indium (In), iron (Fe), ruthenium (Ru), rhenium (Rh), antimony (Sb), tungsten (W), molybdenum (Mo), or bismuth (Bi). In some examples, the metal halide comprises a metal fluoride when the etching agent comprises a fluorocarbon. Some examples of metal fluorides include, but are not limited to, tungsten hexafluoride (WF_6) and molybdenum hexafluoride (MoF_6). In other examples, the metal halide comprises a metal chloride when the etching agent comprises a chlorocarbon. Some examples of metal chlorides include, but are not limited to, titanium tetrachloride ($TiCl_4$), tungsten hexachloride (WCl_6) and molybdenum pentachloride ($MoCl_5$). In yet other examples, the metal halide comprises an oxyhalide. Examples of oxyhalides include tungsten oxytetrafluoride (WOF_4), tungsten oxytetrachloride ($WOCl_4$), molybdenum oxytetrafluoride (MoO_xF_4), and molybdenum oxytetrachloride (MoO_xCl_4). As described in more detail below, the metal halide and/or the etching agent react to form a substance containing a metal from the metal halide on a patterning mask.

[0078] FIG. 2 shows a top-down view of the substrate 106 of FIG. 1. FIG. 3A shows a cross-sectional view of the substrate 106 along line 2-2 of FIG. 2. The substrate 106 comprises a layer 172 of arbitrary composition.

[0079] The substrate 106 further comprises an oxide layer 174 formed on layer 172. The oxide layer can include one or more layers of a doped or an undoped material. In some examples, the oxide layer comprises a metal oxide and/or a metalloid oxide. In some more specific examples, the oxide layer comprises silicon dioxide (SiO_2) and/or TiO_2. In other examples, the oxide layer comprises any other suitable material. Other examples of suitable materials include silicon oxynitride (SiO_xN_y, $0 \leq x \leq 2$, $0 \leq y \leq 1.33$), silicon oxycarbide ($SiC_xO_{2(1-x)}$ ($0 \leq x \leq 1$)), hafnium oxide (HfO_x), tungsten oxide (WO_x), tin oxide (SnO_x), molybdenum oxide (MoO_x), and other oxides of titanium (TiO_x).

mask 176. Any suitable cleaning material can be used to remove the substance 182. Some examples of suitable cleaning materials include ammonia (NH_3) and hydrogen peroxide (H_2O_2).

[0093] In this manner, the oxide layer 174 can be patterned with higher fidelity than can be achieved in plasma etching processes that do not utilize the contemporaneous deposition of the substance containing the metal. Due to the additive deposition of the substance 182 on the hard mask 176, the hard mask 176 may achieve pattern-transfer fidelity similar to that of thicker hard mask materials, while avoiding defects such as line breakage, line roughness, and wiggling.

[0094] FIGS. 4A-4B show another example of a substrate 200. Like the substrate 106 of FIG. 1, the substrate 200 comprises a layer 202 of arbitrary composition. The substrate 200 further comprises an oxide layer 204 formed on layer 202. As described above, the oxide layer 204 may comprise any suitable material. Some examples of suitable materials include SiO_2, TiO_2, SiO_xN_y ($0 \leq x \leq 2$, $0 \leq y \leq 1.33$), $SiC_xO_{2(1-x)}$, ($0 \leq x \leq 1$), HfO_x, WO_x, SnO_x, and MoO_x.

[0095] The substrate 200 further comprises a photoresist patterning mask 206. The photoresist patterning mask 206 selectively exposes portions of the oxide layer 204. The exposed portions of the oxide layer 204 are selectively etched as described above using an etching agent and a metal halide. For example, the plasma generator 128 of FIG. 1 can be used as described above to transform the etching agent and the metal halide into a plasma. The plasma selectively etches the exposed portions of the oxide layer 204 and contemporaneously deposits a substance 208 containing a metal from the metal halide on the photoresist patterning mask 206. In this manner, the oxide layer 204 can be etched without additional hard mask deposition and patterning stages.

