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# CMPUG 2002

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



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EKC == CMP

It doesn't get any planar than that.<sup>sm</sup>



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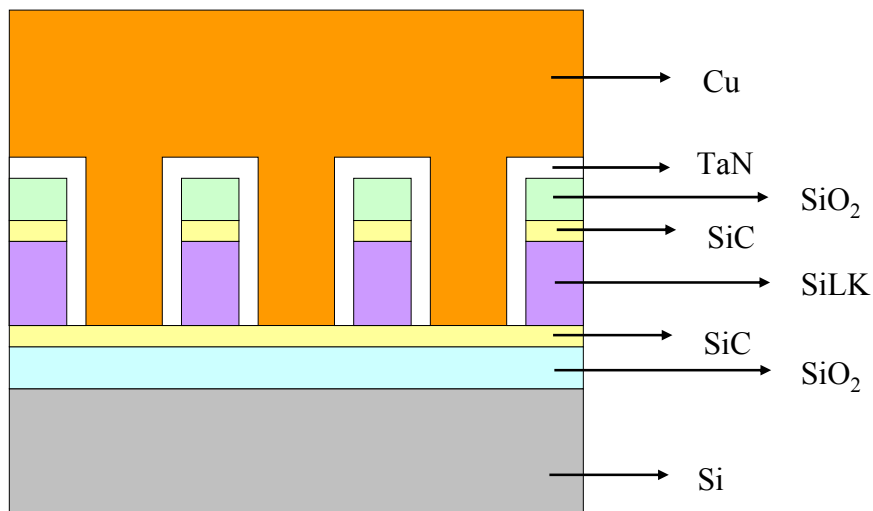
## AGENDA

- ◆ Introduction
  - \* Current Cu/SiLK Integration
  - \* Cu/SiLK CMP Process
  - \* Nitrogen-based slurry
  
- ◆ Experimental Set-up
  - \* Polisher, Pads, Measurement Equipment, Wafers and Slurries
  
- ◆ Results
  - \* Step 2 Hydroxylamine/Silica-Based Slurry for Cu/SiLK (porous and regular) Applications
    - a. High Selectivity
    - b. Low/Non Selectivity
  - \* Copper and SiLK Surface RmS, FTIR After CMP
  
