The Changing Needs of CMP: How to Design for Technology Shifts

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Solutions for Wafer Cleaning, Surface Preparation and CMP Processes

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EKC CMP Products

CMP Products	pH	Abrasive
– MicroPlanar™ CMP1000™ former generation oxide slurries	10-11	Silica
– MicroPlanar™ CMP2000™ Advanced Planarization Slurries		
• Including STI2100™, IMD2400™ and PMD2700™	4-6	Ceria
– MicroPlanar™ CMP3000™ series Tungsten Slurries		
• Ferric nitrate based slurries	1-2	Alumina
• Non ferric nitrate based slurries	2-8	Alumina/ SiO_2
– MicroPlanar™ CMP9000™ series Copper Slurries		
• Phase I : Nitrogen based slurries	3-5	Alumina/ SiO_2
• Phase II : Nitrogen based slurries	4-9	Silica
Post CMP Cleaning Products		
– MicroPlanar™ PCMP5000™ series Post-CMP Cleaning Solutions	2-9	
CMP Tool Cleaning Products		
– MicroPlanar™ PCMP100™ series products	1-2	

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Different metals, different depositions...

- Copper, Aluminum
- Barrier material
  - Ti
  - Ta
  - W
  - and why not WN?
  - What about TiSiN?, TaSiN?
- Thinner layers

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…and different dielectric options...

Material	Supplier	k value
CVD OSG Dielectrics		
Black Diamond I & II	Applied Materials	2.4 - 3.1
Coral	Novellus Systems	2.4 - 2.8
Flowfill CVD, Orion low k	Trikon Technologies	2.8, <=2.2
Aurora 2.7	ASM International	<=2.7
CVD etch stop/hard mask		
BLOk	Applied Materials	4.5
Low-k SiC	ASM International	3.8
Spin-On Dielectrics (SODs)		
Polyaromatic (SiLK)	Dow Chemical	2.65
HSQ (Fox), Porous HSQ (XLK)	Dow Corning	2.9, 2.0
MSQ, Porous MSQ	JSR	2.7, 2.0-2.2
Porous silica (MesoELK)	Air Products/Schumacher	1.9
OSG (HOSP), OSG etch stop (HOSP BESt)	Honeywell	2.5, 2.6
Organic (GX-3) & porous organic (GX-3p)	Honeywell	2.6, 1.9
Porous silica (NANOGLASS)	Honeywell Elec. Materials	1.3 - 2.2

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Mechanical Properties of SiO_2 vs low-k Films

…and different mechanical and chemical properties of these different materials...

Materials Properties	PECVD TEOS SiO_2[21, 22]	Zirkon	SiLK	SiLK (v7) film	Fox	XLK	SiCOH	a-SiC:H
k value (Pre-CMP)	4	2.25	2.65	<2.4	2.9	2	2.7+/-0.1	5.1
Hardness (GPa)	8	0.45	0.2	0.16	0.6	0.2	0.25	NA
Modulus (GPa)	71.7	3.1	3.2	2.5	6	2	3.2	NA
CTE (ppm/°C)	0.94	16	66	NA	20	<10	NA	NA
k value (Post CMP)	NA	NA	2.7+/-0.04	2.44+/-0.04	NA	>4.1+/-1.26	3.05+/-0.24	5+/-0.16

