AVS CMP Users Group Meeting

"High Selectivity Ceria Slurry for Next Generation STI CMP Processes"

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Outline

- Introduction to Ferro
- Shallow trench isolation (STI)
- Silicon nitride passivation
- Ceria polishing mechanism
- Next generation STI slurries

Ferro Overview

- Founded 1919 as Ferro Enameling Company in Cleveland, Ohio USA
- Worldwide leader in production of glass enamels, porcelain enamels, ceramic tile coatings
- Nearly 4,000 associates working in 26 countries
- 2015 sales of $1.1 billion

Approaching centennial as a growing innovator of glass-based coatings and color solutions

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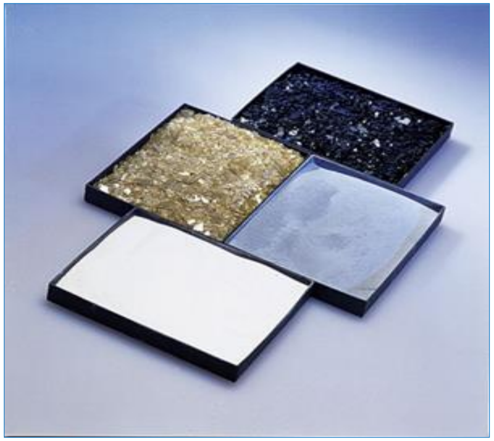
Ferro’s Core Technologies

- Particle engineering
- Color and glass science
- Surface chemistry and surface application
- Formulation




Penn Yan Site

- ✓ Located on 63 Acres
- ✓ Lake Frontage of 1100 feet
- ✓ 320,000 Ft^2 Under Roof
- ✓ Global R&D Center: Dielectrics and Surface Technologies
- ✓ Customer Service Center for:
  - Cleveland, OH
  - Vista, California
  - Penn Yan, NY

Penn Yan Products

- **Manufacturer of ceramic powders and slurries**

Dielectrics

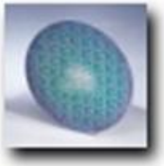
- High purity engineered powders and formulations for the multi-layer ceramic capacitor (MLCC) industry

Surface Finishing Material

- Zirconia, ceria and alumina based powder and slurry formulations for the LCD glass, glass ceramic hard disk, flat glass, cover glass, precision sapphire, plastic lens, metals and automotive polishing applications

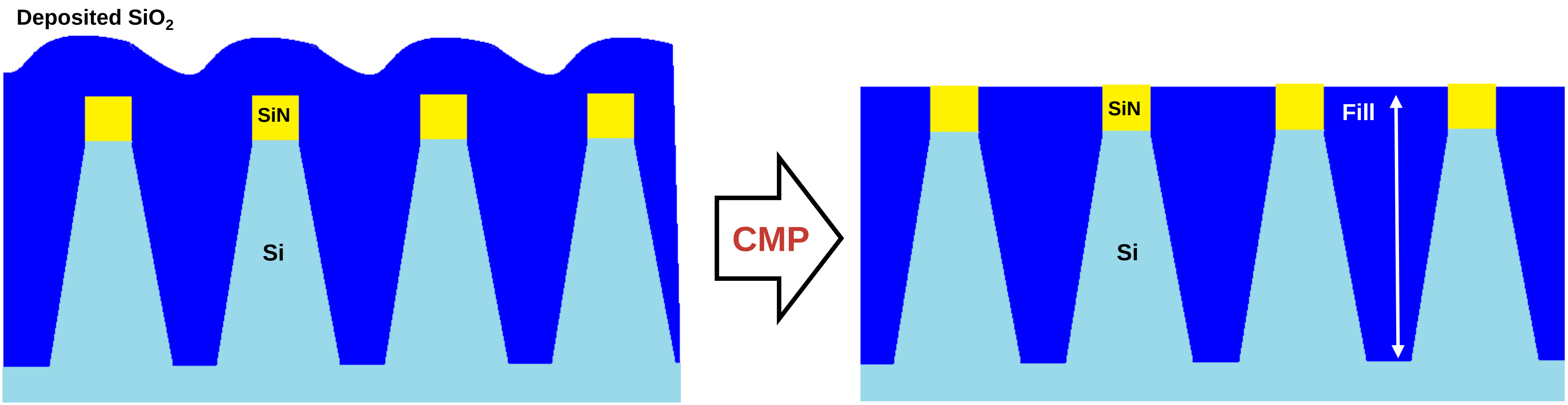
CMP

- Ceria based powders and formulations used in semiconductor applications



Shallow Trench Isolation (STI)

