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Approach toward Enhanced Cerium Residue Control on Post-CMP-Cleaned Surface

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1. Introduction

Owing to the push of the semiconductor industry toward advanced technology nodes, ceria-based slurries have been widely applied to achieve rapid removal rates of silicon oxide (TEOS) in front-end-of-line (FEOL) chemical mechanical planarization (CMP) processing. In addition to the relatively strong chemical bonding with the oxide surface, the opposite charge and smaller size of ceria abrasives make the post-CMP cleaning of ceria-based slurries a greater challenge than that of traditional silica-based CMP slurries. As a result, formulation chemistry has emerged in the market, gradually replacing commodity chemistry, such as dilute HF (dHF), SPM, and SC1, in both logic and memory applications.

2. Formulation vs. Commodity

Bulk chemicals are used to remove ceria residue by breaking the bonds between ceria and dielectrics. However, most commodity chemical-based cleaners have limitations such as compatibility issues with dielectrics and tungsten as well as safety concerns. In addition, ceria post-CMP cleaning relies on some aggressive matrixes such as SPM, which is not suitable for an in-line clean system and consequently will lower the overall production throughput. Alternatively, the use of EKC PCMP2110 (formulating chemistry) provides great materials compatibility and is also suitable for an in-line post-CMP clean system without safety concerns.

Cleaner	Commodity					Formulation
	Ammonia	TMAH	SC1	SPM	HF	EKC PCMP2110
Dielectric Compatibility	Poly-Si loss	Poly-Si loss	Poly-Si loss	-	TEOS loss	◯
Tungsten Compatibility	X	X	X	X	X	◯
Safety	Hazard	Hazard	Hazard	Hazard	Hazard	◯
Direct Clean	◯	◯	◯	EX-Situ	◯	◯

3. Inspection Methods

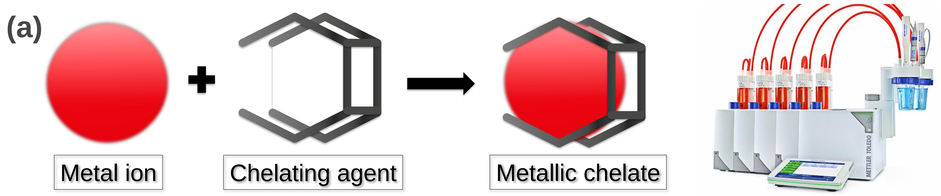


Figure 1. (a) Titration-based technique as the chelator screening methodology and **(b)** hydrolysis of Ce^{3+}, which explains the decreasing complexation for some chelators at pH above 7.

4. Results

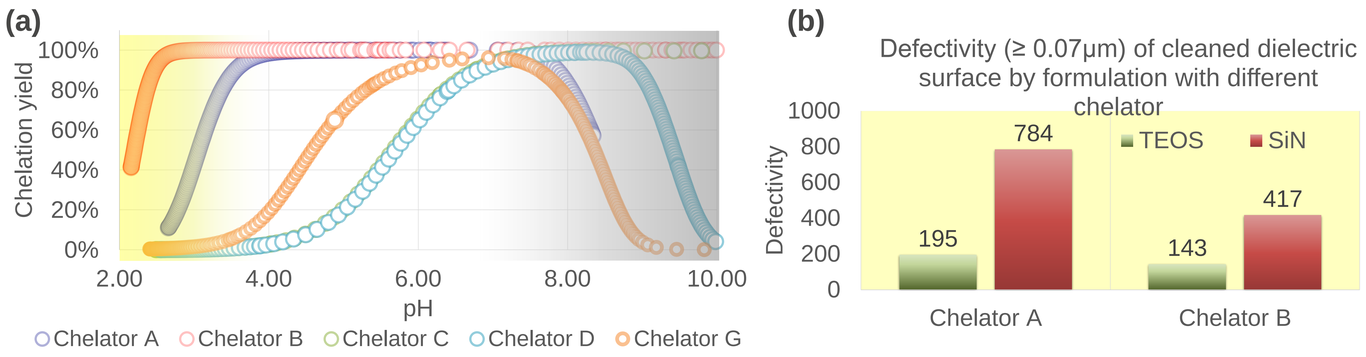
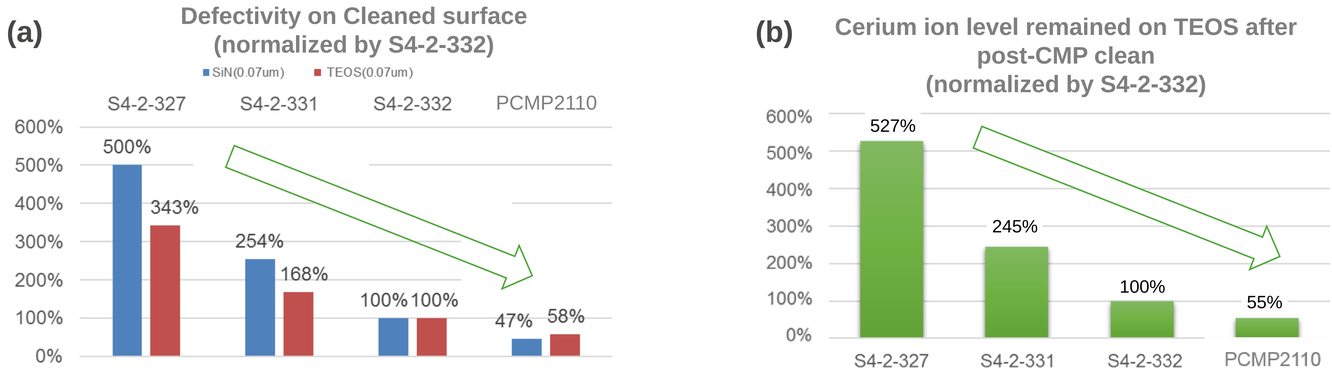


Figure 2. (a) Complexation yield of chelator upon Ce^{3+} ion in aqueous matrix, chelator B with broaden working window outperforms other complexation agents; **(b)** Template with chelator B gives better cleaning performance than that of chelator A.



Template modification	S4-2-327	S4-2-331	S4-2-332	PCMP2110
Chelator Template #1	1X			
Chelator Template #2		1X		
Chelator Template #3			1X	
Chelator Template #4				1X

Figure 3. Ceria residue control after post-CMP clean in brush box: (a) defectivity and (b) cerium ion level.

5. Conclusions and Future Applications

- EKC PCMP2110 (formulating chemistry) provides great materials compatibility and is also suitable for an in-line post-CMP clean system without safety concerns, making it a viable replacement for commodity chemicals in ceria post-CMP cleaning.
- Voltammetry titration provides valuable information for PCMP processing, such as the working window of complexation in cleaner matrix.
- Chelator B has the most broadened complexation window in the tested pH rage and shows the greatest cleaning capability.
- By optimizing the chelant, EKC cleaners can achieve improved cerium residue removal as manifested in both defectivity and cerium ion level.
- EKC PCMP2110 performs state-of-the-art ceria post-CMP cleaning, which has been validated by a major chip maker.