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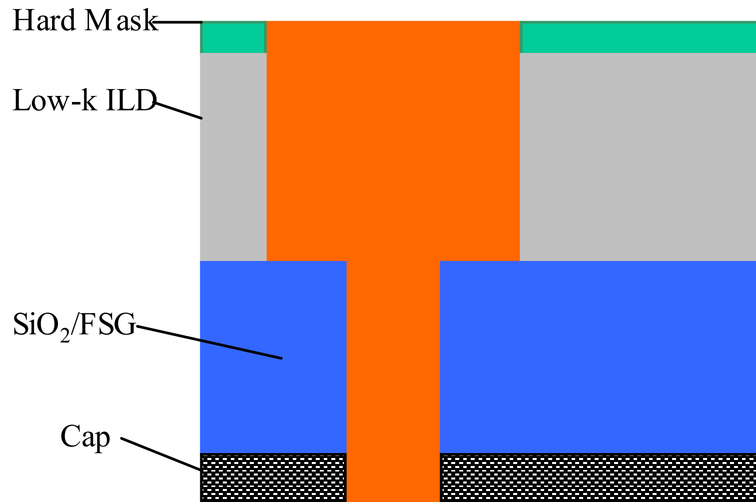
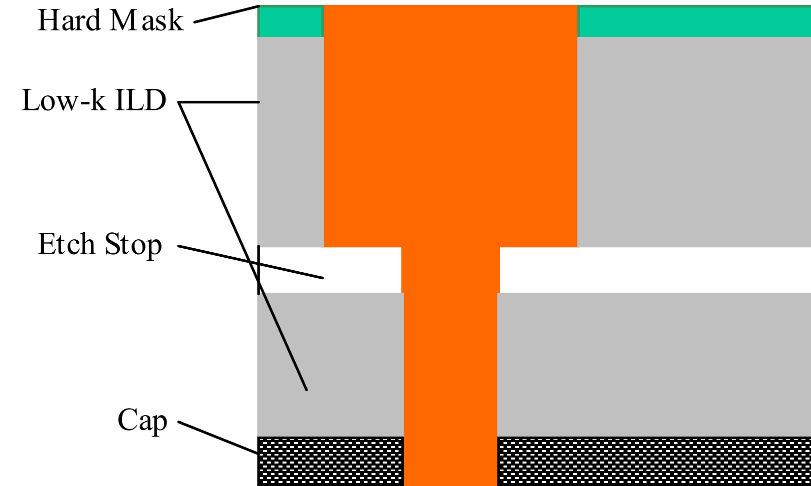
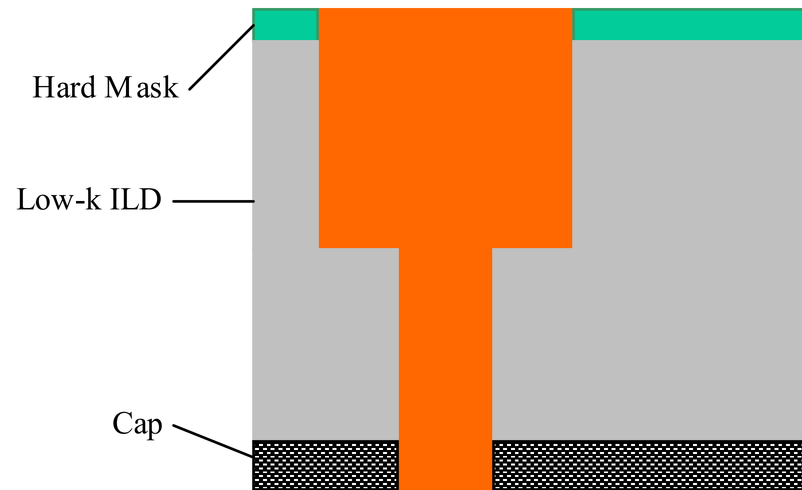
…and different Integration Schemes…





Hybrid Integration

Low-k with etch stop



Low-k with timed etch

Dow Chemical Co.

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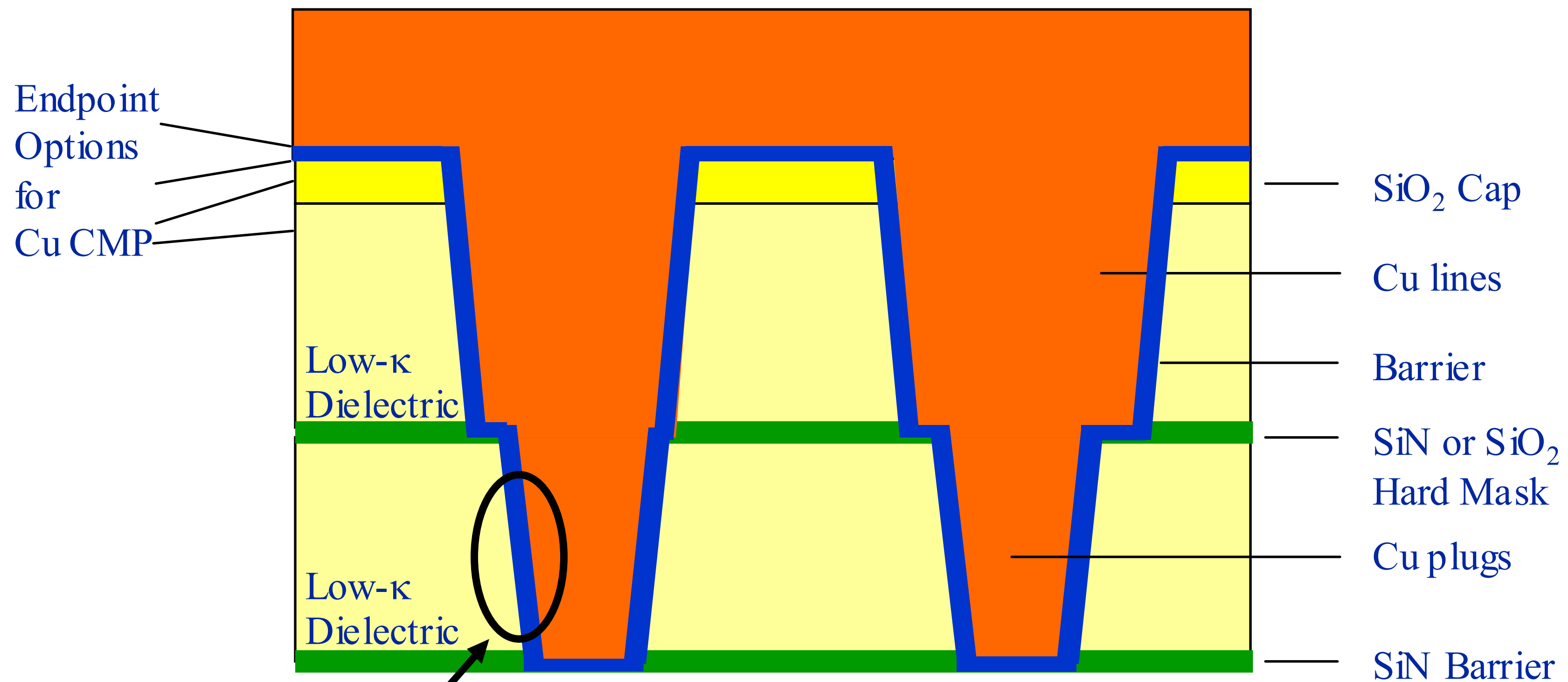
…and different selectivity strategies...