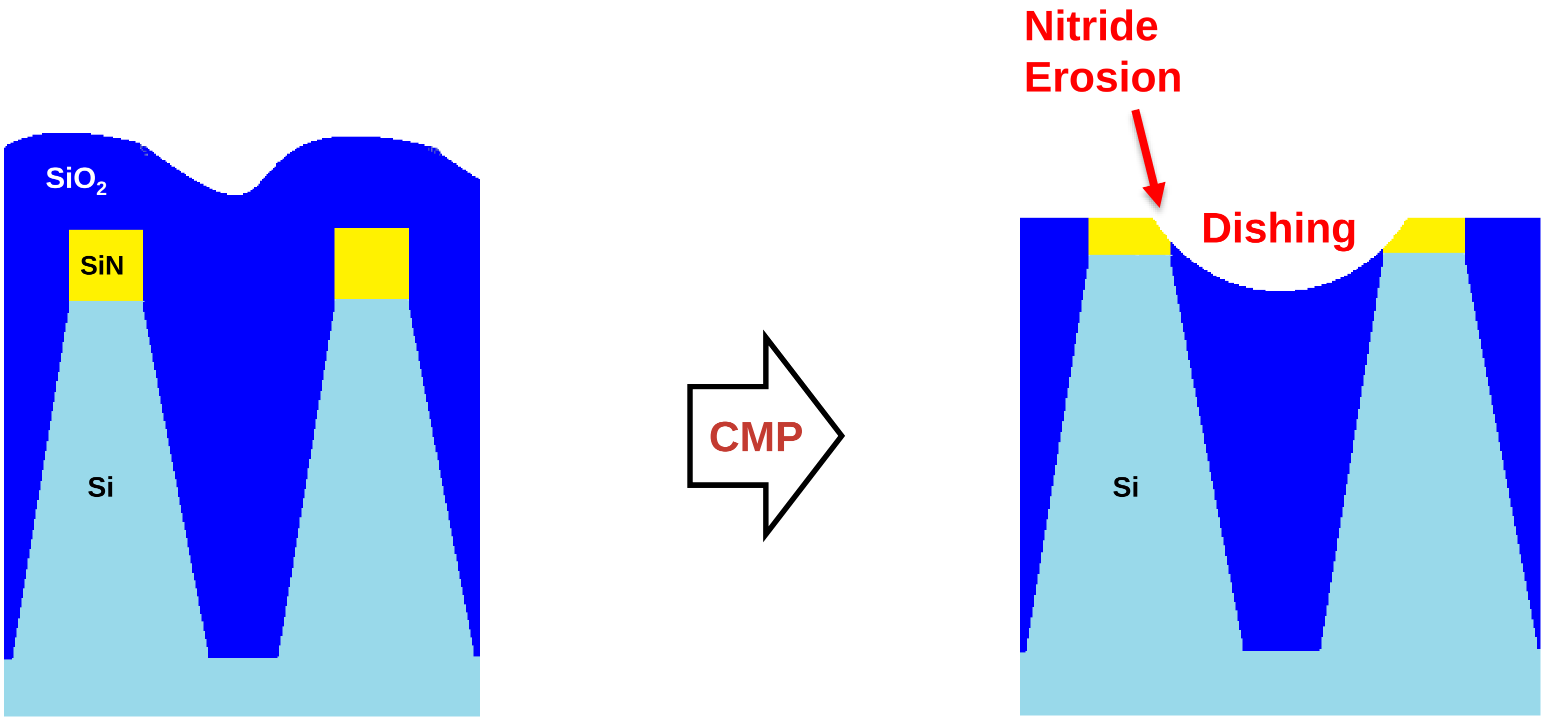
- Silicon dioxide (SiO_2) dielectric used to fill trenches in Si substrate in order to electrically isolate the transistors of an integrated circuit



- STI slurry is required to planarize the deposited SiO_2 then stop on an underlying layer of silicon nitride (SiN)

- First CMP process needed in IC fabrication

STI Slurry Challenges



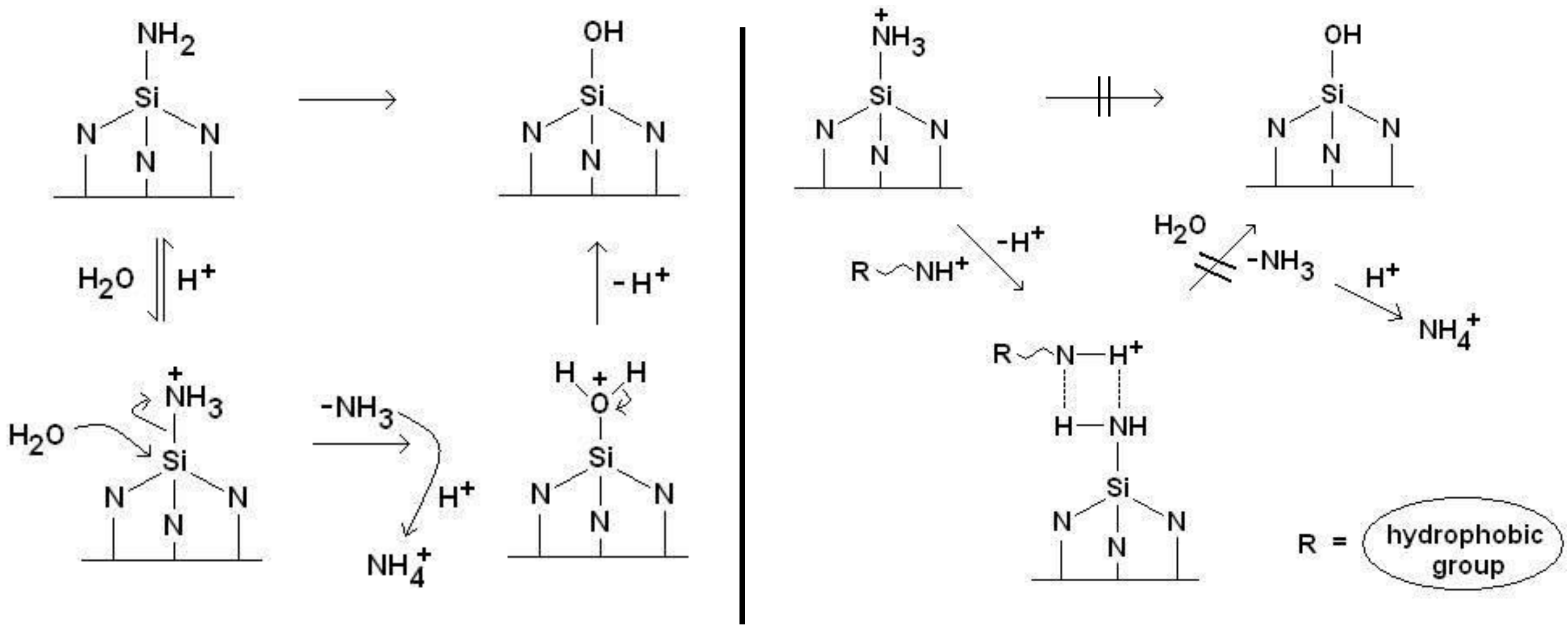
- Wide trench = large dishing
- Narrow nitride = large nitride loss
- Low pattern density: Wide trench + narrow nitride = large dishing + large nitride loss