- ◆ Conclusion

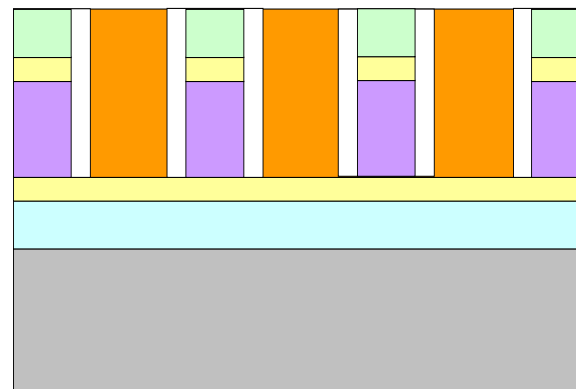


## Nitrogen-Based Slurry Development for Copper/Low-k (SiLK™) Integration

# Copper/SiLK Integration Scheme



Structure with a cap layer

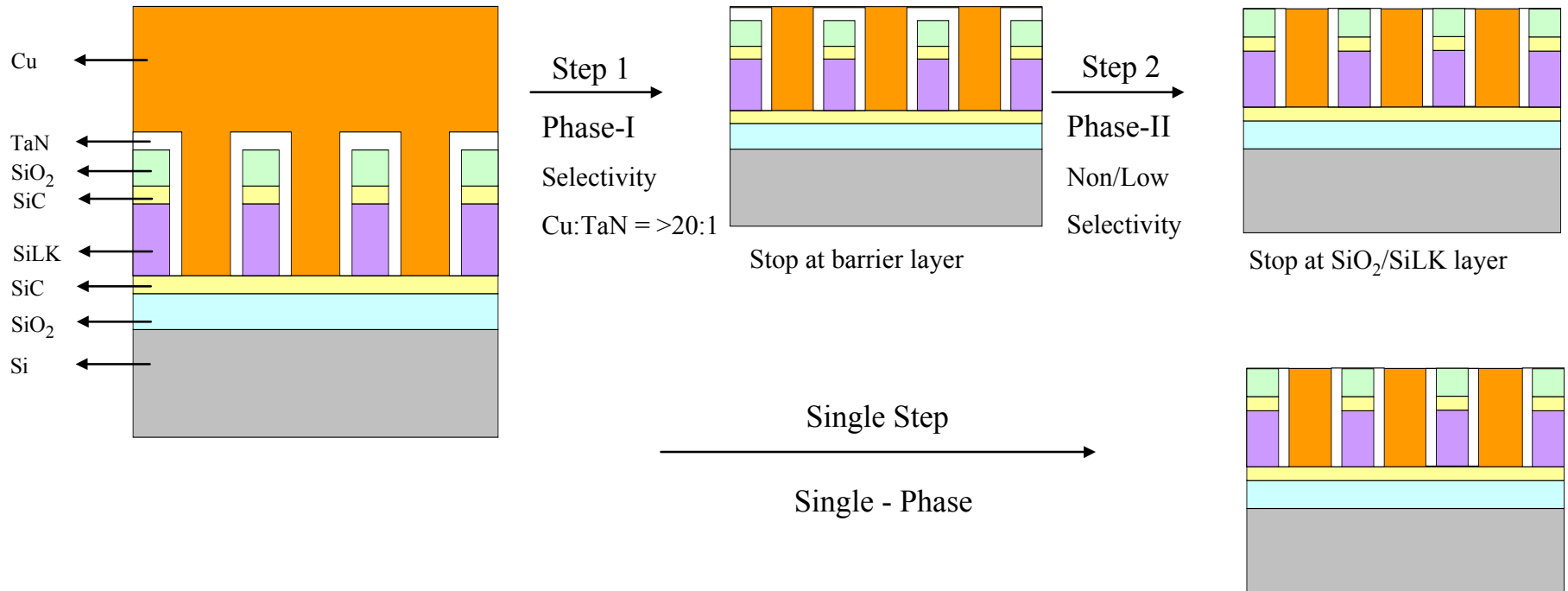


The final stop layer is at ILD layer  
With Cap layer: Stop at SiO<sub>2</sub>  
Without Cap layer: Stop at Low-k layer



