

photon particles. Such particles are ordinarily required to achieve anisotropic etch with atomic oxygen plasmas in the prior art, but cause secondary damage to the underlying substrate. Furthermore, the reaction products should be highly volatile and easily removed from the etched substrate. In addition, the aforementioned limitations that are encountered when etching Cu-containing layers using conventional chlorine chemistry, show that there is a need for new low temperature dry etching methods in semiconductor manufacturing using chemical approaches that do not involve chlorine-based reactants.

SUMMARY OF THE INVENTION

[0011] Embodiments of the present invention seek to provide a method and an apparatus for anisotropic dry etching of pure Cu layers and Cu-containing layers used in integrated circuits.

[0012] There is disclosed a method and an apparatus that uses a directional beam of high kinetic energy (hyperthermal) neutral O-atoms to anisotropically oxidize Cu layers, and an etching gas comprising an organic compound gas such as CH_3COOH that readily reacts with the oxidized Cu layers to form volatile Cu-containing etch products. The high directionality of the O-atom beam allows for anisotropic etching of the Cu layers in accordance with a patterned hard mask or photoresist.

[0012a] According to a first aspect of the present invention, there is provided a method for etching a copper-containing layer on a substrate, comprising: loading a substrate into a processing chamber having a neutral beam source and a substrate holder, the substrate having a copper-containing layer and etch mask formed thereupon; exposing the copper-containing layer to a neutral beam comprising a reacting gas, the reacting gas forming a first copper-containing compound on exposed surfaces of features formed in the copper-containing layer; introducing a reducing gas into processing chamber, proximate the substrate holder, the reducing gas reacting with the first copper-containing compound to form a volatile copper-containing compound; pumping the volatile copper-containing compound from the processing chamber, to form a pattern in the copper-containing layer.

[0012b] According to a second aspect of the present invention, there is provided a method for anisotropically etching a Cu-containing layer comprising the steps of: providing a Cu-containing layer overlying a substrate; introducing a directional beam of neutral oxygen atoms having a kinetic energy between 100eV and 1eV; oxidizing the Cu-containing layer by exposure to the beam of oxygen atoms; introducing an organic compound gas forming

volatile etch products when reacted with the oxidized Cu-containing layer; and removing the etch products from the Cu-containing layer.

[0012c] According to a third aspect of the present invention, there is provided a method for etching a copper-containing layer on a substrate, comprising: loading a substrate into a processing chamber having a neutral beam source and a substrate holder, the substrate having a copper-containing layer and etch mask formed thereupon; exposing the copper-containing layer to a neutral beam comprising a reacting gas, the reacting gas forming a first copper-containing compound on exposed surfaces of features formed in the copper-containing layer; introducing acidic acid gas into processing chamber, proximate the substrate holder, the acetic acid gas reacting with the first copper-containing compound to form a volatile copper-containing compound; and pumping the volatile copper-containing compound from the processing chamber, to form a pattern in the copper-containing layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

FIG. 1 is a flowchart for etching a Cu-containing layer in accordance with the present invention;

FIGS. 2a-2d show a schematic cross-sectional representation of anisotropic etching of Cu-containing layers in accordance with the present invention;

FIG. 3 shows a schematic cross-sectional representation of anisotropic etching of Cu-containing layers in accordance with the present invention;

FIG. 4 shows a processing system according to a preferred embodiment of the present invention;

FIG. 5 shows an example of an organic compound gas supply unit in the etching apparatus of FIG. 4.