Chemical improvement of EUV ruthenium capping layer against active oxygen and hydroxyl radicals.

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It has been challenging to find suitable chemistries for cleaning of EUV mask consisting of various materials including multilayer (multiple stacking layer of silicon/ molybdenum), absorber, and capping layers.

Recent investigation reveals that tantalum-based absorber layer has limited resistance against SPM chemicals while ruthenium-based capping layer is still robust. Active oxygen or hydroxyl radical cleaning which is more effective than SPM in removal of organic contaminant including carbon contamination on EUV mask surface turns out to cause serious damages on ruthenium capping layer.

It is hypothesized that diffusion of oxygen radicals into capping layer oxidizes metallic ruthenium into more unstable ruthenium oxide compounds and the oxidized compounds are further damaged by following alkali cleaning combined with physical forces. Such diffusion of oxygen through ruthenium might oxidize layers beneath it to weaken the adhesion between ruthenium and beneath layers, which can further accelerate damage propagation on ruthenium capping.

In this work, we try to understand root-causes of ruthenium damage by using of qualitative analysis of TOF-SIMS, TEM, EDX, and XPS. Based on the analysis, we propose innovative and powerful technologies of ruthenium passivation to mitigate diffusion of oxygen radicals into ruthenium layer, thereby reducing oxidation and damage of ruthenium capping layer.

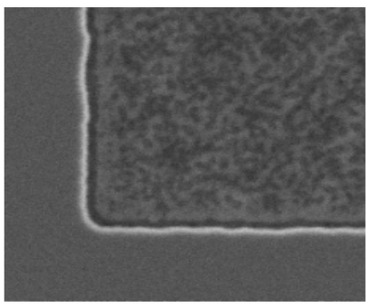

Fig.1 Scanning electron microscope image of ruthenium layer damaged by cleaning of active ozone or hydroxyl radicals.

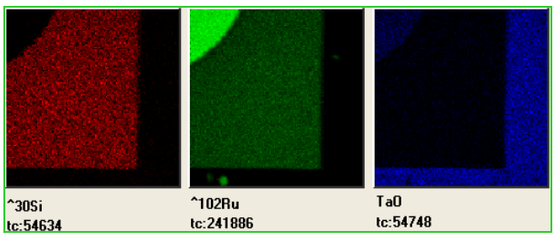

Fig.2 TOF-SIMS surface mapping of ruthenium layer damaged by cleaning of active ozone or hydroxyl radicals.

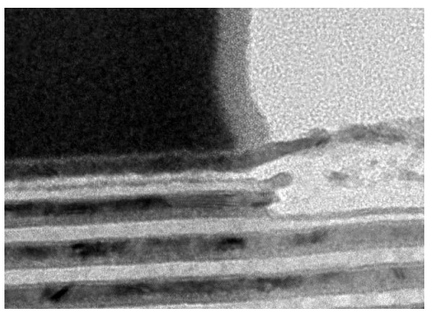

Fig.3 TEM profile of ruthenium layer damaged by cleaning of active ozone or hydroxyl radicals.