High (oxide:nitride) selectivity is critical!

STI Slurry Formulation Overview

- Ceria particles
  - Abrasive particle needed for material removal
- Suppressant
  - Amine-based chemistry for passivation of SiN surface
- Other additives
  - Accelerants to boost SiO_2 removal rate
  - Dispersants to stabilize particle
  - Rheology modifiers
  - Biocides to promote long slurry shelf life

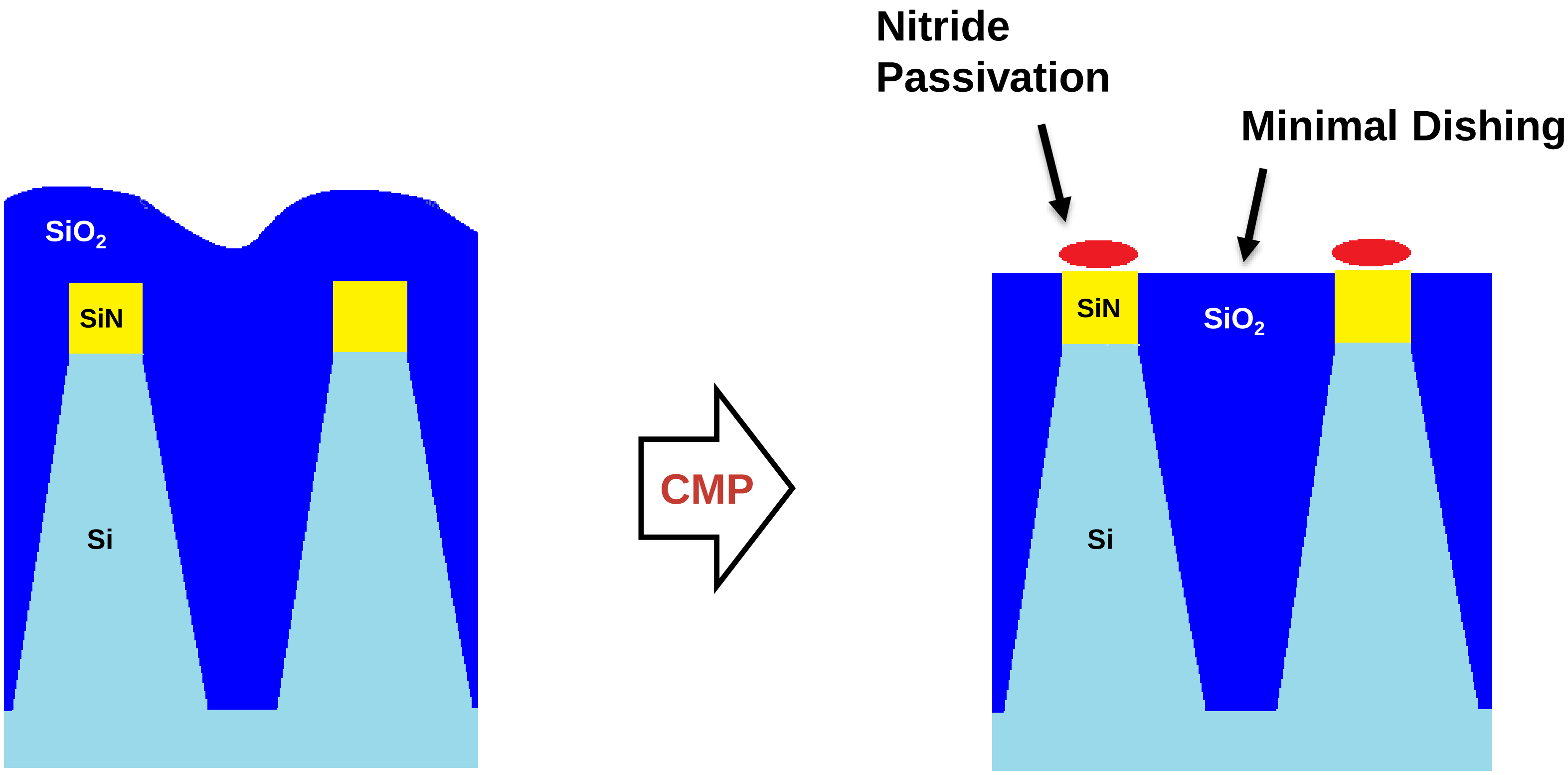
Mechanism of SiN Passivation



Without suppressant

With amine suppressant

SiN Passivation Model



- Nitride loss is minimal following formation of passivation layer
- High planarization efficiency with long over-polish window
- Dishing and erosion minimized

Ferro’s Historical STI Slurries

	Dmean (nm)	D0 (nm)	LPC’s > 0.5 um	% Ceria	HDP Removal Rate (A/min.)	Nitride Removal Rate (A/min)
1st Gen STI Slurry	145	450	500,000	4	2000	<20 A/min.
2nd Gen STI Slurry	145	450	450,000	4	2700	<20 A/min.