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

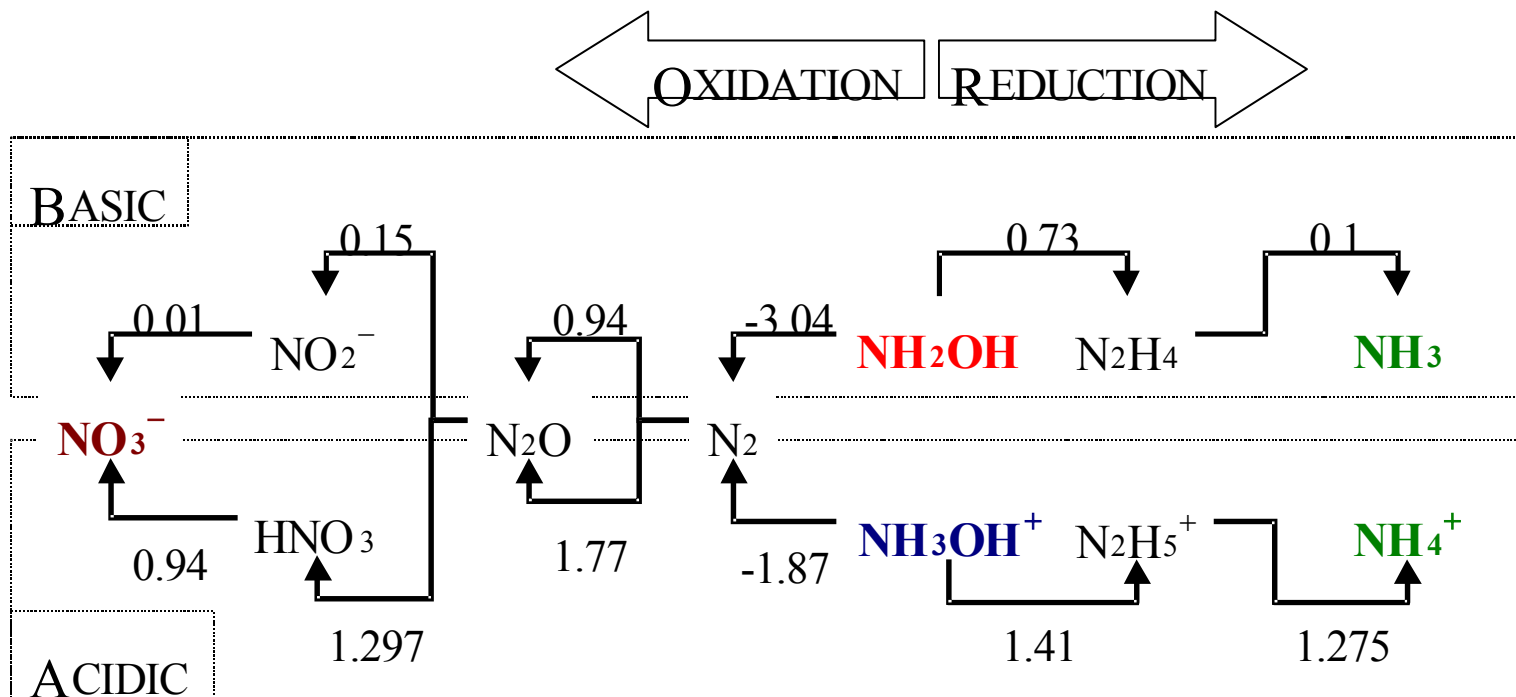
## Copper/SiLK Integration CMP Process





# Nitrogen-Based Slurry Development for Copper CMP

## Hydroxylamine Reduction Potentials & Reaction Paths



Reference: Dr. Srin Raghavan "Copper Removal in Hydroxylamine Based Slurries" 7th International Symposium



# Hydroxylamine-Based Slurry Development for Copper CMP

## Current EKC Cu Slurries

	Oxidizer	Abrasive	Application
Cu Phase-I	Hydroxylamine Based	$\text{Al}_2\text{O}_3$	Removal Cu layer
Cu Phase-II	Hydroxylamine Based	Colloidal Silica (Supply A)	Removal TaN with a high selectivity
	Hydroxylamine Based	Colloidal Silica (Supply A & B)	Removal Cu, TaN, TEOS at a same speed (non selectivity)
Single Phase	Hydroxylamine Based	$\text{Al}_2\text{O}_3$	Removal Cu, barrier and stop at ILD layer



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

## ◆ Experimental Set-up

\* Polisher: IPEC 472;

\* Polishing Pads: Rodel IC1000 k-groove/Suba IV or Politex Embossed polishing pads

\* Measurement Equipment: Cu and TaN Thickness: CDE ResMap 176

TEOS Thickness: KLA-Tencor 650

SiLK Thickness: KLA-Tencor 650 and Gaertner Ellipsometry

SiLK surface chemical change: BioRad FT-IR spectrometer (FTS175C)

Cu Surface roughness: Digital Instrument AFP200

\* Slurries: EKC Cu Phase-I and Phase-II oxidizers, EKC Cu Alumina and Silica Abrasives