CLAIMS:

1. A method of etching a feature in an oxide layer on a substrate, the method comprising:

introducing a gas mixture comprising an etching agent and a metal halide into a plasma formed in a processing chamber in which the substrate is located, the substrate comprising a patterning mask partially covering the oxide layer; and

contemporaneously etching the feature in an unmasked portion of the oxide layer and depositing a substance containing a metal from the metal halide on the patterning mask.

2. The method of claim 1, wherein the etching agent comprises a fluorocarbon.

3. The method of claim 1, wherein the etching agent comprises hydrogen fluoride.

4. The method of claim 1, wherein the oxide layer comprises a metal oxide or a metalloid oxide.

5. The method of claim 1, wherein the oxide layer comprises silicon dioxide or titanium dioxide.

6. The method of claim 1, wherein the patterning mask comprises one or more of a metal oxide, amorphous carbon, boron-doped carbon, tungsten-doped carbon, titanium nitride, silicon, silicon nitride, silicon carbide, silicon carbonitride, or a photoresist material.

7. The method of claim 1, wherein the metal halide comprises a halide of one or more of silicon, germanium, tin, titanium, zirconium, hafnium, vanadium, niobium, tantalum, boron, aluminum, gallium, indium, iron, ruthenium, rhenium, antimony, tungsten, molybdenum, or bismuth.

8. The method of claim 1, wherein the metal halide comprises one or more of tungsten hexafluoride or molybdenum hexafluoride.

9. The method of claim 1, wherein the metal halide comprises an oxyhalide.

10. A processing tool, comprising:

a processing chamber;

a plasma generator configured to generate a plasma in the processing chamber;

a substrate holder positioned within the processing chamber;

flow control hardware configured to control a flow of each of one or more processing chemicals into the processing chamber; and

a controller configured to

control the flow control hardware to introduce a gas mixture comprising an etching agent and a metal halide into the processing chamber; and

control the plasma generator to generate the plasma in the processing chamber, wherein the gas mixture and the plasma are configured to etch an unmasked oxide layer on a substrate, and contemporaneously deposit a substance containing a metal from the metal halide on a masked portion of the substrate comprising a patterning mask that covers a portion of the oxide layer.

11. The processing tool of claim 10, further comprising an etching chemical source wherein the etching chemical source comprises a fluorocarbon.

12. The processing tool of claim 10, further comprising an etching chemical source wherein the etching chemical source comprises hydrogen fluoride.

13. The processing tool of claim 10, further comprising a metal halide source, wherein the metal halide source comprises a halide of one or more of silicon, germanium, tin, titanium, zirconium, hafnium, vanadium, niobium, tantalum, boron, aluminum, gallium, indium, iron, ruthenium, rhenium, antimony, tungsten, molybdenum, or bismuth.

14. The processing tool of claim 13, wherein the metal halide source comprises an oxyhalide.

15. A method of removing patterning mask remnants from a substrate between a resist development process and an etching process, the method comprising:

introducing a metal halide into a plasma formed in a processing chamber in which the substrate is located, the substrate comprising a photoresist patterning mask and patterning mask remnants, to deposit a substance containing a metal from the metal halide at least on the photoresist patterning mask to protect the photoresist patterning mask during removal of the patterning mask remnants.

16. The method of claim 15, wherein the photoresist patterning mask comprises a metal oxide photoresist.

17. The method of claim 15, wherein the removal of the patterning mask remnants and deposition of the substance containing a metal from the metal halide occurs contemporaneously.

18. The method of claim 15, wherein the deposition of the substance containing a metal from the metal halide and the removal of the patterning mask remnants occur sequentially.

19. The method of claim 15, wherein the substrate comprises a hard mask layer beneath the photoresist patterning mask.

20. The method of claim 15, wherein deposition of the substance containing a metal from the metal halide further occurs both before and contemporaneously with the removal of patterning mask remnants.