Direct contact between metal & low-κ is unavoidable

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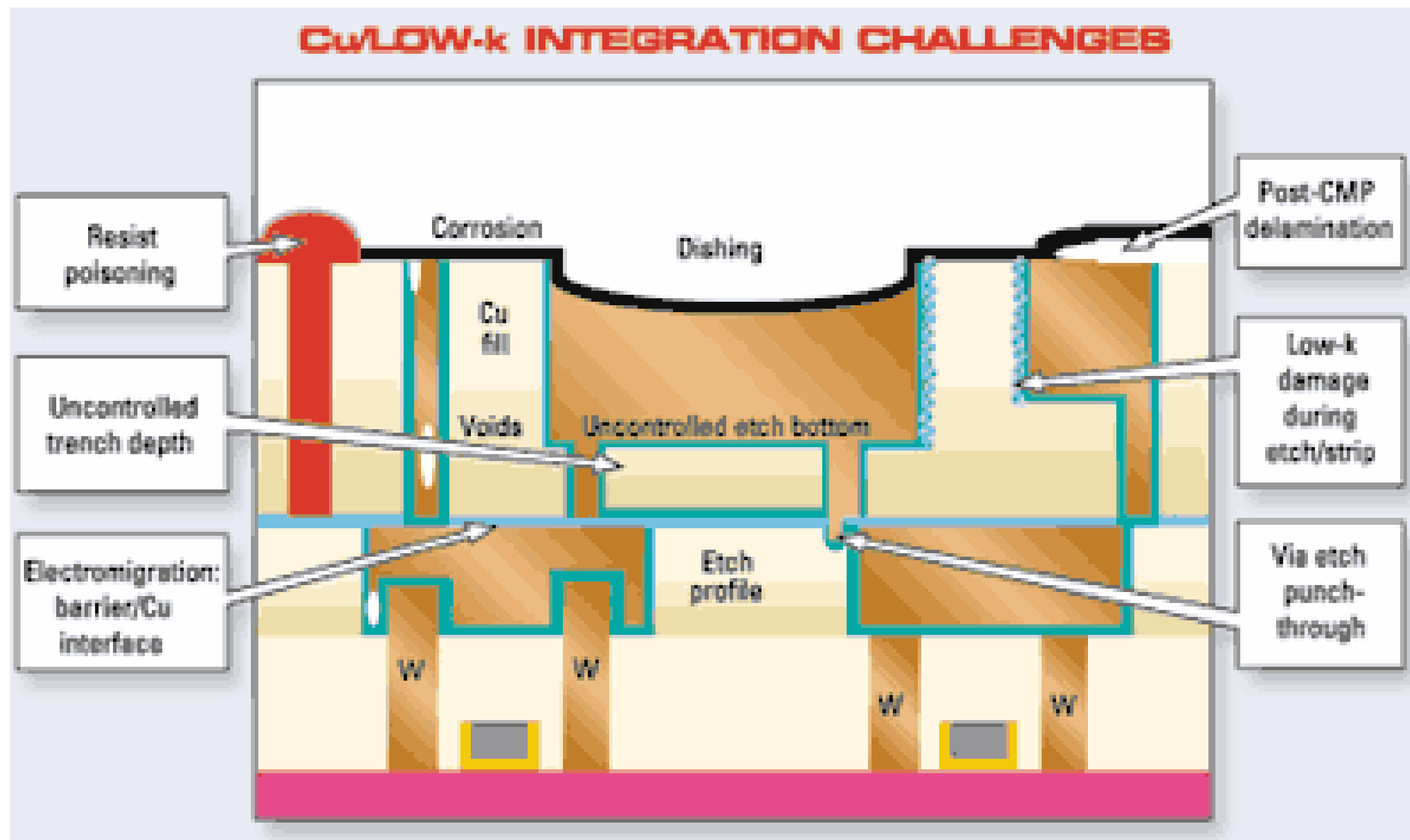
…and different challenges...



