and/or decreased dose to size.

15. The patterning structure of claim 10, wherein the underlayer further comprises beta hydrogen atoms configured to be released upon exposure to radiation and/or oxygen atoms configured to form oxygen bonds to an atom in the imaging layer.

16. The patterning structure of claim 10, wherein the imaging layer comprises an Extreme Ultraviolet (EUV)-sensitive inorganic photoresist layer, a chemical vapor deposited (CVD) film, a spin-on film, a tin oxide film, or a tin oxide hydroxide film.

17. The patterning structure of claim 10, wherein the imaging layer comprises a vapor deposited organometallic imaging layer.

18. The patterning structure of claim 17, wherein the vapor deposited organometallic imaging layer comprises tin or organotin.

19. The patterning structure of claim 10, wherein the imaging layer comprises a spin-on organometallic imaging layer.

20. The patterning structure of claim 19, wherein the spin-on organometallic imaging layer comprises tin or organotin.

21. The patterning structure of claim 19, further comprising a hard mask between the substrate and the underlayer, and optionally wherein the hard mask is ashable.

22. A method of making a patterning structure, the method comprising:

providing a substrate in a process chamber;

depositing, by a plasma-enhanced chemical vapour deposition (PECVD) process in the process chamber, an underlayer on the substrate, wherein the underlayer comprises an amorphous hydrogenated carbon film with sp2 carbons, sp carbons, and/or unsaturated carbon-containing bonds, wherein the underlayer comprises at least 30 atomic % hydrogen, and wherein the underlayer has a density of 0.7 g/cm^3 to 1.4 g/cm^3; and

forming an organo metal oxide EUV resist imaging layer on the underlayer, wherein the underlayer is configured to increase adhesion between the substrate and organo metal oxide EUV resist imaging layer and/or reduce a radiation dose for effective photoresist exposure.

23. The method of claim 22, wherein:

the substrate is a partially fabricated semiconductor device film stack;

the substrate further comprises or is a hardmask, amorphous carbon film, amorphous hydrogenated carbon film, silicon oxide film, silicon nitride film, silicon oxynitride film, silicon carbide film, silicon boronitride film, amorphous silicon film, polysilicon film, or a combination thereof;

the amorphous hydrogenated carbon film of the underlayer is doped with oxygen (O), silicon (Si), nitrogen (N), tungsten (W), boron (B), iodine (I), chlorine (Cl), or a combination of two or more of any of these; and

the amorphous hydrogenated carbon film has a thickness of no more than 25 nm.

24. The method of claim 22, wherein the underlayer is vapor deposited on the substrate using a hydrocarbon precursor in the presence or absence of an oxocarbon precursor, thereby providing a carbon-containing film; and optionally wherein the oxocarbon

precursor co-reacts with hydrogen (H_2) or a hydrocarbon and optionally further co-reacts with a silicon (Si) source dopant.

25. The method of claim 24, wherein the hydrocarbon precursor comprises an alkane, an alkene, or an alkyne.

26. The method of claim 22, wherein depositing the underlayer by the PECVD process comprises use of a silicon (Si)-containing precursor that co-reacts with an oxidizer, and wherein the Si-containing precursor optionally further co-reacts with a carbon (C) source dopant.

27. The method of claim 22, wherein the underlayer comprises 1 atomic % to 30 atomic % oxygen (O) and/or wherein a surface of the underlayer comprises hydroxyl groups, carboxyl groups, and/or peroxy groups.

28. The method of claim 22, wherein the underlayer further provides increased etch selectivity, and optionally wherein the underlayer further provides decreased line edge and line width roughness and/or decreased dose to size.

29. The method of claim 22, wherein the underlayer further comprises beta hydrogen atoms configured to be released upon exposure to radiation and/or oxygen atoms configured to form oxygen bonds to an atom in the organo metal oxide EUV resist imaging layer.

30. The method of claim 22, wherein depositing the underlayer by the PECVD process comprises applying a bias at a bias power of 0 W to 1000 W and using a duty cycle of 5% to 100%.