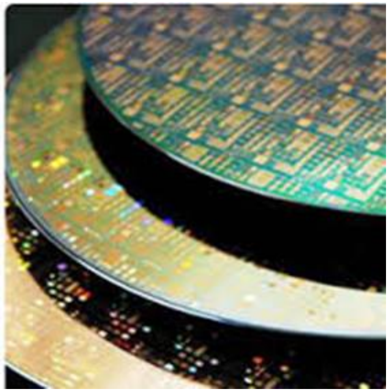
- SiN passivation chemistry accomplishes high selectivity

New Device Requirements

- As devices get smaller and more complex, the demands on the STI slurries that enable their construction increase:

  Defects

  - Continuous push for reduction in defects
  - Large particle count (LPC) control has been demonstrated to be key



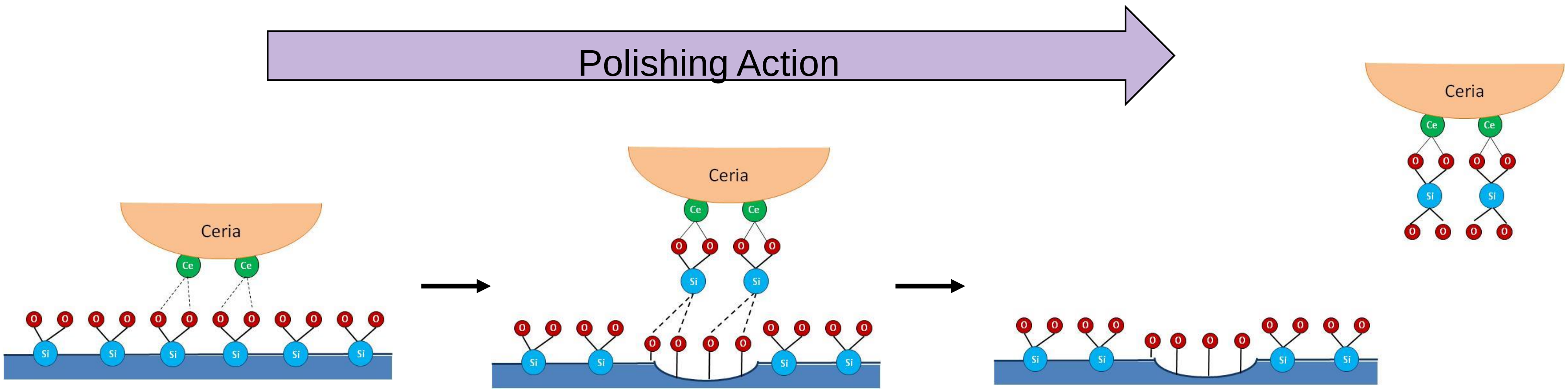
How do we get there?

1. Fundamental understanding of ceria polishing

2. Reduction of particle size and LPC’s

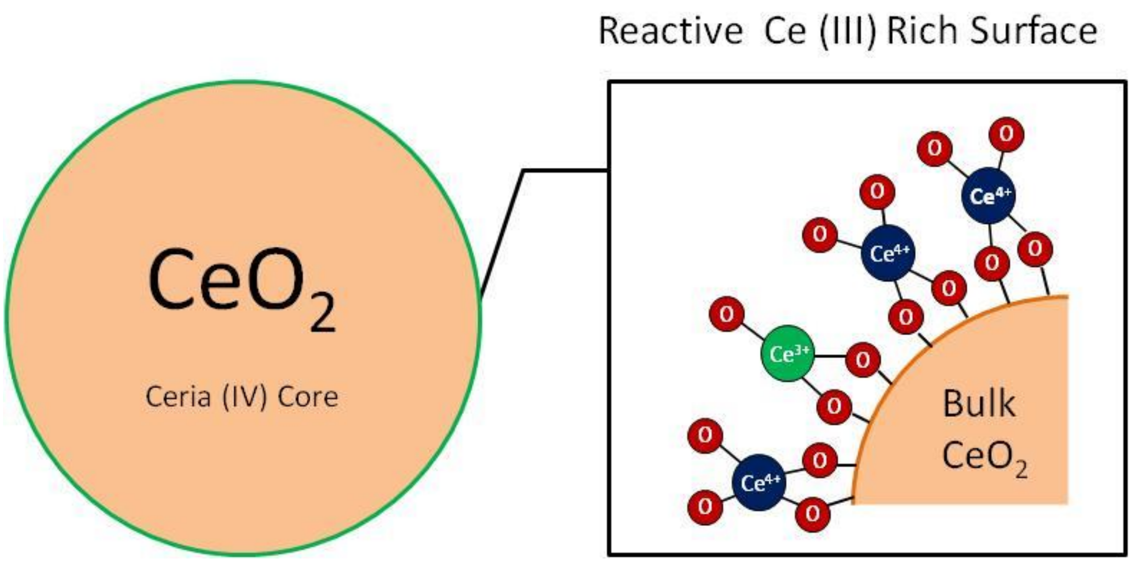
Ceria Polishing Mechanism: Surface Chemical Action

- As opposed to other abrasive types, ceria has a large surface chemical action during oxide polishing