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…requires:

- Supplier Flexibility and ability to tune Product
- Tighter Cu and Oxide loss, better planarization, lower defects or higher yields, no corrosion, compatible PCMP solutions
- Lots of communications are needed:
  - Fab / Supplier:
    - » TELL US WHAT YOU DO
    - » TELL US WHAT YOU WANT
    - » TELL US WHEN YOU CHANGE DIRECTION
  - Supplier / Supplier:
    - » Equipment vendor / consumable vendor
    - » Pad vendor / slurry vendor (or pad vendor / conditioning disk vendor,…)
- Technology extension
    - » Product / Process
    - » Alternative technology ??

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MicroPlanar™ CMP3550™

- CMP3550™ abrasive
- Alumina and PIA based slurry (low plug recess and etch rate)
- pH range= ~2 (after mixed with oxidizer)
- Oxidizer= PIA (H_5I0_6) (CMP3510™
- Stable process, no titration required
- Blanket wafers
  - W removal rate = ~3600 Å/min
  - Ti removal rate = ~ 800 to 900 Å/min
  - TEOS removal rate = 350-450 Å/min

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RJX-Series - Summary of Work

- Slurry Information
  - Oxidizer: MicroPlanar™ CMP 3510™ (PIA based)
  - Abrasive: Alumina or Silica
  - After mixing: pH=5.0, solids: 1-3%
- Process: 5.5psi/0psi/120rpm/110rpm/175ml, Ex-situ conditioning
- Pad: IC1000/SubaIV
- Blanket wafer
  - W removal rate =4840Å/min
  - Ti removal rate =1230Å/min
  - TEOS removal rate = 395Å/min

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Effect of Additives with RJX Slurries

Effect of Additive A Concentration on Tungsten Removal Rate
pH=5.0

Concentration of Additive A (%)	Rate (A/min)
0.15	3726
0.25	3670
0.35	3994
0.50	4212
0.75	4741
1.00	4868
1.25	4787

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CSX-Series- Summary of Work

- Slurry Information
  - Oxidizer: CSX291(PIA based)
  - Abrasive: Silica
  - After mixing: pH=3.5, solids: 3%
- Process: 6psi/0psi/90rpm/90rpm/175ml, Ex-situ condition.
- Pad: IC1000/SubaIV
- Blanket wafer
  - W removal rate =4910Å/min±7.6%
  - Ti removal rate =1020Å/min ±6.1%
  - TEOS removal rate = ~400Å/min

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BSSX-Series- Summary of Work

- Slurry Information
  - Abrasive: BSSX-180 or 200 (Silica)
  - After mixing: pH=3.0, solids: 2.5%
- Process: 5psi/0psi/110rpm/90rpm/175ml, Ex-situ condition.
- Pad: IC1000/Suba IV
- Blanket wafer
  - W removal rate = 4750-5200Å/min
  - Ti removal rate = >2000Å/min
  - TEOS removal rate = 250-300Å/min

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Customer Evaluation of BSSX-200

	Slurry A	BSSX-200
Downforce	1	1.11
Tablespeed	1	1
Flow(ml/min)	300	400
Pad	IC1000 Perf	IC 1000 Perf
Tungsten Removal	4011 - 4105Å	4011 - 4052Å
Uniformity	1.64 - 3.64	1.61 - 3.00
Oxide Loss	150 - 250Å	200 - 300Å
Defectivity(total)	<50 @ 0.19µm	<50 @ 0.19µm

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EKC Cu Barrier Slurry Summary

EKC Cu Barrier (TaN) Slurry Summary

Chemistry - Colloidal Silica with Hydroxylamine Chemistry
pH 3.0 - 10.0
SiO_2: 0 - 15% solids

Process - Polishing pressure: 1.5psi - 3.0psi
- Platen speed: 35 rpm - 95 rpm
- Slurry flow: 150 ml/min - 250 ml/min