\* Blanket Wafers: 200mm EP copper, TaN, TEOS and SiLK: **V9-LC (porous),**

**V9-HC (porous)**

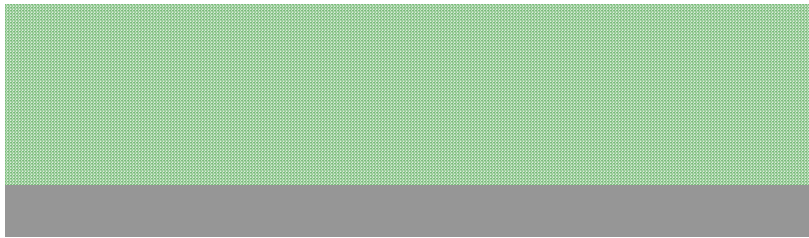
**SiLK-I (regular)**

**SiLK\*I (Ensemble) .**



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

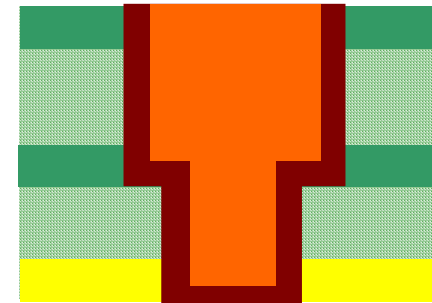
## SiLK Blanket Wafer Types



**Porous SiLK (V9-LC & V9-HC)**



**Regular SiLK (SiLK-I)**

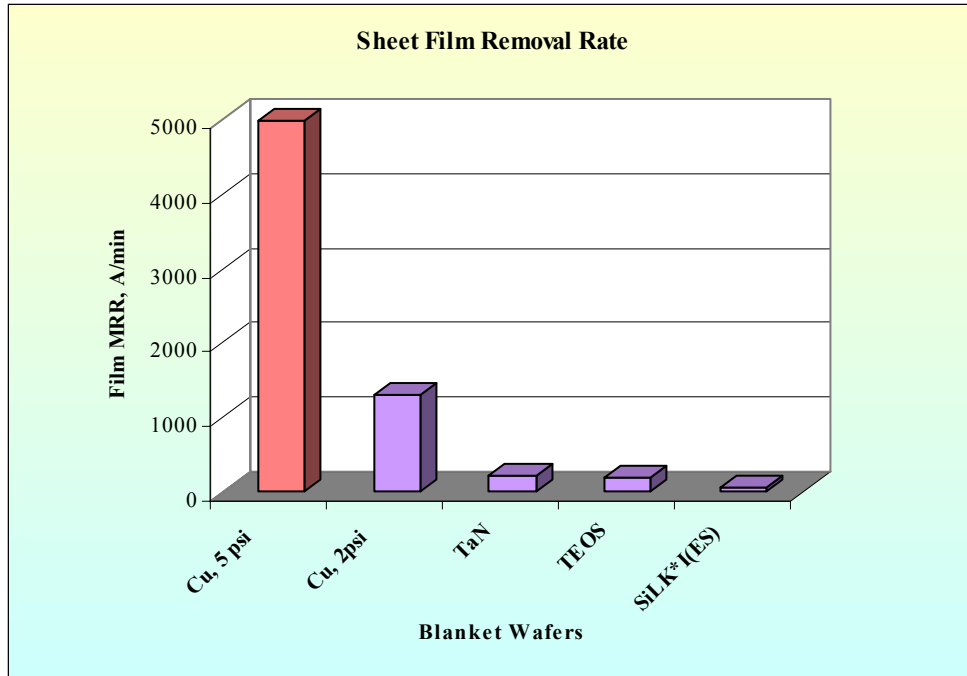


**SiLK+Ensemble Integrated Stack**



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

# Alumina Based Slurry for SiLK Film



IPEC 472 Polisher / IC1000 k<sub>g</sub>/Suba IV Pad

Process (soft landing)	Slurry mixing (v/v/v):
2 psi polishing pressure	50% Cu Oxidizer,
70 rpm platen speed	25% DIW
75 rpm carrier speed	25% Al <sub>2</sub> O <sub>3</sub> (5% solids)
200 ml/min slurry flow	

### RESULTS

- 1) SiLK film RR was 60% lower than the TEOS. TEOS RR = 195Å/min, SiLK RR = 50 Å/min
- 2) Both Cu and SiLK Rms reduced after CMP.

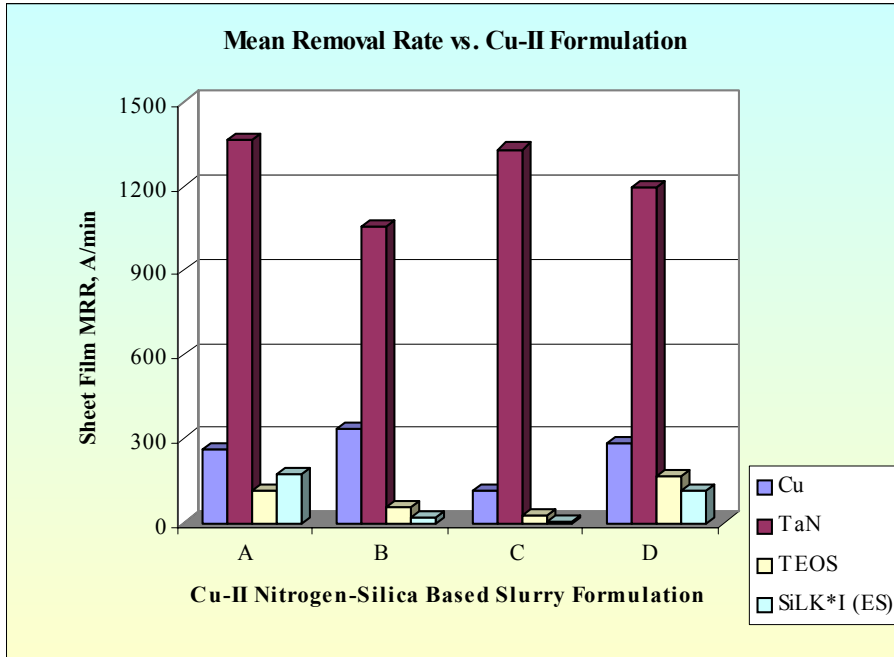
Pre-CMP: Cu >> 30Å, SiLK = 6.5 Å.    Post CMP Cu = 7.3 Å, SiLK = 5.6 Å





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

## Silica Based Slurry for High Selectivity Application



IPEC 472 Polisher / Politex Embossed Pad

Process:

3 psi polishing pressure, 50 rpm platen speed

55 rpm carrier speed, 200 ml/min slurry flow

no conditioning in between

## RESULTS

- 1) Selectivity of Cu:TaN:SiLK = 1: 3-11: <1
- 2) TaN removal rate is related to Cu-II oxidizer concentration as expected.
- 3) Reducing either oxidizer or abrasive will reduce SiLK removal rate.
- 4) Post CMP Rms of Cu and SiLK was 5-10 Å.

