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Integration of wet cleaning in 45 nm pitch BEOL processing

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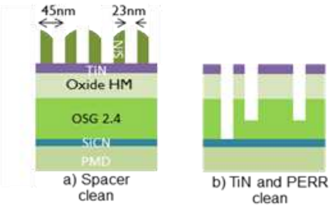
A partial-trench via first with self-aligned double patterning (SADP) approach is used to realize 45 nm pitch on dual damascene compatible hardmask. This BEOL integration approach is used to investigate the ability to integrate advanced low-k materials and more specifically to assess their patterning performance. Within this SADP integration approach different specific cleaning steps are required. A first cleaning process is needed after spacer etch and amorphous-carbon (a-C) strip (Fig. 1a) to remove the spacer etch residues that are formed. Further in the integration flow, a TiN clean is needed together with a post-etch residue removal (PERR) after low-k etch (Fig. 1b).

To strip the a-C an O_2-based or N_2/H_2 –based plasma was used and typically residues were present between the SiN spacers (due to TiN overetch(OE)). X-ray photoelectron spectroscopy (XPS) results confirm that these residues formed during the plasma process were not organic CFx-type, but rather Ti-F type of residues. For the wet clean, both aqueous (dilute HF and SC1 1/4/50) and commercial organic cleans (TMAH-based clean and a semi-organic clean) were considered. Little/no residues were removed using commercial, organic clean solutions, while much better residue removal was obtained using SC1 as shown in Figure 2. This result was also confirmed by XPS data. Dilute HF was also able to remove the residues, but at the same time Si_3N_4 recess was observed. During the patterning of the low-k dielectric layer (Fig. 1b), a thin layer of polymer is intentionally deposited on the dielectric sidewalls and TiN hardmask to ensure anisotropic etching and prevent/minimize dielectric degradation. This polymer layer must be removed prior to the subsequent processing steps to achieve good adhesion and coverage of materials deposited in the etched features. The compatibility requirement is even more stringent for advanced low-k dielectrics, i.e. materials with lower k-value and higher porosity. The post-etch residue (PER) amount and properties are specific and depend on the stack structure and the plasma that is used for patterning. The low-k material and hardmask that are used in this work are respectively an OSG type of low-k material with k=2.4 (25% open porosity) and TiN. Recent results [1,2] clearly showed the presence of a highly fluorinated layer deposited on the trench sidewalls during the plasma etch using fluorocarbon plasma [3]. Aqueous cleaning solutions, such as diluted HF, do not efficiently remove polymer without etching the underlying layer (lift-off), leading to a dimension loss. Another possibility that can be considered is a 1-step clean using commercial chemistries or a 2-step clean in which a UV pre-treatment is followed by a wet clean [4]. Compatibility tests of different chemistries, with and without a UV pre-treatment, have been performed on the OSG 2.4 low-k dielectric material and TiN hardmask (Fig. 3a, b). From Figure 3a it is clear that UV exposure does not impact the material properties of OSG 2.4. A good compatibility with pristine OSG 2.4 has been observed for the chemistries tested, while plasma-damaged low-k was etched by dilute HF. The commercial chemistry used for cleaning TiN-based residues is compatible with OSG 2.4, but a more thoroughly rinse is required. As expected, significant reduction in TiN thickness was observed after wet clean with SC1 and to some extent with dHF. Commercial chemistry for removal of TiN-based residues is compatible with TiN (Fig. 3b). It was already shown recently that a UV pre-treatment enables the removal of PER [4]. Since this 2-step cleaning process (UV + SC1, organic mixture or commercial chemistry) is quite universal, the effect of UV exposure on the change of Cu oxidation has been checked. Experimental results showed that Cu oxide thickness remained unchanged after 254 nm UV irradiation under O_2-flow. This means that UV/O_2 irradiation does not induce Cu oxidation.

The cleaning tests using the same chemistries showed different performance in terms of PER removal; these results will be presented and discussed at the conference.



a) Spacer clean
b) TiN and PERR clean

Figure 1 : a) Clean required after spacer etch and amorphous carbon strip and b) TiN and PERR clean after low-k etch.

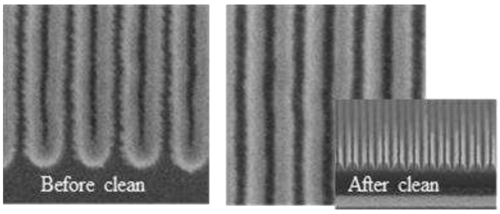


Figure 2 : Residues formed after spacer etch are completely removed using SC1 1/4/50 for 1 min at 50C.

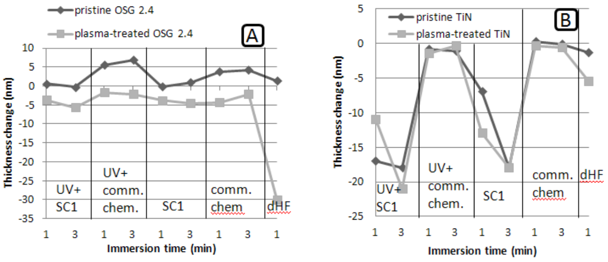


Figure 3 : A) Compatibility tests of different cleans with and without UV on OSG 2.4 and B) on TiN.

[1] M. Darnon et al., Microelectron. Eng., **85**, 2226 (2008).

[2] Q. T. Le et al., presentation at UCPSS 2010, Ostend, Belgium (2010).

[3] T. Mukherjee et al., ECS Solid-St. Lett. 2, N11-N14 (2013).

[4] E. Kesters et al., Solid St. Phenom., **195**, 114 (2013).