Performance - Films (Cu, TaN. Oxide, Low-k, etc) selectivities can be tuned

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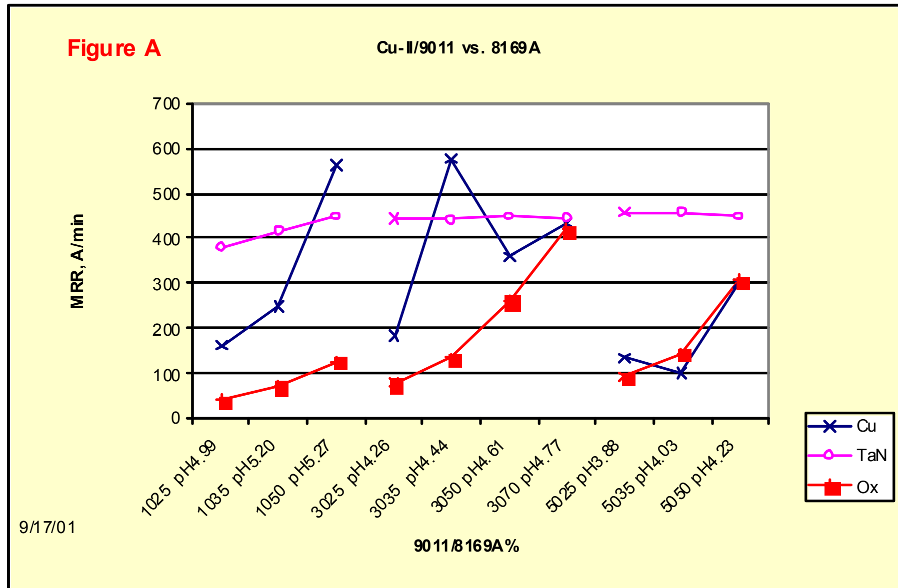
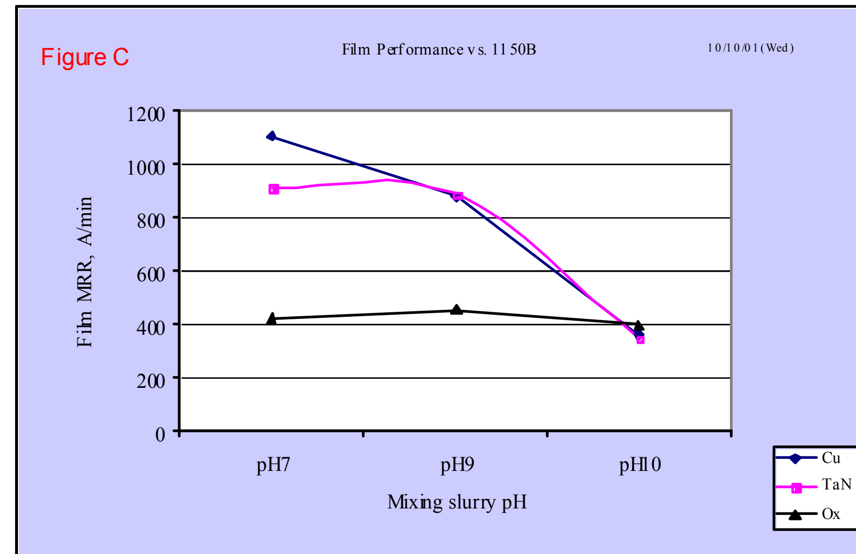
EKC Product Flexibility for Copper



Selectivities can be adapted with simple chemistry and/or mixing ratio adjustments



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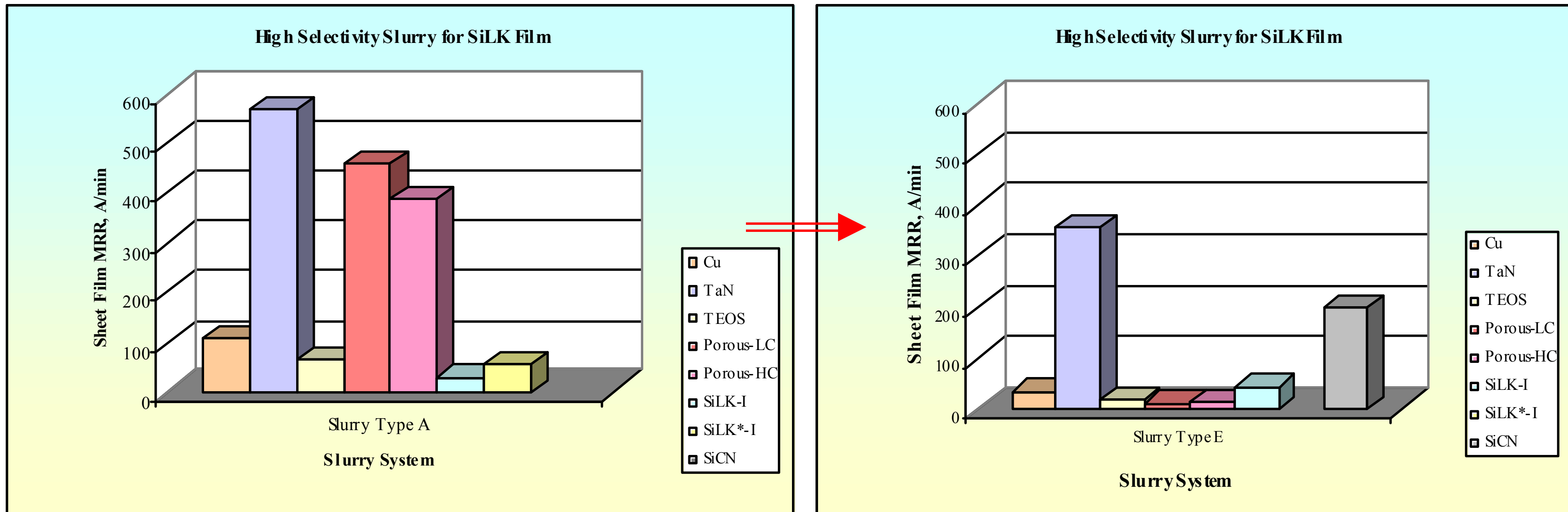
Nitrogen-Based Slurry Development for Copper/Low-k (SiLK™) Integration