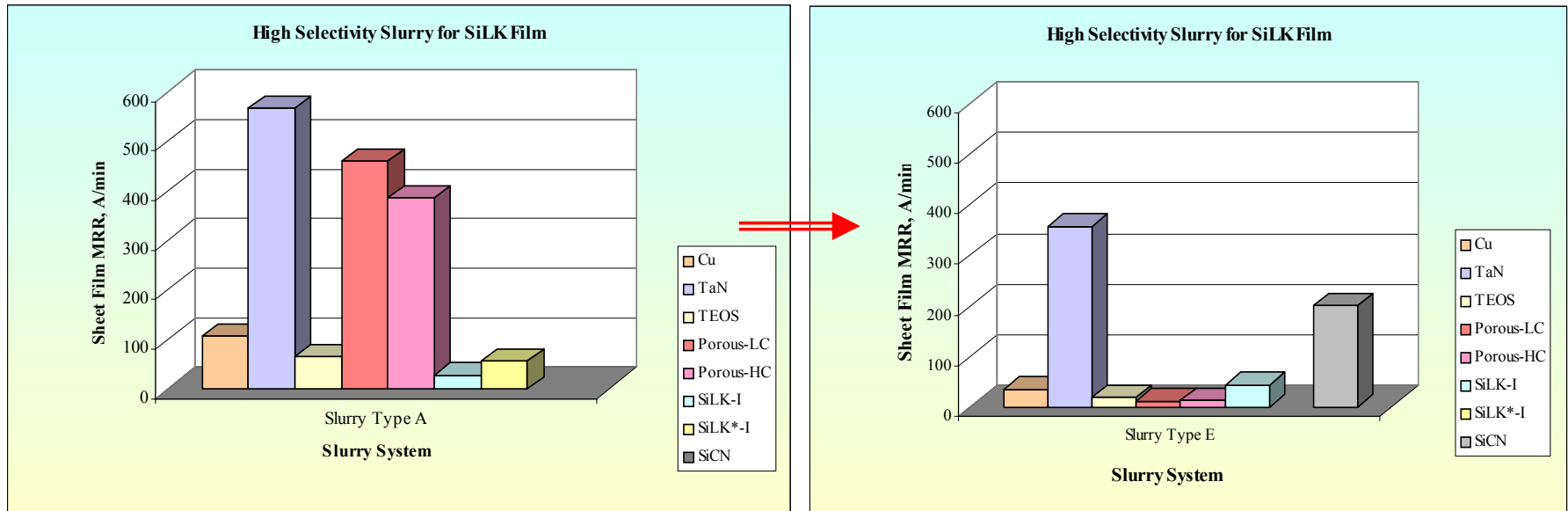
Slurry Formulation				Post CMP Rms (Å)	
Formu	Oxidizer	Silica Solids	Abrasive Type	Cu	SiLK
A	50%	5%	Abra-I	7	5
B	20%	5%		10	7
C	50%	1%		9	6
D	50%	5%	Abra-II	7	5





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

## Silica Based Slurry for High Selectivity Application



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

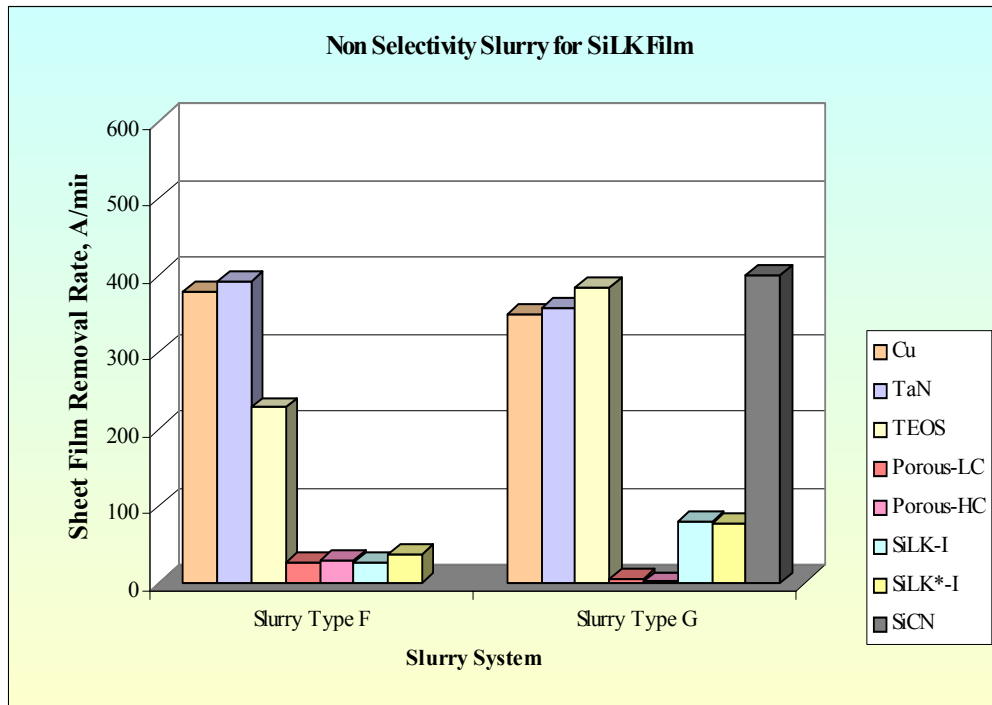
Process: 2 psi polishing pressure, 70 rpm platen speed, 75 rpm carrier speed,

200 ml/min slurry flow.