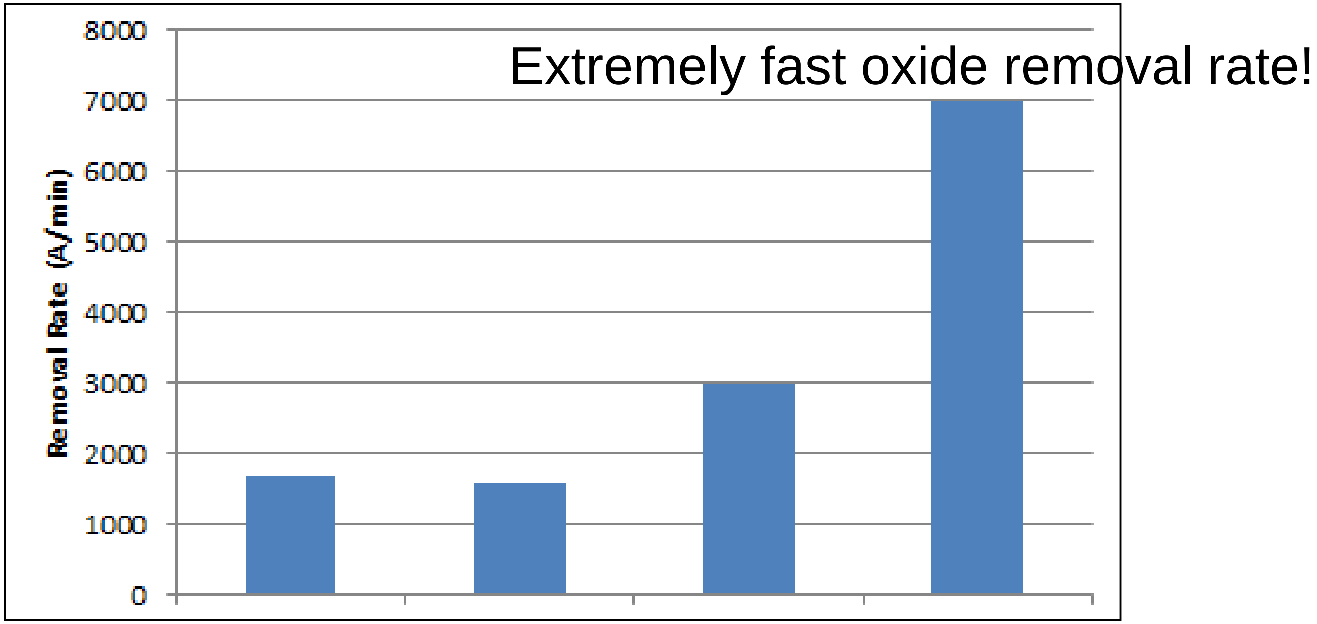
- Studies have shown that **Ce^{3+}** sites on the surface of ceria particles are critical for SiO_2 removal rate
  - Veera Dandu (Clarkson thesis, also presented at 17th Annual International Symposium on Chemical Mechanical Planarization, August 12th-15th, 2012, Lake Placid, NY)

Cerium (III) Stabilization



- Ferro has developed an additive package that stabilizes the Ce^{3+} on the surface of the ceria, leading to a higher population of Ce^{3+} sites and the subsequent acceleration of SiO_2 removal rates
  - Additive is stable in solution (beyond 12 month shelf life)
  - Additive also buffers pH in low regime (pH=3-4)

Rate Accelerant Performance



Particle	145 nm ceria	130 nm ceria	130 nm ceria	130 nm ceria
pH	low	low	high	low
Accelerant Package	no	no	no	yes

All systems tested at 3 wt% ceria

Ferro's STI Slurry Evolution

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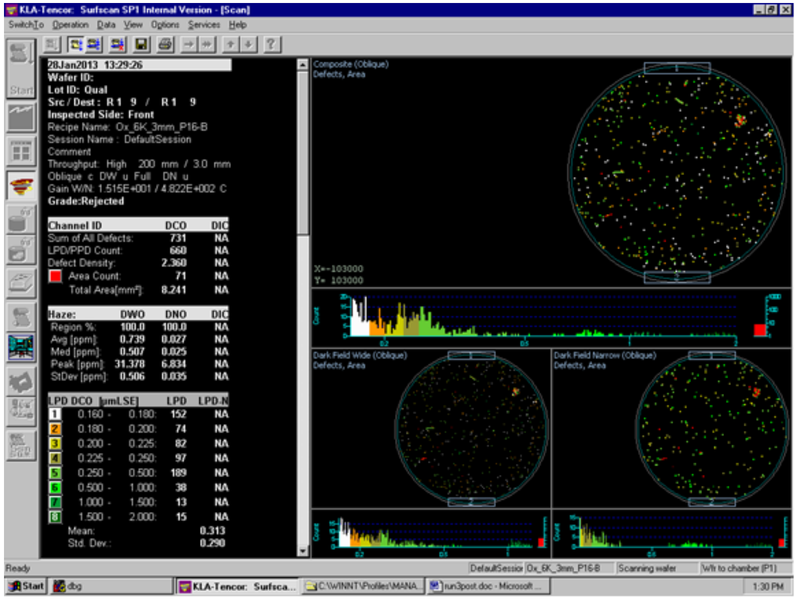
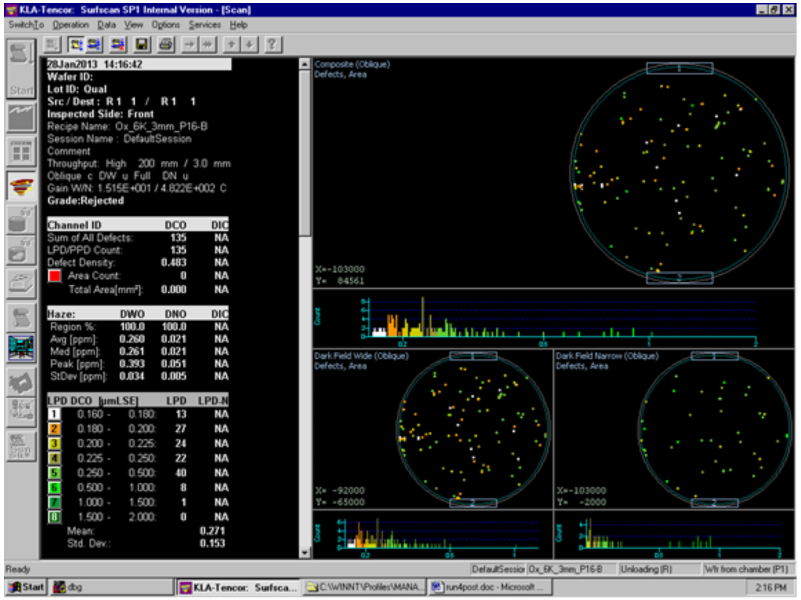
	Dmean (nm)	D0 (nm)	LPC's > 0.5 um	% Ceria	HDP Removal Rate (A/min.)	Nitride Removal Rate (A/min)
1st Gen STI Slurry	145	450	500,000	4	2000	<20 A/min.
2nd Gen STI Slurry	145	450	450,000	4	2700	<20 A/min.
3rd Gen STI Slurry	130	300	<40,000	3	3500	<20 A/min.
SRS-2092	130	260	<10,000	0.5	2700	<20 A/min.