Silica Based Slurry for High Selectivity Application, <u>2 PSI</u>



Target: Lower SiLK Film MRR

* Original high selectivity slurry (Type A, Cu:TaN:Oxide = 1: 5: 1) shows a higher porous SiLK MRR

* Slurry Type E reduced porous SiLK MRR efficiently.

Process Set up: IPEC 472 Polisher / Politex Embossed Pad

Process: 2 psi polishing pressure, 70 rpm platen speed,75 rpm carrier speed, 200 ml/min slurry flow.

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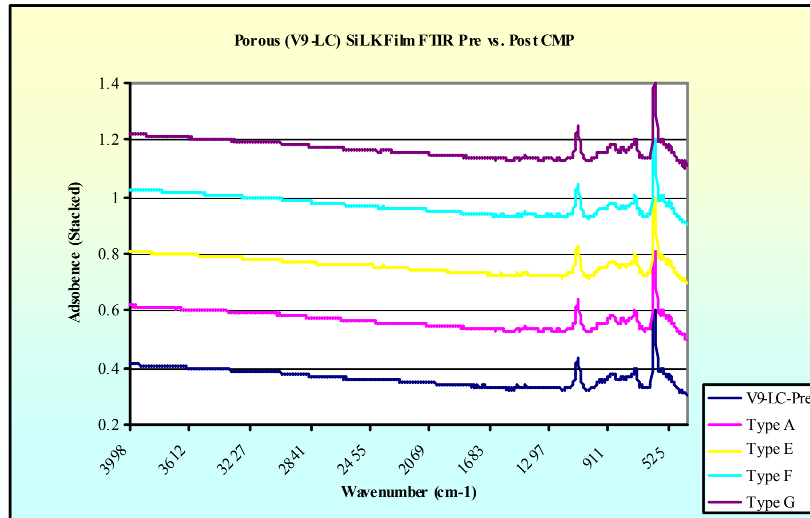
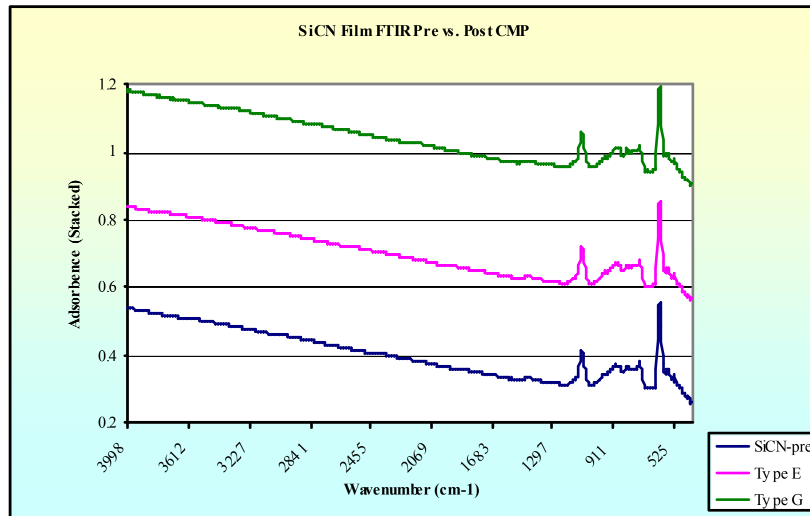
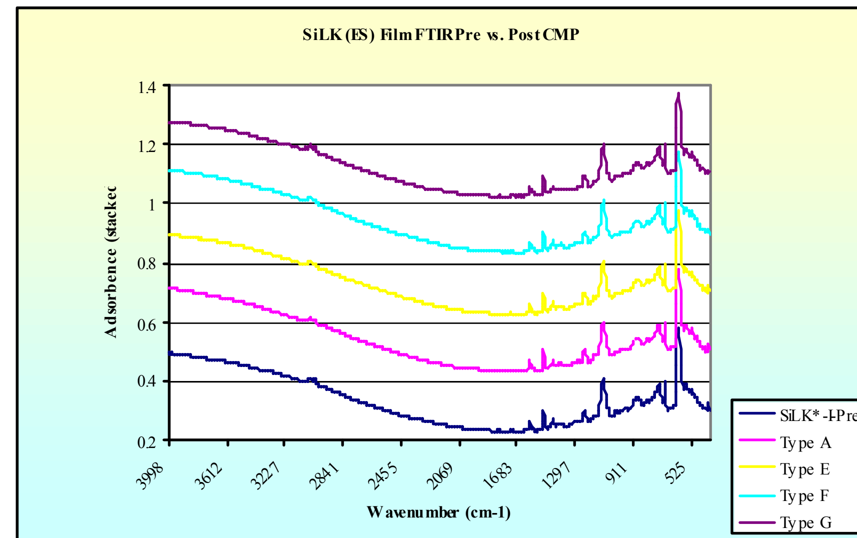
Technology Extension: Compatibility with low-k for direct contact with slurry