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

## Silica Based Slurry for Low/Non Selectivity



### RESULTS

**Low/Non Selectivity slurry (Type C and D) showed similar TaN MRR to Cu and Oxide.**

**They also showed a good control for SiLK porous film as well as regular SiLK film.**

**SiCN MRR is similar to oxide**

Process Set up: IPEC 472 Polisher / Politex Embossed Pad

Process: 2 psi polishing pressure, 70 rpm platen speed

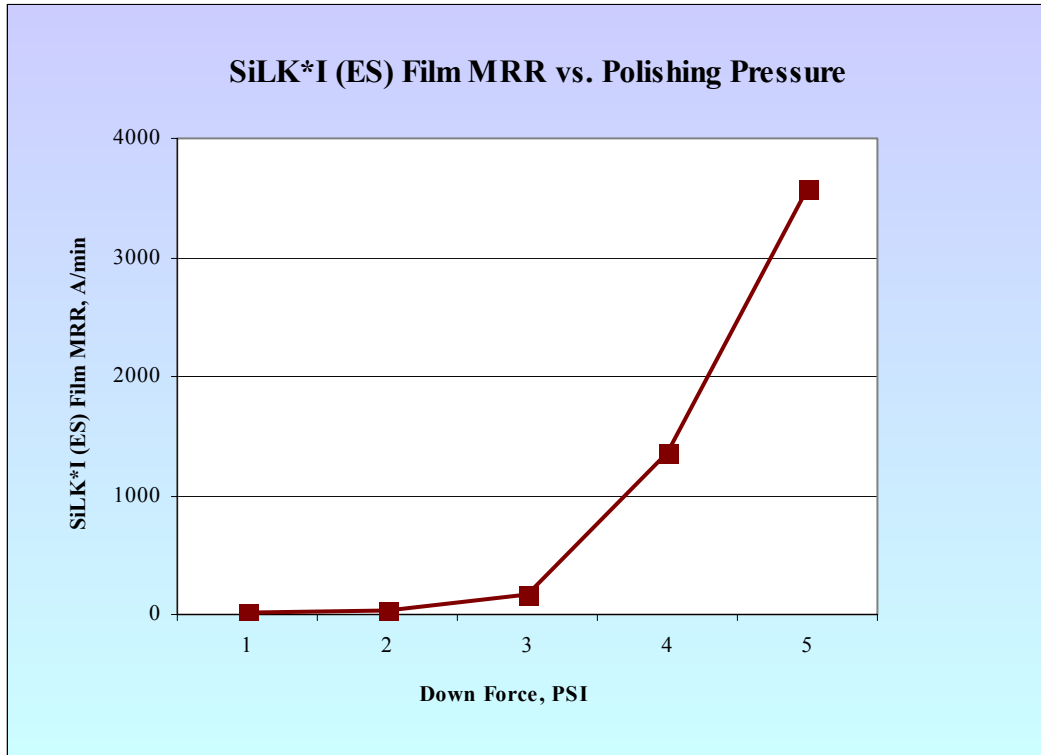
75 rpm carrier speed, 200 ml/min slurry flow





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

## SiLK\*I (Ensemble) Film MRR vs. Polishing Pressure



Polishing Pressure (PSI)	Removal Rate (A/min)	SiLK*I (ES) Rem NU %
1	15	n/a
2	40	n/a
3	174	
4	1367	15.8
5	3576	6.5