31. The method of claim 30, wherein applying the bias provides the underlayer with an increased density, as compared to an underlayer formed without applying the bias.

32. The method of claim 22, further comprising, after depositing the underlayer by the PECVD process, modifying the underlayer to provide a roughened surface and optionally exposing the underlayer or the roughened surface to an oxygen-containing plasma to provide an oxygen-containing surface.

33. The method of claim 22, wherein forming the organo metal oxide EUV resist imaging layer on the underlayer comprises vapor depositing the organo metal oxide EUV resist imaging layer on the underlayer.

34. The method of claim 22, wherein forming the organo metal oxide EUV resist imaging layer on the underlayer comprises spin-coating the organo metal oxide EUV resist imaging layer on the underlayer.

35. The method of claim 34, further comprising, after the spin-coating, performing a post-application bake at a temperature below 200°C.

36. The method of claim 22, wherein the underlayer is deposited on a hardmask layer.

37. The method of claim 22, wherein a temperature of the substrate during the PECVD process is 0°C to 250°C.

38. The method of claim 22, wherein a temperature of the substrate during the PECVD process is 0°C to 100°C.

39. The method of claim 22, wherein a temperature of the substrate during the PECVD process is 23°C to 150°C.

40. The method of claim 22, wherein a pressure in the process chamber during the PECVD process is 0.1 Torr to 10 Torr.

41. The method of claim 22, wherein depositing by the PECVD process comprises introducing a carbon-containing precursor selected from the group consisting of methane (CH_4), acetylene (C_2H_2), ethylene (C_2H_4), propylene (C_3H_6), propyne (C_3H_4), allene (C_3H_4), cyclopropene (C_3H_4), butane (C_4H_{10}), cyclohexane (C_6H_{12}), benzene (C_6H_6), and toluene (C_7H_8).

42. The method of claim 41, wherein the carbon-containing precursor comprises acetylene or propylene.

43. The method of claim 41, wherein the PECVD process further comprises introducing a gas selected from the group consisting of helium (He), argon (Ar), krypton (Kr), neon (Ne), nitrogen (N_2), and hydrogen (H_2).

44. The method of claim 22, wherein the PECVD process comprises a capacitively-coupled plasma (CCP).

45. The method of claim 22, wherein depositing the underlayer by the PECVD process comprises supplying RF power from an RF power supply to a pedestal in the process chamber for powering a plasma.

46. The method of claim 22, wherein the underlayer further comprises oxygen atoms configured to form metal-oxygen bonds in the organo metal oxide EUV resist during or after a post-exposure bake (PEB).

47. A method of depositing an underlayer for an organo metal oxide EUV resist, the method comprising:

providing a substrate in a process chamber; and

depositing, by a plasma-enhanced chemical vapor deposition (PECVD) process in the process chamber, the underlayer on the substrate, wherein the underlayer comprises an amorphous hydrogenated carbon film with sp2 carbons, sp carbons, and/or unsaturated carbon-containing bonds, wherein the underlayer comprises at least 30 atomic % hydrogen, and wherein the underlayer has a density of 0.7 g/cm^3 to 1.4 g/cm^3.

48. The method of claim 47, wherein depositing by the PECVD process comprises introducing a carbon-containing precursor selected from the group consisting of methane (CH_4), acetylene (C_2H_2), ethylene (C_2H_4), propylene (C_3H_6), propyne (C_3H_4), allene (C_3H_4), cyclopropene (C_3H_4), butane (C_4H_{10}), cyclohexane (C_6H_{12}), benzene (C_6H_6), and toluene (C_7H_8).

49. The method of claim 48, wherein the carbon-containing precursor comprises acetylene or propylene.

50. The method of claim 47, wherein the PECVD process further comprises introducing a gas selected from the group consisting of helium (He), argon (Ar), krypton (Kr), neon (Ne), nitrogen (N_2), and hydrogen (H_2).