1) SiLK Porous and SiLK (ES) Film have no changes on FTIR before and after CMP with EKC slurry

2) SiCN Film has no changes on FTIR before and after CMP with EKC slurry



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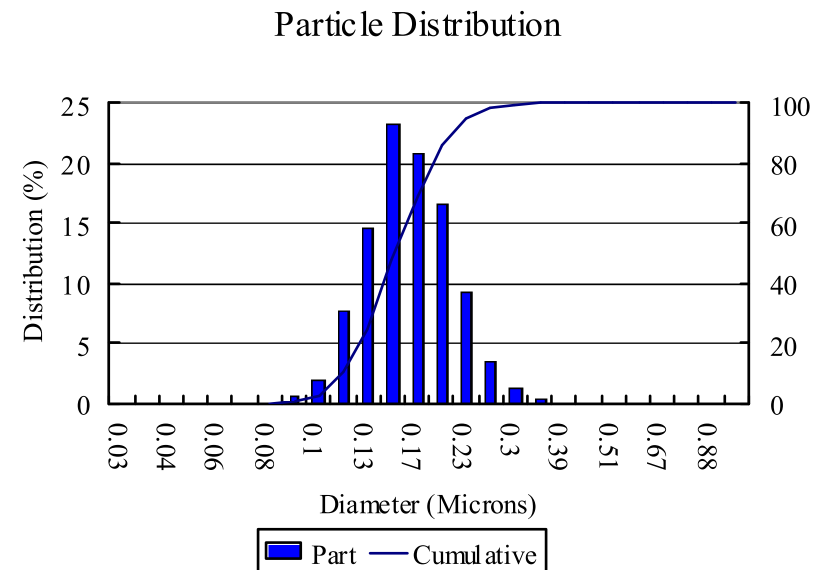
STI*2100*™ STI Slurry

- EKC Exclusive High Purity Ceria
- Low Abrasive Concentration
- Mean Diameter Particle Control: 150 nm
- pH : 5 (desirable pH range)
- Formulated with cAiP™

  (chemical Activator, inhibitor, Planarizer)



Ceria, Horiba LA-920 data

Advantages

- Enables Excellent Planarization
- Reasonable Cost for Advanced STI Slurry
- Single Component

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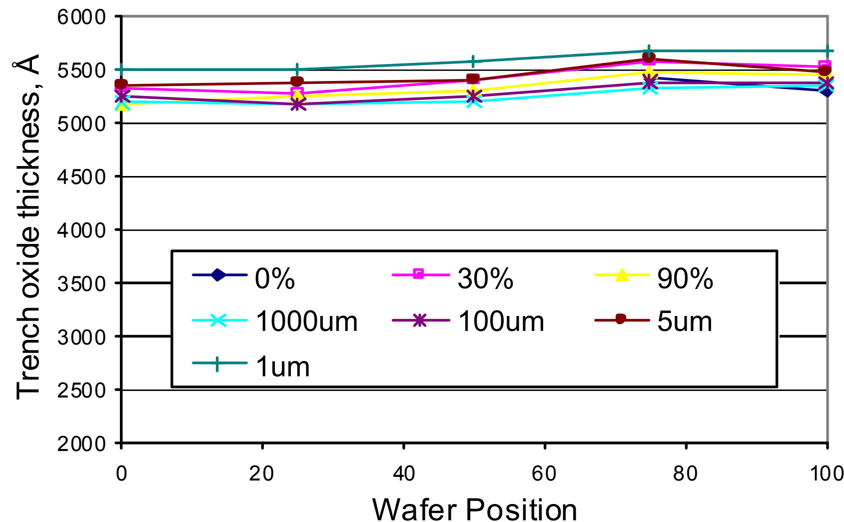
STI*2100*(TM) Performance

Slurry	pH	Abrasive %	Blanket Wafer Removal Rate
Colloidal silica	10.5	20	3400 Å /min
Fumed silica	10.5	12.5	3400 Å /min
Ceria (abrasive only)	9	1	6500 Å /min
STI*2100*™	5	1.5	200 Å /min

Process on EBARA EPO-222D:

