**Ozonated HF applications in a spray processing tool**

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## INTRODUCTION

Frequently, HF and SC1 based wet chemistries are used in combination with oxidative chemistries for the removal of polysilicon etch residues (including resist layers). Initial experience indicates that HydrOzone™ [1] is feasible for resist removal, however the etch (and ash) polymers are more resistant. Development of a wet process based on HydrOzone™ would be effective from a cost and throughput point of view. This was realized by extending the HydrOzone™ process with an additional ozonated HF step. Also, for pre-gate clean applications, the ozonated HF process under study shows potential.

## EXPERIMENTAL

CMOS wafers (8", p-type, Cz, <100>) were given a standard C025 poly/gate (5nm/250 nm thickness) stack deposition, followed by an etching step. Strip after NVM poly etching was done on 8 inch wafers, which got a 250 nm poly on top of a 100 nm thermal oxide followed by a non critical I-line print (C035). Both wafer types were exposed either to an IMEC standard strip, a HydrOzone™ strip with $NH_4OH$ as additive or HydrOzone™ strip followed by an ozonated HF step. The IMEC standard strip (ca. 20') features ammonium hydroxide peroxide and sulfuric acid. The HydrOzone™ (ozone and DIwater) strip for CMOS wafers is performed for about 6' at 85C and high rotational speed (800 rpm) with $NH_4OH$ (1/2500) as additive. The new strip sequentially processes wafers, first through HydrOzone™ and then through an ozonated HF (0.1% @95C) step at low rotational speed (50 rpm). The combined process steps are sequentially performed in the same chamber of a spray- processing tool.

Cleanliness is inspected with a Scanning Electron Microscope (PHILIPS SEM XL 30) and Advanced In-line Defect inspection (Surfscan AIT, KLA Tencor). Electrical characterization, i.e. $Q_{BD}$ and transistor parameters, are meanly performed on non-overlapping meander capacitors of a C025 integration lot.

For pre-gate clean applications, bare silicon wafers (roughness), wafers contaminated with particles or metals, doped polysilicon, TEOS and thermal oxide wafers were exposed to the extended HydrOzone™ (with ozonated HF step) process. The etch selectivity towards polysilicon, TEOS and thermal oxide was investigated. As well as particle/metal removal efficiency and surface roughening.

## RESULTS AND DISCUSSION

The HydrOzone™ step at high rotational speed (800 rpm) removes the resist layer but not the polymers or polymer-etch residues. To remove these polymers, an additional step, ozonated HF, is used at a low rotational speed (50 rpm). In this way, a thicker boundary layer is present on the wafer and thus the polymer etch residues are restrained to re-adsorb on the wafer surface. Therefore, formation of polymer clusters does not occur. Also, at low rotational speed a longer contact time of the solution with the polymers on the wafer exists. Figure 1 shows SEM pictures of CMOS structures after conventional and extended HydrOzone™ treatment.

The ozonated HF process is able to remove both resist and polymers, while with the conventional HydrOzone™ strip polymers still remain on the structures and the surface.

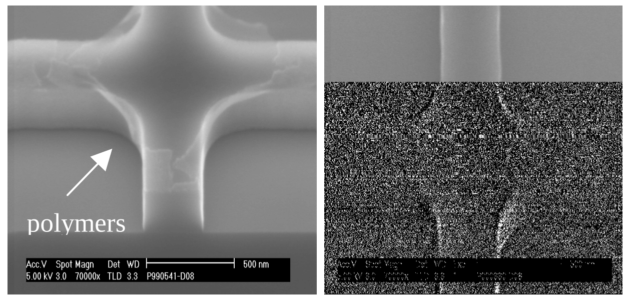


Fig. 1: SEM photographs of a CMOS structure after a HydrOzone™ strip with $NH_4OH$ (left) and an extended HydrOzone™ strip with ozonated HF (right).

For NVM processing, highly polymerizing etch chemistries are used. Therefore, slightly longer process times are needed to remove resist and polymer-etch residues.

If an influence of the strip after polysilicon etch is expected on the quality of the gate oxide, the non overlapping meander capacitor will be the most sensitive. A Weibull plot of large meander n-well capacitors (CAP-GME_NWn) is represented in Figure 2. No significant differences were seen between the IMEC standard and the ozonated HF strip.

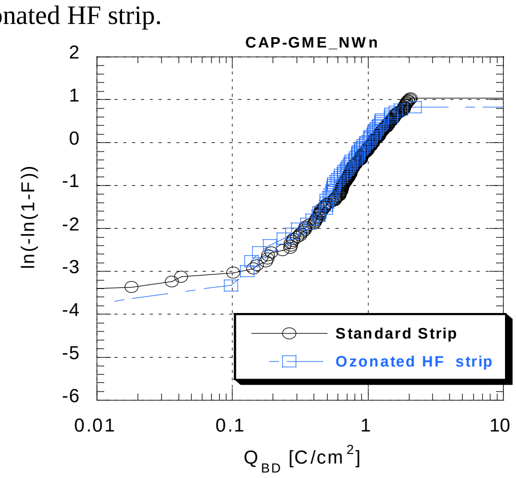


Fig.2: $Q_{BD}$ data for standard strip and ozonated/HF strip.

The ozonated HF process also shows potential for pre-gate clean applications in a spray-processing tool. Low rotational speed is needed in both process steps in order to obtain a more uniform oxide etching (6Å/min). The metal removal efficiency was better than 99,5%. $SiO_2$ particles were easily (> 96 %) removed from thermal oxide and bare silicon wafers. A slight increase (0.5 Å) in surface roughness on control wafers with roughness smaller than 1 Å was observed. The impact on device performance still need to investigated.

## CONCLUSIONS

An ozonated HF process, applied in a spray-processing tool is feasible in removing both resist and polymer etch residues after polysilicon etch. With this method both the chemical use and process time are reduced significantly. Pre-gate clean applications with the ozonated HF process were also investigated.

## REFERENCES

[1] S. De Gendt *et al.*, ECS proceedings, vol. 99-36 (1999) 391.