51. The method of claim 47, wherein the PECVD process comprises a capacitively-coupled plasma (CCP).

52. The method of claim 47, wherein a pressure in the process chamber during the PECVD process is 0.1 Torr to 10 Torr.

53. The method of claim 47, wherein a temperature of the substrate during the PECVD process is 0°C to 250°C.

54. The method of claim 47, wherein a temperature of the substrate during the PECVD process is 0°C to 100°C.

55. The method of claim 47, wherein a temperature of the substrate during the PECVD process is 23°C to 150°C.

56. The method of claim 47, wherein depositing the underlayer by the PECVD process comprises supplying RF power from an RF power supply to a pedestal in the process chamber for powering a plasma.

57. The method of claim 47, wherein the underlayer comprises beta hydrogen atoms configured to be released upon exposure to radiation.

58. The method of claim 47, wherein the underlayer further comprises oxygen atoms configured to form metal-oxygen bonds in the organo metal oxide EUV resist during or after a post-exposure bake (PEB).

59. The method of claim 47, wherein the underlayer is deposited on a hardmask layer.

60. The method of claim 47, wherein the underlayer is configured to increase adhesion between the substrate and the organo metal oxide EUV resist and reduce a radiation dose for effective photoresist exposure of the organo metal oxide EUV resist.

61. A method, comprising:

spin-coating an organo metal oxide EUV resist on an underlayer on a substrate, wherein the underlayer comprises an amorphous hydrogenated carbon film with sp2 carbons, sp carbons, and/or unsaturated carbon-containing bonds, wherein the underlayer comprises at least 30 atomic % hydrogen, wherein the underlayer has a density of 0.7 g/cm^3 to 1.4 g/cm^3, and wherein the underlayer is configured to increase adhesion between the

substrate and the organo metal oxide EUV resist and reduce a radiation dose for effective photoresist exposure of the organo metal oxide EUV resist.

62. The method of claim 61, wherein a temperature of the substrate during the PECVD process is 0°C to 250°C.

63. The method of claim 61, wherein a temperature of the substrate during the PECVD process is 0°C to 100°C.

64. The method of claim 61, wherein a temperature of the substrate during the PECVD process is 23°C to 150°C.

65. The method of claim 61, wherein a pressure in the process chamber during the PECVD process is 0.1 Torr to 10 Torr.

66. The method of claim 61, wherein depositing by the PECVD process comprises introducing a carbon-containing precursor selected from methane (CH_4), acetylene (C_2H_2), ethylene (C_2H_4), propylene (C_3H_6), propyne (C_3H_4), allene (C_3H_4), cyclopropene (C_3H_4), butane (C_4H_{10}), cyclohexane (C_6H_{12}), benzene (C_6H_6), and toluene (C_7H_8).

67. The method of claim 66, wherein the carbon-containing precursor comprises acetylene or propylene.

68. The method of claim 61, wherein the PECVD process further comprises introducing helium (He), argon (Ar), krypton (Kr), neon (Ne), nitrogen (N_2), hydrogen (H_2), or combinations thereof.

69. The method of claim 61, wherein the PECVD process comprises a capacitively-coupled plasma (CCP).

70. The method of claim 61, wherein depositing the underlayer by the PECVD process comprises supplying RF power from an RF power supply to a pedestal in the process chamber for powering a plasma.

71. The method of claim 61, wherein the underlayer comprises beta hydrogen atoms configured to be released upon exposure to radiation.

72. The method of claim 61, wherein the underlayer further comprises oxygen atoms configured to form metal-oxygen bonds in the organo metal oxide EUV resist during or after a post-exposure bake (PEB).

73. The method of claim 61, wherein the underlayer is deposited on a hardmask layer.

74. The method of claim 61, wherein the underlayer is configured to increase adhesion between the substrate and the organo metal oxide EUV resist and reduce a radiation dose for effective photoresist exposure of the organo metal oxide EUV resist.

