

# Recent Advances in the Development of Ceria-Based Slurries for Inner Layer Dielectric CMP

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## 1. Introduction

Standard Inner Layer Dielectric (ILD) polishing utilizes an endpoint detection or a fixed time process to determine when to stop polishing. This can create non-uniformities across the oxide surface caused by both within die topography variations and within wafer polishing rate variations (1). Incorporation of a stopping layer would help, but the standard ILD process does not use any. One way to minimize non-uniformity and also to widen the process window is to formulate an ILD slurry with self-stopping characteristics.

A self-stopping slurry (SSS) is one that shows a moderate to high (>3000 Å/min) step height removal rate (SHRR) when polishing topography, but reverts to a low (<300 Å/min) removal rate of the oxide after removal of the topography (i.e. the wafer polishes like a blanket wafer). This type of slurry, when used in an optimized process, would result in effective removal of topography to leave a very planar surface. Additionally, the slurry should show very low pattern density dependency across a wide range of feature sizes and densities (up to 1000µm and an active area density range of 10-90%).

This paper describes some ceria-based ILD slurries that have been formulated with self-stopping characteristics, efficient topography removal and low pattern density dependency (2).

## 2. Experimental

Polishing at the Ferro Penn Yan facility was carried out using a Strasbaugh 6EC single platen 200mm platform. Polishing at the customer site was carried out on a Novellus Momentum 200mm platform.

All single-component ILD slurries used in this study were manufactured at the Penn Yan facility of Ferro Electronic Material Systems. The silica slurry SS-12, was obtained from Cabot Corporation. Blanket thermal oxide wafers were used to measure removal rates and SKW 7-2 ILD wafers from SKW were used to generate performance and defectivity data in Penn Yan. Figure 1 shows a cross-section of the Up oxide and Down oxide areas on the SKW 7-2 wafer. The polishing endpoint was determined to be when the Up oxide had been polished down to 10,000 Angstroms thickness (on an SKW 7-2 wafer with an initial Up oxide thickness of approximately 20,000 Angstroms). At this point, the topography was less than 500 Angstroms. The customers own wafers (cross-section shown in figure 2) with over 40,000Å of Up oxide thickness were used at the customer site.

Oxide thickness was measured using a ThermoWave 3290DUV Optiprobe. Defect inspection was carried out using an Applied Materials WF-736 Orbot tool. Post-CMP cleaning was carried out using an Ontrak double-sided brush scrubber with megasonics.

## 3. Results and Discussion

### 3.1. ILD Slurry Development

The development work was carried out at the Ferro Penn Yan site on a Strasbaugh 6EC tool. Many candidate slurries were screened and the sections below describe two of the slurries with very promising properties.

#### 3.1.1. SRS-977 ILD Slurry

The SRS-977 slurry was formulated to give moderate SHRR (2500–3000Å/min, depending on process conditions) and a low thermal oxide blanket rate (100-500Å/min). In-house testing showed that this product was

less pattern dependent than SS-12 silica slurry (see figures 8 and 9). The moderate SHRR of SRS-977 means that 8000A topography (on a SKW 7-2 wafer) can be removed in around 200-250 seconds (depending on process conditions).

However, during evaluation at a customer facility, it was found that SRS-977 exhibited self-stopping behavior. The wafers used in this case are shown in figure 2. The Optiprobe plots for the Up and Down oxide are shown in figures 3 and 4 respectively. A highly planarized surface is obtained after polishing.

The self-stopping behavior is shown in Figure 5. Here the remaining Up oxide is plotted against polishing time and it is seen that the curves level off after 400 seconds polishing, at most downforce pressures. Figure 6 shows Down oxide removal vs Up oxide removal. Even when the wafer is planarized (around 20,000A of Up oxide removed), less than 2000A of Down oxide has been removed and therefore, the planarization efficiency is high.

The self-stopping behavior is thought to occur when an optimized slurry formulation is used under optimum process conditions. During the customer tests, many slurries were evaluated for self-stopping behavior and SRS-977 was the only slurry which showed such features.

### 3.1.2. SRS-985 ILD Slurry

It became desirable to formulate a slurry which retained self-stopping features, but showed an increased SHRR. SRS-985 was one candidate that came out of that work. Again, this slurry removed 20,000A of topography on a customer wafer in 180 seconds, with minimal Down oxide removal, to produce a highly planar surface. On a SKW 7-2 wafer, 8000A of topography was removed in 60 seconds. This slurry was shown to be excellent for fast topography removal, however the blanket removal rate (>1500A/min on TEOS) was too high for it to exhibit true self-stopping behavior. Figure 7 shows remaining oxide vs polishing time with overpolish. It can be seen that after the endpoint (180 secs), the rate slows down, but does not stop.