### Other Parameters

IPEC472 polisher  
Politex reg pad  
90 rpm pp  
95 rpm cs  
200 ml/min sf

**Slurry Type F**

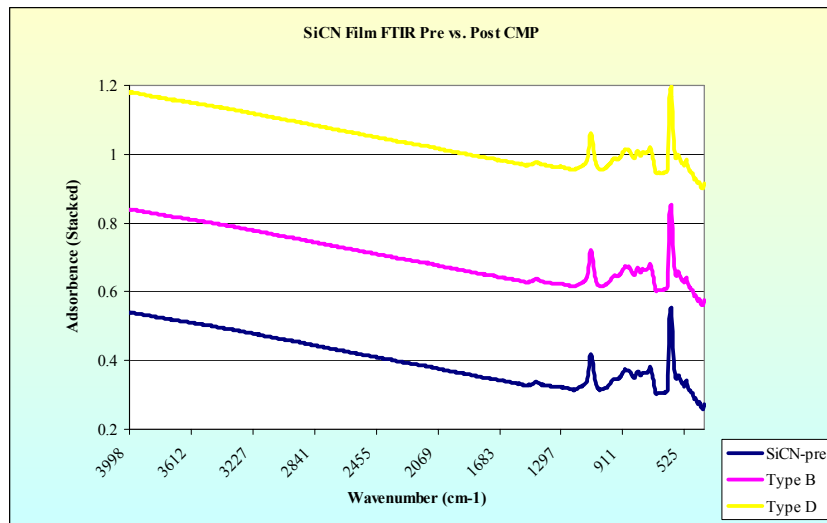
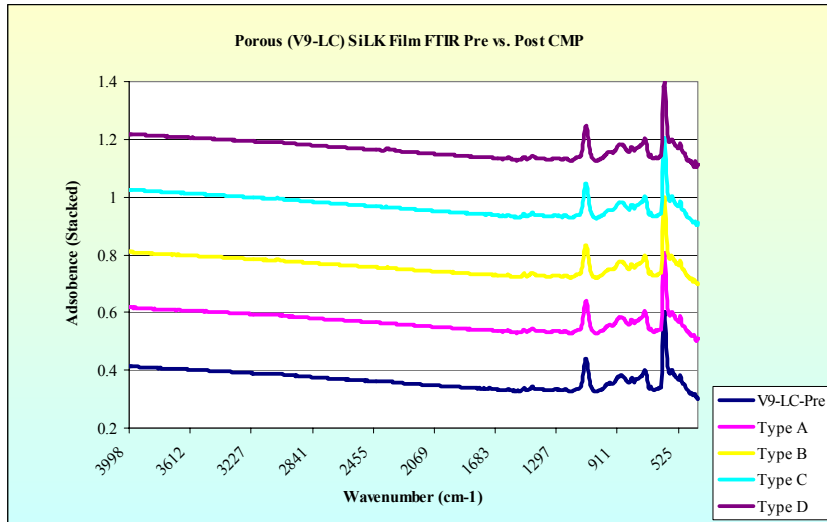
### RESULTS

**SiLK\*I (ES) film has a lower removal rate with lower polishing pressure.**



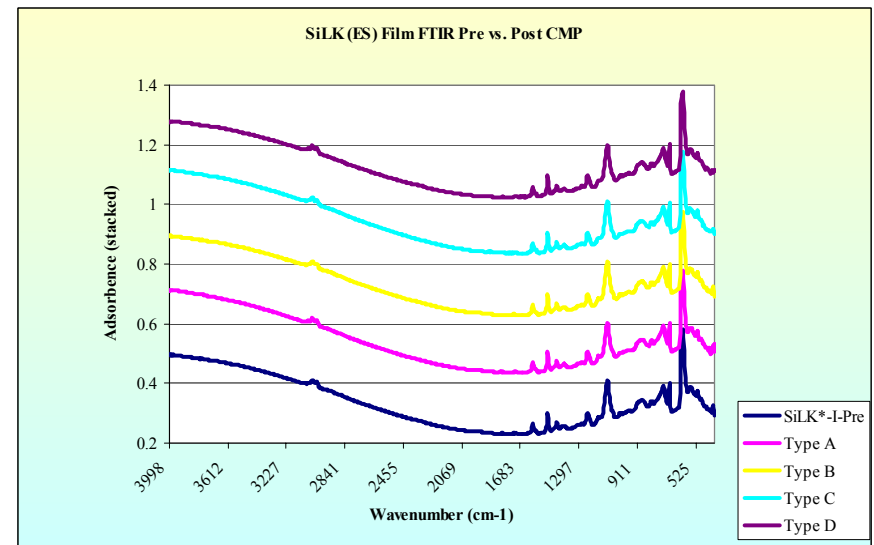
# Nitrogen-Based Slurry Development for Copper/Low-k (SiLK™) Integration