- Same rate/selectivity with significantly lower ceria content
- Lower COO at 0.5% ceria loading

Continuous Improvement for Lower Defects



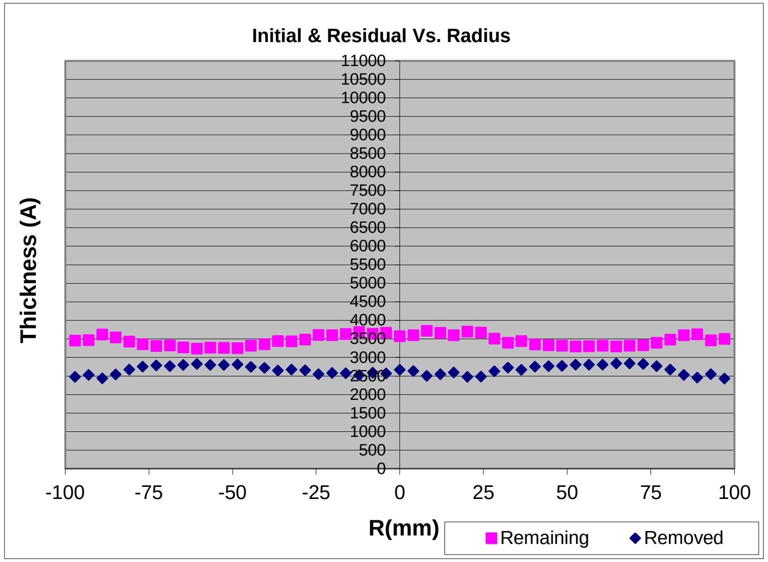
2nd Gen. STI slurry
LPD Adder = 600



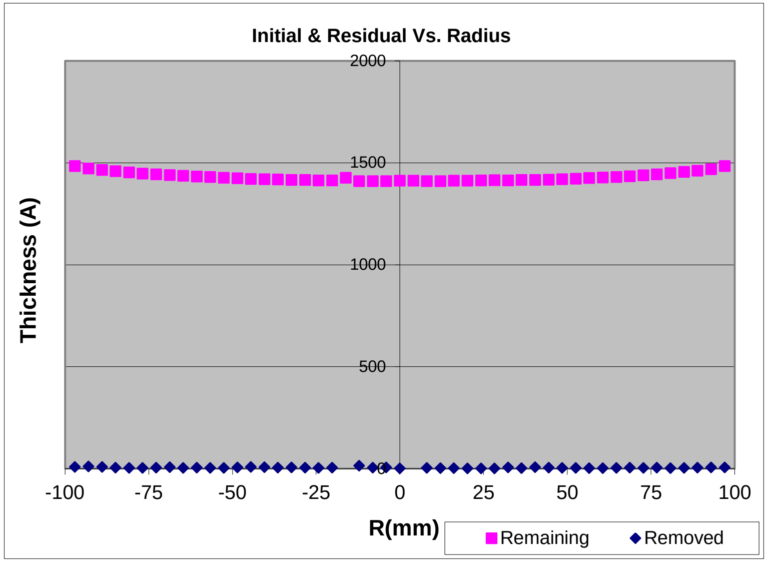
SRS-2092
LPD Adder = 100

- Lower defectivity at smaller particle sizes and reduced LPC's

SRS-2092: Low Solids STI Slurry



HDP: 2658 A/min RR



Nitride: 4 A/min RR

- Customer has reported >500:1 selectivity!