One excellent feature of the SRS-985 slurry is that it shows almost no pattern dependency and this can be seen in figures 8 and 9, for Up and Down oxide respectively. Here the pattern dependency of SRS-985 is compared with SRS-977 and a commercial silica slurry (SS-12). SKW 7-2 wafers, with densities in the 10-90% (active nitride) range were used here. The silica slurry is very pattern dependant and this is one reason why silica slurries are coming to the end of their useful life as options for the next generation of ILD polishing.

### 4. Slurry Manufacture and Defectivity

The capability to control the manufacture of the abrasive particle in-house is critical to the production of a consistent product. Ferro have the capability to completely control both the abrasive manufacturing process and the final product formulation. In this way, large defect-generating particles can be eliminated, whilst still retaining the particle size distribution required for optimum oxide polishing.

Typically, both total defects (including particles) and CMP-induced defects are fewer than those from a commercial silica slurry (up to three times less). CMP-induced defects include scratches, micro-scratches and pullouts.

### 5. Conclusions

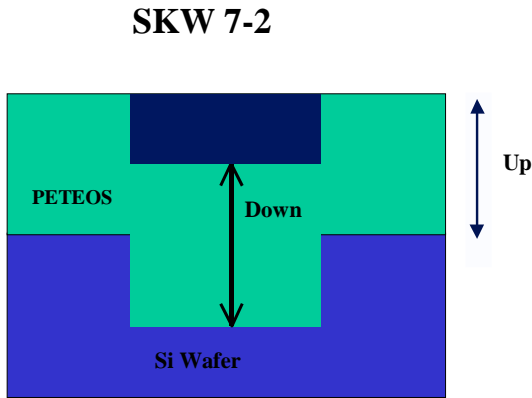
New ceria-based slurries for ILD CMP have been developed that meet the extremely rigorous objectives necessary for the production of sub-90nm devices. The slurries are single component products with long shelf- and pot-lives. Control of both the ceria particle manufacture (solid state or solution grown) and the slurry formulation in-house is critical for the production of consistent product, to minimize lot-to-lot variability.

Slurries with self-stopping behavior and high SHRR have been described in this paper. Recent work has led to slurries with both high SHRR and self-stopping capability and this will be reported in the near future.

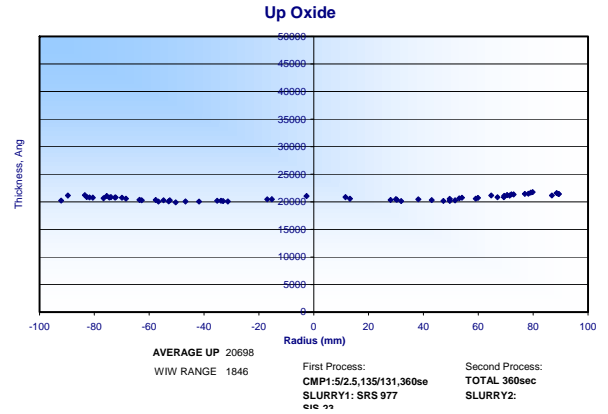
### 6. References

1. J.M.Steigerwald, S.P.Murarka, R.J.Gutmann, 'Chemical Mechanical Planarization of Microelectronic Materials', John Wiley & Sons, New York, 1997, pp. 129-180.

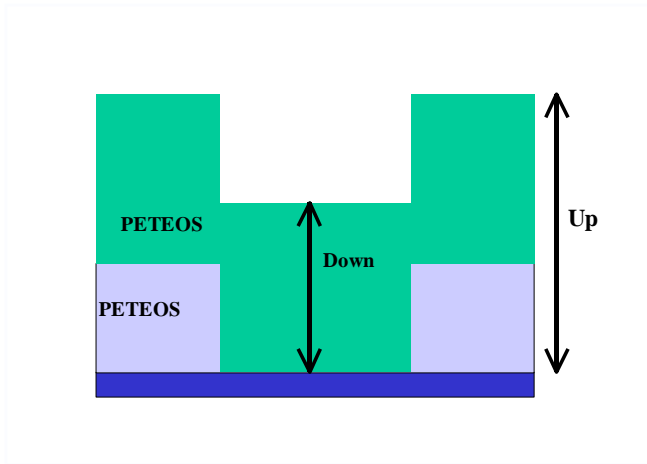
- D.Merricks, Proceedings of the CAMP 9<sup>th</sup> International Symposium on CMP, Lake Placid, New York, August 9-11, 2004