75. A patterning structure, comprising:

a substrate;

an organo metal oxide EUV-sensitive imaging layer disposed over the substrate; and

an underlayer disposed below the organo metal oxide EUV-sensitive imaging layer, wherein the underlayer comprises an amorphous hydrogenated carbon film with sp2 carbons, sp carbons, and/or unsaturated carbon-containing bonds, wherein the underlayer comprises at least 30 atomic % hydrogen,

wherein the underlayer has a density of 0.7 g/cm^3 to 1.4 g/cm^3, and wherein the underlayer is configured to increase adhesion between the substrate and the organo metal oxide EUV-sensitive imaging layer and reduce a radiation dose for effective photoresist exposure of the organo metal oxide EUV-sensitive imaging layer.

76. The patterning structure of claim 75, wherein the amorphous hydrogenated carbon film of the underlayer is doped with oxygen (O), silicon (Si), nitrogen (N), tungsten (W), boron (B), iodine (I), chlorine (Cl), or a combination of two or more of any of these; and optionally wherein the amosphous hydrogenated carbon film of the underlayer is doped with iodine and is configured to improve generation of secondary electrons upon exposure to radiation.

77. The patterning structure of claim 75, wherein the underlayer comprises 1 atomic % to 30 atomic % oxygen (O) and/or wherein a surface of the underlayer comprises hydroxyl groups, carboxyl groups, and/or peroxy groups.

78. The patterning structure of claim 75, wherein the underlayer provides increased etch selectivity; and optionally wherein the underlayer further provides decreased line edge and line width roughness and/or decreased dose to size.

79. The patterning structure of claim 75, wherein the underlayer further comprises beta hydrogen atoms configured to be released upon exposure to radiation.

80. The patterning structure of claim 75, wherein the underlayer is deposited on a hardmask layer.

81. The patterning structure of claim 75, wherein the underlayer comprises a thickness of no more than 25 nm.

82. The patterning structure of claim 75, wherein the underlayer comprises oxygen atoms configured to form metal-oxygen bonds in the organo metal oxide EUV-sensitive imaging layer during or after a post exposure bake (PEB).

83. The patterning structure of claim 75, wherein the underlayer comprises 1 atomic % to 30 atomic % oxygen.

84. The patterning structure of claim 75, wherein the underlayer is configured to increase adhesion between the substrate and the organo metal oxide EUV-sensitive imaging layer and reduce a radiation dose for effective photoresist exposure of the organo metal oxide EUV-sensitive imaging layer.

85. A patterning structure, comprising:

a substrate;

a hard mask on the substrate;

an underlayer on the hard mask; and

a spin-on organometallic imaging layer on the underlayer;

wherein the underlayer comprises a vapor deposited film of hydronated carbon doped with oxygen (O), silicon (Si), nitrogen (N), tungsten (W), boron (B), iodine (I), chlorine (Cl), or a combination thereof.

86. The patterning structure of claim 85, wherein the hard mask is ashable.

87. The patterning structure of claim 85, wherein the organometallic imaging layer comprises tin or organotin.

88. The patterning structure of claim 85, wherein the underlayer comprises a thickness of no more than 25 nm.

89. The patterning structure of claim 85, wherein the underlayer comprises beta hydrogen atoms configured to be released upon exposure to radiation.

90. The patterning structure of claim 85, wherein the underlayer comprises oxygen atoms configured to form metal-oxygen bonds in the organo metal oxide EUV-sensitive imaging layer during or after a post exposure bake (PEB).

91. The patterning structure of claim 85, wherein the underlayer comprises 1 atomic % to 30 atomic % oxygen.

92. The patterning structure of claim 85, wherein the underlayer is configured to increase adhesion between the substrate and the spin-on organometallic imaging layer and reduce a radiation dose for effective photoresist exposure of the spin-on organometallic imaging layer.

93. An apparatus for processing a substrate, the apparatus comprising:

a process chamber comprising a substrate support;

a process gas source connected with the process chamber and associated flow-control hardware;

substrate handling hardware connected with the process chamber; and

a controller having a processor and a memory, wherein the processor and the memory are communicatively connected with one another, the processor is at least operatively connected with the flow-control and substrate handling hardware, and the memory stores computer-executable instructions for conducting the operations recited in the methods of any one of claims 22, 47, or 61.