SRS-2092: Over-Polish Behavior

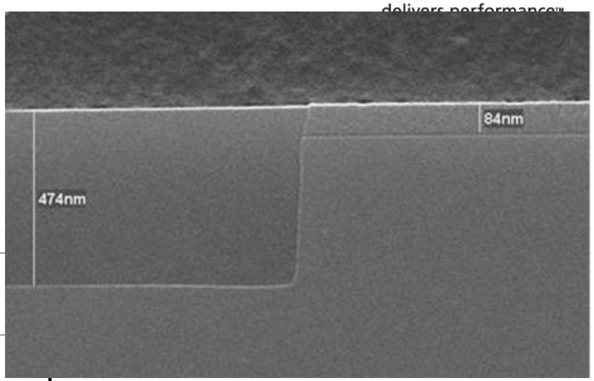
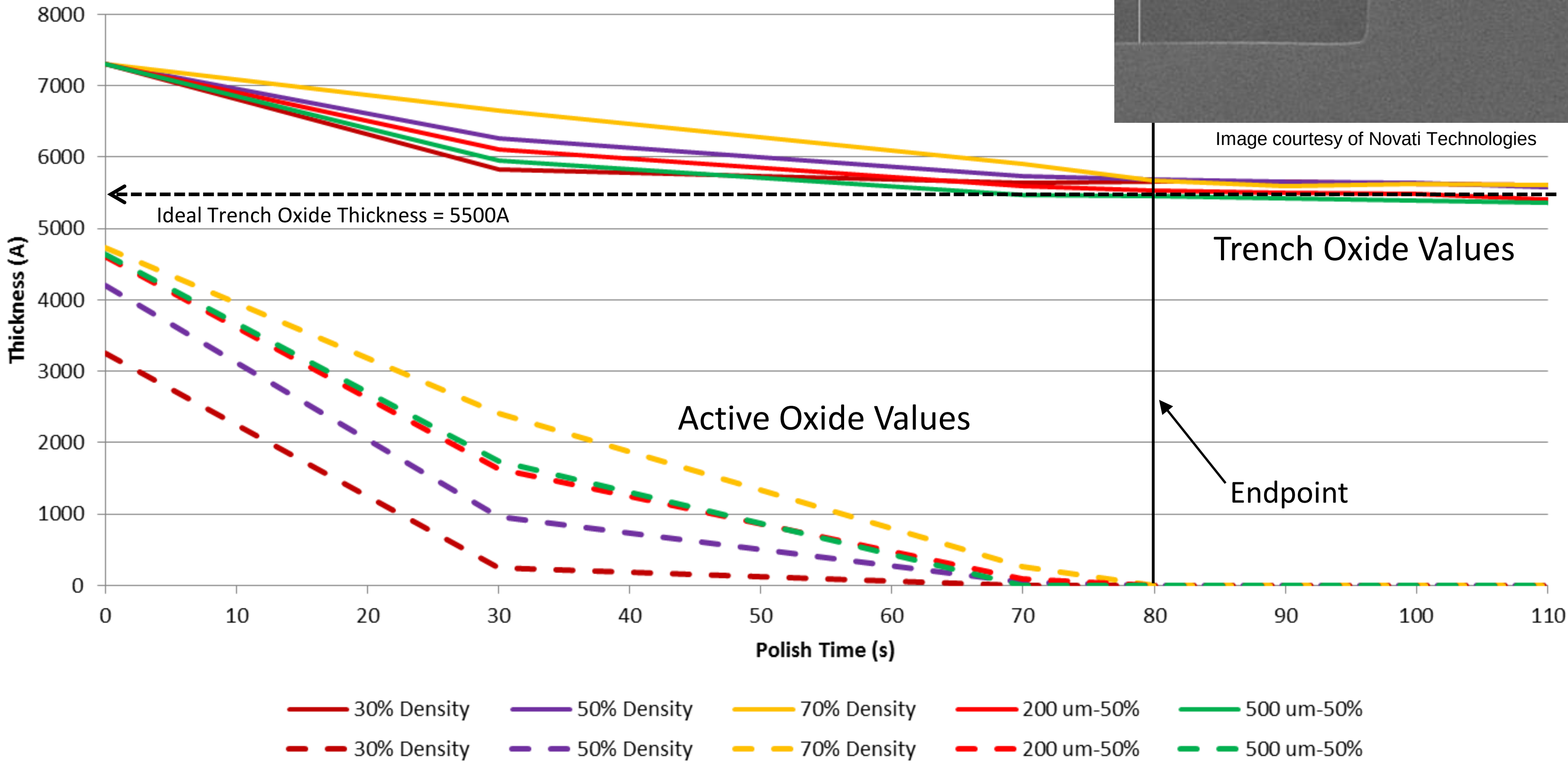


Image courtesy of Novati Technologies



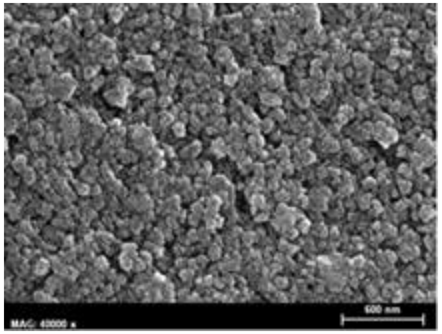
- Extremely long over-polish window with minimal trench loss

Where to next?

