CLAIMS

1. A method of processing a semiconductor substrate, comprising:

providing in a process chamber a photopatterned metal-containing resist on a substrate layer of a semiconductor substrate; and

developing the photopatterned metal-containing resist by selectively removing a portion of the photopatterned metal-containing resist by exposure to a development chemistry comprising a halide to form a resist mask.

2. The method of claim 1, wherein the photopatterned metal-containing resist is a photopatterned metal-containing EUV resist.

3. The method of claim 2, wherein developing the photopatterned metal-containing EUV resist comprises selectively removing an EUV-unexposed portion of the photopatterned metal-containing EUV resist relative to an EUV-exposed portion with the development chemistry to form the resist mask.

4. The method of claim 3, further comprising:

non-selectively removing the EUV-unexposed portion and the EUV-exposed portion of the photopatterned metal-containing resist without removing the substrate layer.

5. The method of claim 1, wherein the development chemistry comprises a hydrogen halide, hydrogen gas and halogen gas, an organic halide, an acyl halide, a carbonyl halide, a thionyl halide, or mixtures thereof.

6. The method of claim 5, wherein the development chemistry comprises hydrogen fluoride (HF), hydrogen chloride (HCl), hydrogen bromide (HBr), or hydrogen iodide (HI).

7. The method of claim 5, wherein the development chemistry comprises hydrogen gas (H_2) and fluorine gas (F_2), chlorine gas (Cl_2), bromine gas (Br_2), or iodine gas (I_2).

8. The method of claim 1, wherein the halide is flowed with a carrier gas into the process chamber, the carrier gas including helium (He), neon (Ne), argon (Ar), xenon (Xe), or nitrogen (N_2).

9. The method of claim 1, wherein developing the photopatterned metal-containing resist by exposure to the development chemistry comprises dry developing the photopatterned metal-containing resist by exposure to a dry development chemistry.

10. The method of claim 9, wherein dry developing the photopatterned metal-containing resist comprises applying a remote plasma including radicals of the halide to the photopatterned metal-containing resist.

11. The method of claim 9, wherein dry developing the photopatterned metal-containing resist comprises exposure to at least the halide in a plasma-free thermal process.

12. The method of claim 9, wherein dry developing the photopatterned metal-containing resist occurs at a temperature between about -60°C and about 120°C, at a chamber pressure between about 0.1 mTorr and about 760 Torr, at a gas flow rate of the halide between about 100 sccm and about 2000 sccm, an etch selectivity of the resist mask being tunable based at least in part on the temperature, the chamber pressure, the gas flow rate, or combinations thereof.

13. The method of claim 12, wherein the temperature is between about -20°C and about 20°C.

14. The method of claim 12, wherein a profile of the resist mask is controllable based at least in part on the temperature, the chamber pressure, the gas flow rate, or combinations thereof.

15. The method of any one of claims 1–14, wherein the photopatterned metal-containing resist is an organo-metal oxide or organo-metal-containing thin film.

16. The method of claim 15, wherein the photopatterned metal-containing resist comprises an organotin oxide.

17. The method of any one of claims 1–14, wherein the photopatterned metal-containing resist comprises an element selected from the group consisting of: tin, hafnium, tellurium, bismuth, indium, antimony, iodine, and germanium.

18. The method of any one of claims 1–14, wherein providing the photopatterned metal-containing resist comprises vapor depositing a metal-containing resist film on the substrate layer.

19. The method of any one of claims 1–14, wherein providing the photopatterned metal-containing resist comprises spin-coating a metal-containing resist film on the substrate layer.

20. The method of any one of claims 1–14, wherein a thickness of the photopatterned metal-containing resist is between about 10 nm and about 50 nm.

21. The method of any one of claims 1–14, further comprising:

exposing, after developing the photopatterned metal-containing resist, the photopatterned metal-containing resist to an inert gas plasma.

22. The method of claim 21, further comprising:

repeating operations of developing the photopatterned metal-containing resist and exposing the photopatterned metal-containing resist to the inert gas plasma.

23. The method of any one of claims 1–14, further comprising:

baking, prior to developing the photopatterned metal-containing resist, the photopatterned metal-containing resist at an elevated temperature.

24. The method of any one of claims 1–14, wherein providing the photopatterned metal-containing resist comprises:

depositing a metal-containing EUV resist film on the semiconductor substrate;

non-selectively removing portions of the metal-containing EUV resist film on a backside and bevel edge of the semiconductor substrate; and

exposing the metal-containing EUV resist film to EUV light to form the photopatterned metal-containing resist.

25. The method of any one of claims 1–14, further comprising:

depositing a metal-containing EUV resist film on the semiconductor substrate; and

non-selectively removing the metal-containing EUV resist film from the semiconductor substrate without removing the substrate layer prior to providing the photopatterned metal-containing resist.

26. An apparatus for conducting development of resist, the apparatus comprising:

a process chamber with a substrate support;

a vacuum line coupled to the process chamber;

a development chemistry line coupled to the process chamber; and

a controller configured with instructions for processing a semiconductor substrate, the instructions comprising code for:

providing in the process chamber a photopatterned metal-containing resist on a substrate layer of the semiconductor substrate; and

developing the photopatterned metal-containing resist by selectively removing a portion of the photopatterned metal-containing resist by exposure to a development chemistry comprising a halide to form a resist mask.

27. The apparatus of claim 26, wherein the photopatterned metal-containing resist is a photopatterned metal-containing EUV resist, and wherein the controller configured with the instructions comprising code for developing the photopatterned metal-containing EUV resist comprises code for selectively removing an EUV- unexposed portion of the photopatterned metal-containing EUV resist relative to an EUV-exposed portion with the development chemistry to form the resist mask.

28. The apparatus of claim 26, further comprising:

one or more heaters coupled to the substrate support, wherein the one or more heaters include a plurality of independently controllable temperature control zones.

29. The apparatus of claim 26, wherein an interior of the process chamber is coated with a corrosion inhibitor.

30. The apparatus of claim 26, further comprising:

a cold trap coupled to the process chamber, wherein the cold trap is configured to remove water from the process chamber.

31. The apparatus of any one of claims 26–30, wherein the process chamber comprises a plastic material.

32. The apparatus of any one of claims 26–30, further comprising:

a UV lamp or IR lamp coupled to the process chamber, wherein the UV lamp or IR lamp is configured to cure the photopatterned metal-containing resist or remove excess halide from the process chamber.

33. A method of processing a semiconductor substrate, the method comprising:

providing in a process chamber a dry-deposited photopatterned metal oxide EUV resist on a substrate layer of a semiconductor substrate; and

dry developing the photopatterned metal oxide EUV resist by selectively removing an EUV-unexposed portion of the photopatterned metal-containing EUV resist by exposure to a dry development chemistry comprising HCl and/or HBr to form a resist hard mask from an EUV-exposed portion.

34. The method of claim 33, wherein dry developing occurs in a plasma-free thermal process, wherein exposure to the dry development chemistry occurs at a temperature between about -20°C and about 20°C.

35. The method of claim 33, wherein the photopatterned metal oxide EUV resist includes an organotin oxide.