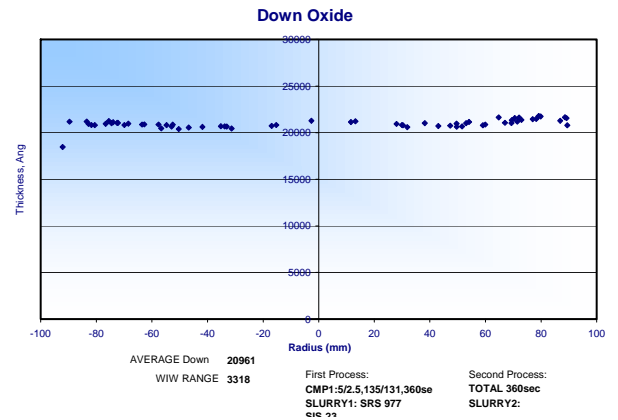
**Figure 1:** SKW 7-2 ILD Mask Cross Section (Up ~ 20,000A)



**Figure 3:** Up Oxide Thickness (customer wafer) after polishing with SRS-977



**Figure 2:** Customer Wafer Cross Section (Up ~ 43,000A)



**Figure 4:** Down Oxide Thickness (customer wafer) after polishing with SRS-977

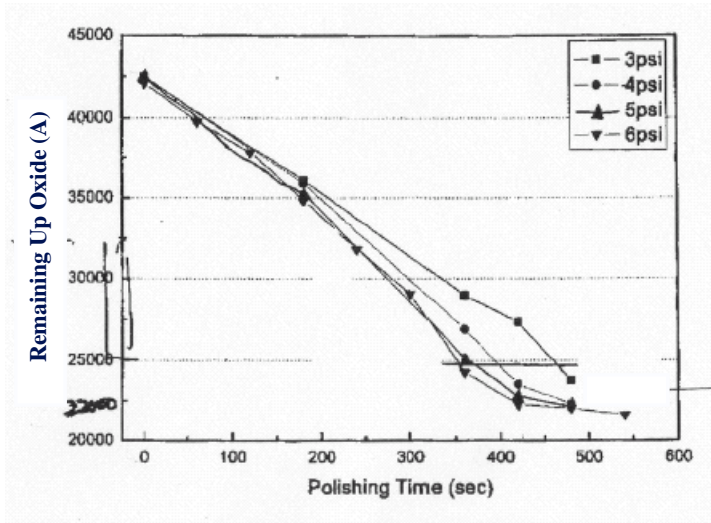


Figure 5: Remaining Up Oxide vs Polishing Time, showing self-stopping behavior (SRS-977)

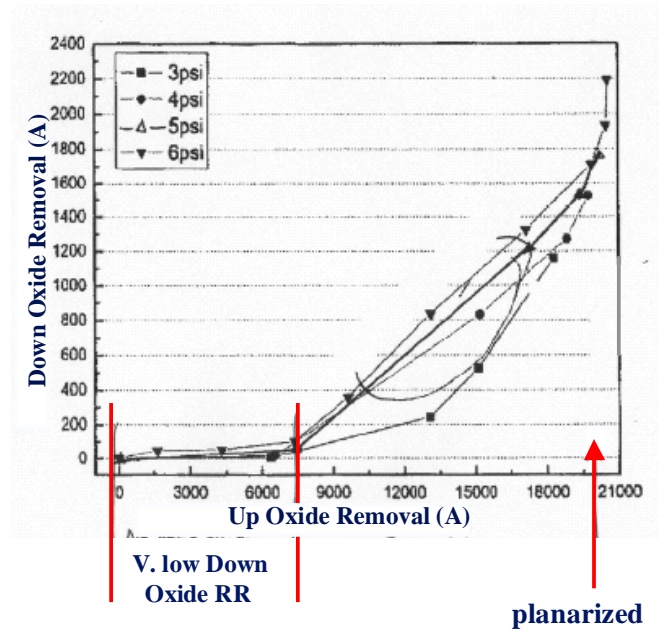


Figure 6: Down Oxide vs Up Oxide Removal, showing high planarization efficiency (SRS-977)