## SiLK Surface FTIR Before and After CMP



### Conclusion

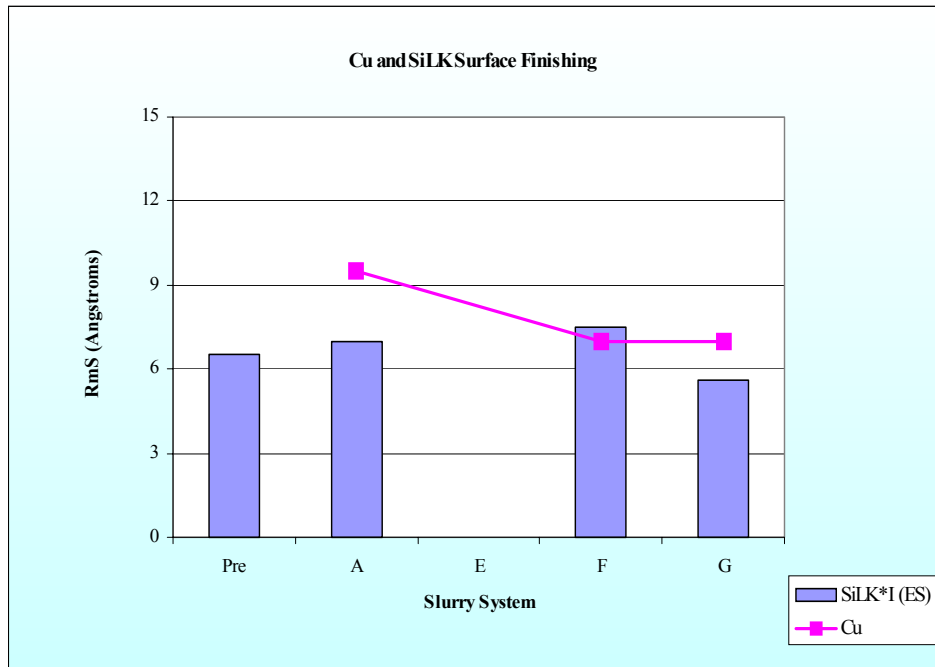
- 1) SiLK Porous and SiLK (ES) Film have no changes on FTIR before and after CMP
- 2) SiCN Film has no changes on FTIR before and after CMP



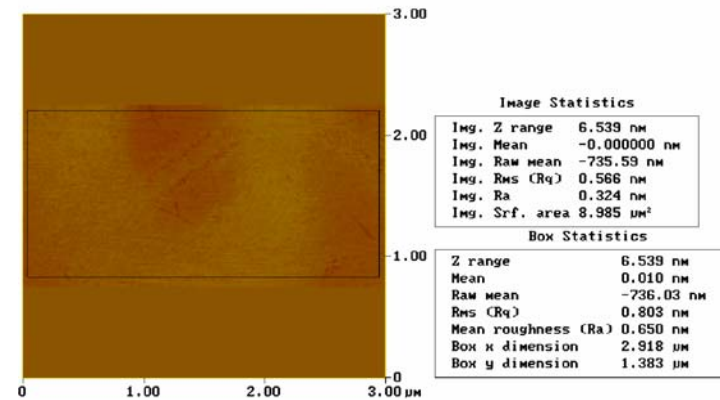


## Nitrogen-Based Slurry Development for Copper/Low-k (SiLK™) Integration

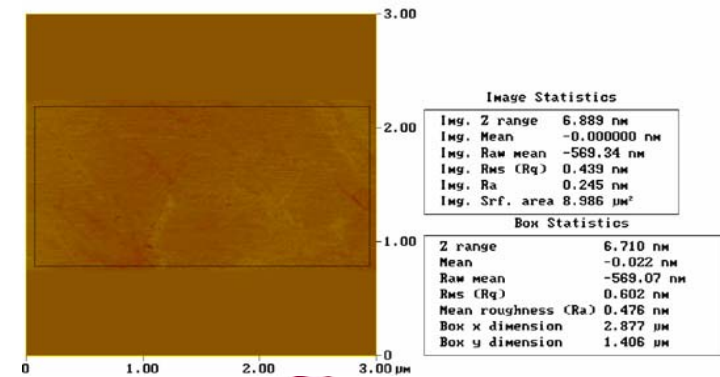
# Copper and SiLK Surface After CMP



Peak Surface Area Summit Zero Crossing Stopband Execute Cursor  
Roughness Analysis



Peak Surface Area Summit Zero Crossing Stopband Execute Cursor  
Roughness Analysis



- 1) SiLK RmS was similar before and after CMP
- 2) Cu preRmS was >30 Å.



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

### Conclusion:

- \* Hydroxylamine-based slurry is compatible for Cu/SiLK (both porous and regular) CMP process.
- \* With silica abrasive, the slurry can be designed for either a high selectivity or non-selectivity of Cu/TaN/Oxide and efficiently stop at SiLK layer.
- \* No delaminating of SiLK films.
- \* SiLK surface RmS and chemical composition were the same as pre-CMP.
- \* Film removal non-uniformity and wafer profile are within the spec.
- \* The new nitrogen-based slurries have the potential to reduce the COO.



# Acknowledgements

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