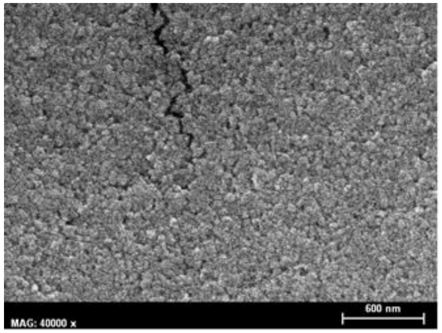
1. Even further reduction of particle size and LPC's

2. Colloidal ceria-based STI slurry

Low Dmean SRS-2092



SRS-2092
~ 130 nm



LDM SRS-2092
~ 70 nm

	Dmean (nm)	D0 (nm)	LPC's > 0.5 um	% Ceria	TEOS Removal Rate (A/min.)	Nitride Removal Rate (A/min)
SRS-2092	130	260	<10,000	0.5	3400	<20 A/min.
LDM SRS-2092	70	131	1,700	0.5	2800	<20 A/min.

- Similar polish behavior as SRS-2092 at almost half the size

Colloidal SRS-2092

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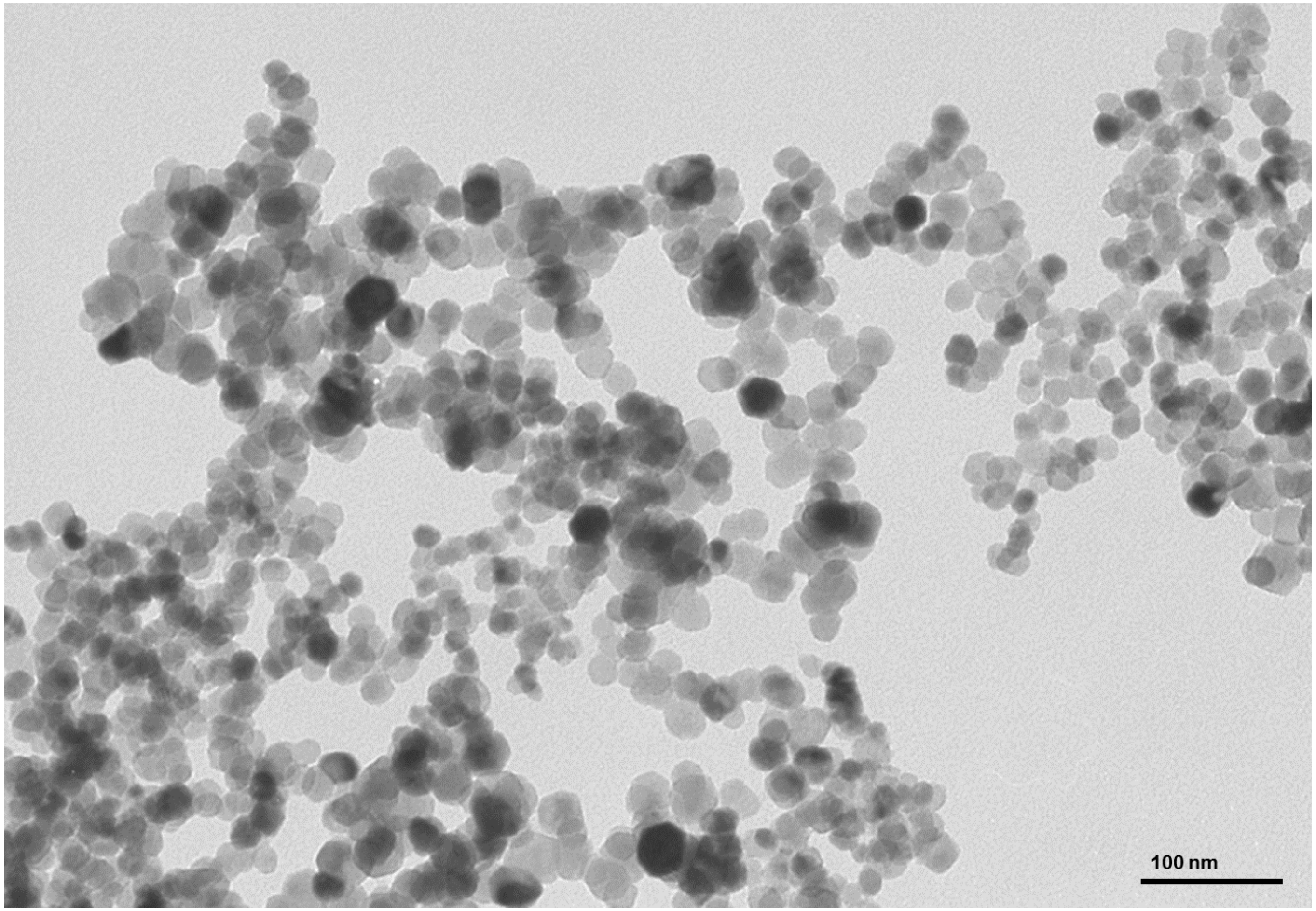
- Colloidal ceria-based slurry under development with the intent to further reduce particle size and potentially defects

	Dmean (nm)	% Ceria	TEOS Removal Rate (A/min.)	Nitride Removal Rate (A/min)
SRS-2092	130	0.5	3400	<20 A/min.
LDM SRS-2092	70	0.5	2800	<20 A/min.
Colloidal SRS-2092	30	0.5	2000	<10 A/min.

- Slightly reduced removal rates with extremely high selectivity

Sub-30nm Ceria

- Ferro is working towards a sub-30nm STI slurry for next generation devices



Conclusions

Ferro has developed next gen. STI slurries with the following considerations

- High Selectivity:
  - Amine passivation chemistry accomplishes the high selectivity needed for STI
- Rate Enhancement:
  - Chemical accelerant package allows for high removal rates with low ceria content
- Defectivity Improvement:
  - Continuous reduction of particle size and LPC’s
  - Colloidal ceria

Acknowledgements

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