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Effects of plasma and wet processes on Si-rich anti-reflective coating to address selective trilayer rework for sub-20nm technology nodes

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Trilayers have been widely adopted in the semiconductor industry as a patterning solution for 32nm node and beyond, as they offer a clever solution to limited photoresist budget in plasma etching of very small CD features. This stack allows to still transfer patterns in ultra-thin photoresist by 193nm lithography while the masking function for plasma etch is now ensured by underlying Si-rich anti-reflective coating (SiARC) and spin-on carbon (SOC) layer.

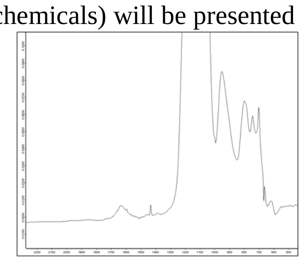
However introducing these new materials raised new challenges, namely for lithography rework which required the development of specific processes. Solutions to thoroughly rework the trilayer stack are now available, however from a cost-saving and cycle time prospective it is very interesting to perform only the photoresist removal selectively to underlying SiARC and SOC layers. This work focused on figuring out process conditions that do not induce SiARC modifications while achieving high photoresist removal efficiency and low defectivity levels in lithography rework on 300mm wafers for 20nm technology node and beyond.

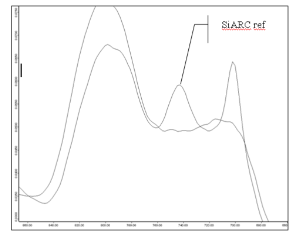
A broad range of plasma processes and chemical treatments were evaluated regarding their impact on SiARC chemical composition, optical properties and roughness. Plasma conditions include microwave, inductively-coupled and capacitively-coupled plasmas with either oxidizing or reducing gas flows. Chemistries encompass usual post-ash clean chemicals such as SPM or SC1, as well as different organic solvents capable to eliminate 193nm photoresists.

Figure 1 shows ATR spectra of the SiARC layer before and after different processes. Figures 1b, 1c and 1d are zoomed in the 660-860cm^{-1} region. They point out the entire extinction of peaks at 702 and 743cm-1 when performing oxidizing microwave plasma, revealing the elimination of the SiARC organic matrix, namely aromatic cycles. In the case of reducing microwave plasma, peak intensities decrease without completely disappearing, evidencing a partial removal of the SiARC organic component consistently with the weaker capability of H_2-based plasma to break down carbon polymer chains compared to oxidizing processes. SC1 process does not show any modification to the SiARC chemical composition, ATR spectrum after process flawlessly superimposing to the pre-process spectrum.

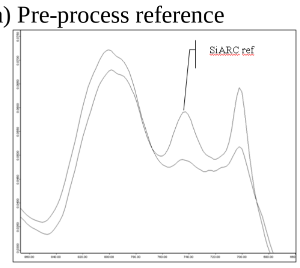
SiARC refractive index was measured by ellipsometry after process to assess whether its value shift during rework may disturb the lithography process. Refractive index variations are summarized in table 1. Optical simulations showed that SiARC refractive index should not vary by more than +/- 0.12 to maintain lithography process window (figure 2), thus only SC1 process and to some extent CCP H_2 based plasma may be used for a selective photoresist rework amongst the processes listed in table 1 (results with solvents not shown), which is consistent with the observation that these processes induce the least modifications to the SiARC composition.

Processes that were found compatible to SiARC were then tested for photoresist removal efficiency. An example is shown by wafer pictures in figure 3 which demonstrate that solvent A thoroughly removes 193nm photoresist on top of a trilayer stack with a 10sec treatment at 30°C in a single-wafer tool. This result is confirmed by particle counts carried out on the remaining SOC + SiARC stack exhibiting only 11 defects at 0.16µm threshold size (figure 4). Optical constant measurements, although not shown here, proved this chemical to be harmless to SiARC. The complete data set including SiARC characterizations and efficiency results for all tested processes (plasmas, inorganic and organic chemicals) will be presented in the final article.

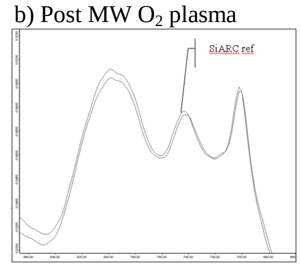

a) Pre-process reference



b) Post MW O_2 plasma



c) Post CCP H_2 plasma



d) Post-SC1

Figure 1: ATR spectra of SiARC layer

PROCESS	Δ n at 193 nm	RMS roughness in nm
SiARC ref	0.00	0.22
Plasma MW O2N2	-0.25	0.14
Plasma MW H2N2	-0.24	0.16
Plasma ICP O2	-0.22	0.17
Plasma CCP H2N2	-0.13	0.21
SC1	0.00	0.12
CARO	-0.26	0.11

Table1: SiARC refractive index modifications and roughness measurements for different processes

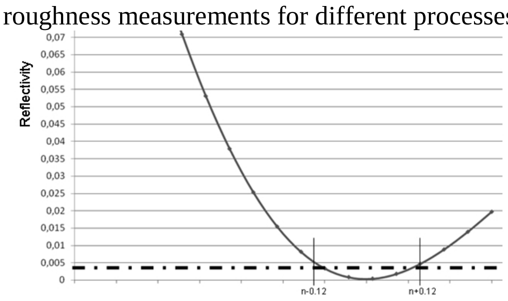
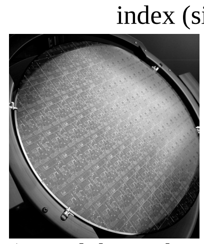


Figure 2: reflectivity as a function of SiARC refractive index (simulation plot)


a) Post-lithography

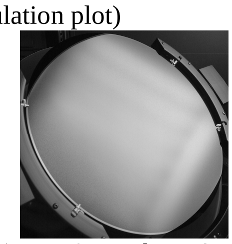

b) Post10sec solvent A at 30°C

Figure 3: pictures of 300mm trilayer wafers.

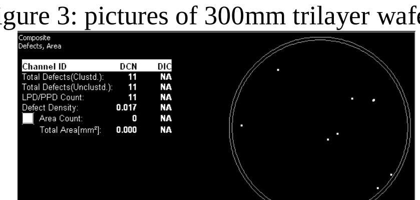


Figure 4: particle count at 0.16µm threshold size after photoresist removal on SOC + SiARC