5.5psi downforce, 100 rpm platen, 107 rpm carrier, IC1000/Suba 400 perf.. Thermal Oxide wafers



On MIT mask patterned wafer:

- **Excellent planarity**
- **Minimum dishing on various densities and pitch sides**

Process on IPEC472: 4psi DF, 100 rpm platen, 107 rpm carrier, IC1000/Suba 400 perf. SKW3-2 wafers

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Cleaning Performance on MIT Mask Patterned wafer

Slurry	Defect # SP1-TBI > 0.14 µm
STI*2100*™	185
STI*2100*™ + H_20_2 Brush*	40

Process : Ebara EPO-222D. 30s rinse followed by DI brush scrub 60s and pencil cleaner.
No buffing.. 15s polishing.
* 30s brush + 40s H_20_2 1% + 30s brush.

- No buffing, Low defectivity
- H_20_2 is efficient for cleaning remaining Ceria particles

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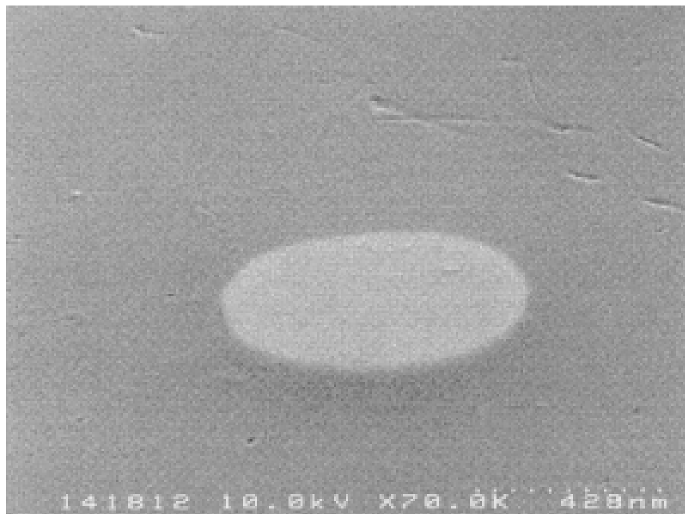
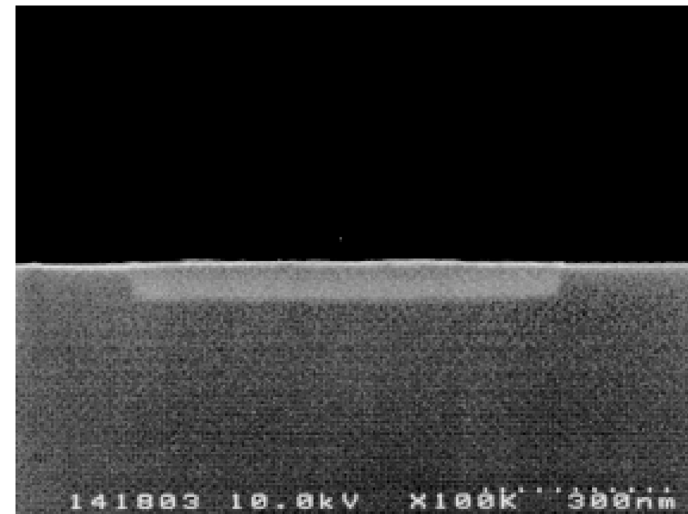
Noble Metals

- Oxidizer and Chemistries currently being evaluated at customer site with great promises.

SEM images of polished Ir/TEOS pattern wafer





Left: Top view of 0.6 micron size Ir plug.
Right: Cross-section of a 150nm deep, 0.6 micron-via size Ir plug.

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LPX-100 Post CMP chemistry

- **Aqueous** (pH 7.5)
- Additional chelation agents and anions
- Good for post CMP copper
- LPX-100.peroxide can clean CeO_2 residues.
- Will not corrode sensitive metal films
- Broad process window
- Environmentally safe and aqueous drain compatible
- Will not corrode equipment
- No sign of bacteria growth (standard plate count CFU/ml)
- No ammonium hydroxide, **No Fluorides**

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Conclusion

- Rapid Technology Shifts and New Challenges Require:
  - Flexible products and processes
  - Close communication with Fabs. More Joint Development Projects.
  - Close communications with Suppliers for a fully integrated supply chain
- EKC and its suppliers are addressing new technologies to answer the needs of the industry

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Technology Extension

- Technology Extension: low down force, gentle process
  - Have I heard < 0.5 PSI? Is my tool capable of this?
- Technology Extension: low shear, lubricity
  - Evaluations on multi layer stacks required. No single layer demo!!
- Technology Extension: lower solids, or no particle ("reactive liquid")
  - Still Chemical Mechanical Planarization
    - Conventional Pads
    - Fixed Abrasive Pads
- Technology Extension: next generation chemistries to modify metal oxide surface for improved removal.
  - More chemical, less mechanical
  - High planarization agents / Topography correction path

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