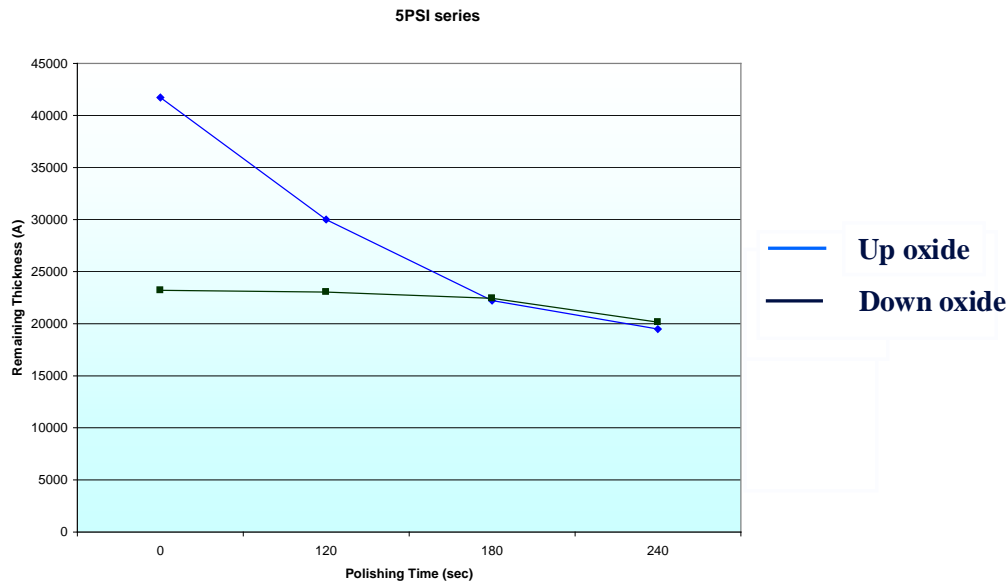


Figure 7: Remaining Oxide Thickness vs Polishing Time (with Overpolish) – SRS-985

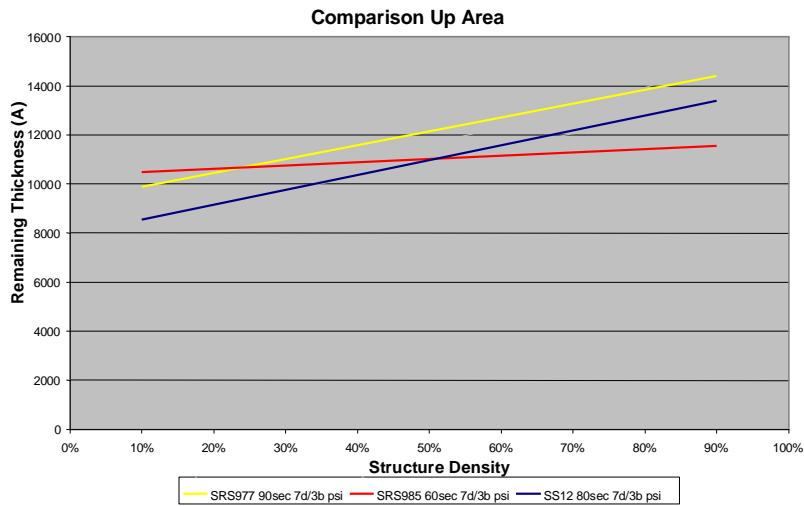


Figure 8: Pattern Dependency (SS-12 vs SRS-977 vs SRS-985) – Up Oxide

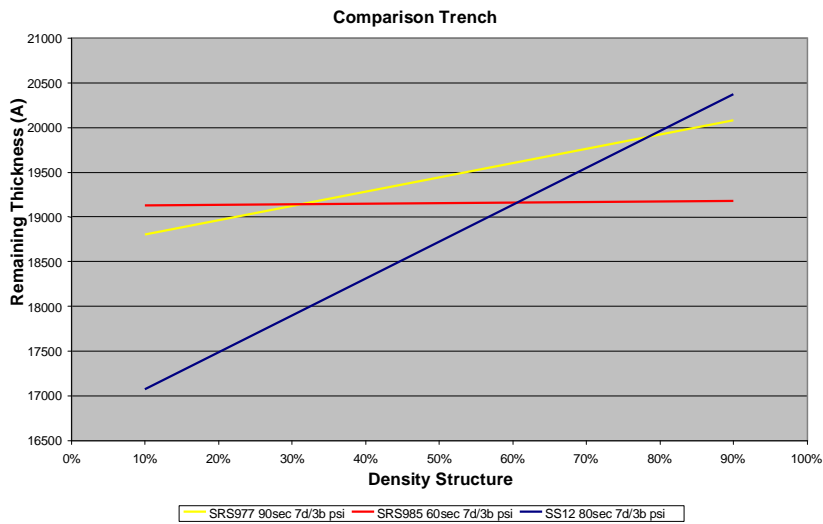


Figure 9: Pattern Dependency (SS-12 vs SRS-977 vs SRS-985) – Down Oxide