CMPUG 2002

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

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It doesn't get any planar than that.^{sm}

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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

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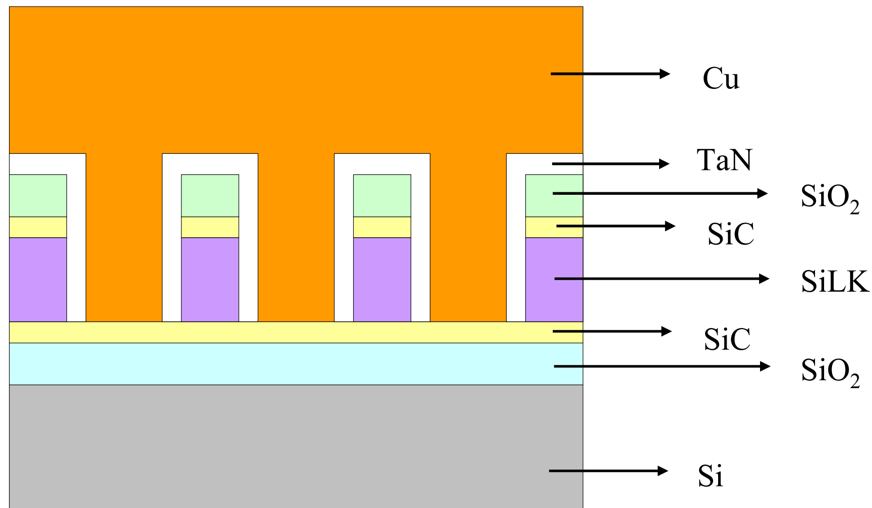
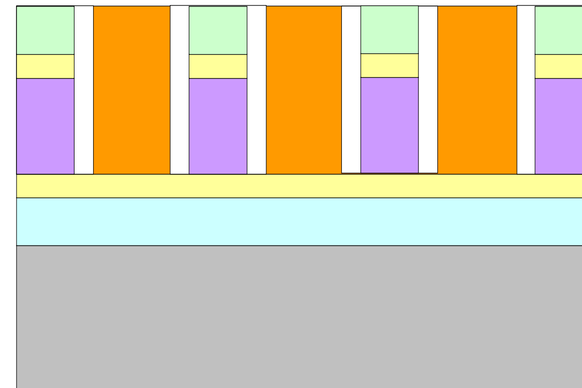
Copper/SiLK Integration Scheme





Structure with a cap layer

The final stop layer is at ILD layer
With Cap layer: Stop at SiO_2
Without Cap layer: Stop at Low-k layer

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Copper/SiLK Integration CMP Process

Cu

TaN

SiO_2

SiC

SiLK

SiC

SiO_2

Si

Step 1

Phase-I

Selectivity

Cu:TaN = >20:1

Stop at barrier layer

Step 2

Phase-II

Non/Low

Selectivity

Stop at SiO_2/SiLK layer

Single Step

Single - Phase

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Hydroxylamine Reduction Potentials & Reaction Paths

OXIDATION ← → REDUCTION

BASIC

NO_3^- ← 0.01 ← NO_2^- ← 0.15 ← N_2O ← 0.94 ← N_2 ← -3.04 ← NH_2OH → 0.73 → N_2H_4 → 0.1 → NH_3

ACIDIC

NO_3^- ← 0.94 ← HNO_3 ← 1.297 ← N_2O ← 1.77 ← N_2 ← -1.87 ← NH_3OH^+ → 1.41 → $N_2H_5^+$ → 1.275 → NH_4^+

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

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Hydroxylamine-Based Slurry Development for Copper CMP

Current EKC Cu Slurries

	Oxidizer	Abrasive	Application
Cu Phase-I	Hydroxylamine Based	Al_2O_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	Al_2O_3	Removal Cu, barrier and stop at ILD layer

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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) .

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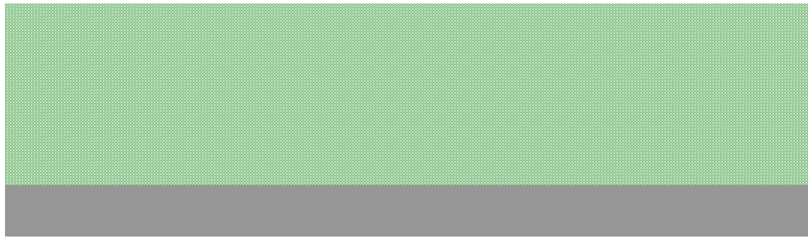
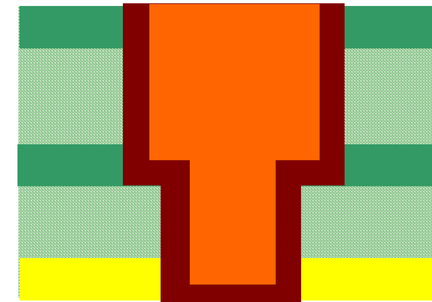
SiLK Blanket Wafer Types



Porous SiLK (V9-LC & V9-HC)

Regular SiLK (SiLK-I)



SiLK+Ensemble Integrated Stack

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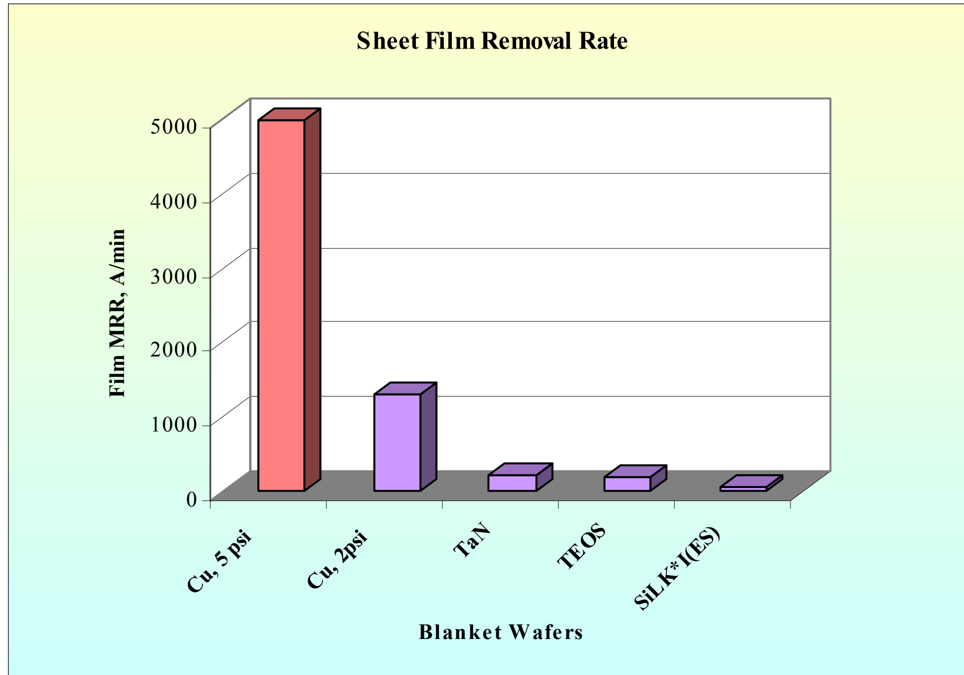
Alumina Based Slurry for SiLK Film



IPEC 472 Polisher / IC1000 k gv/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_2O_3 (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

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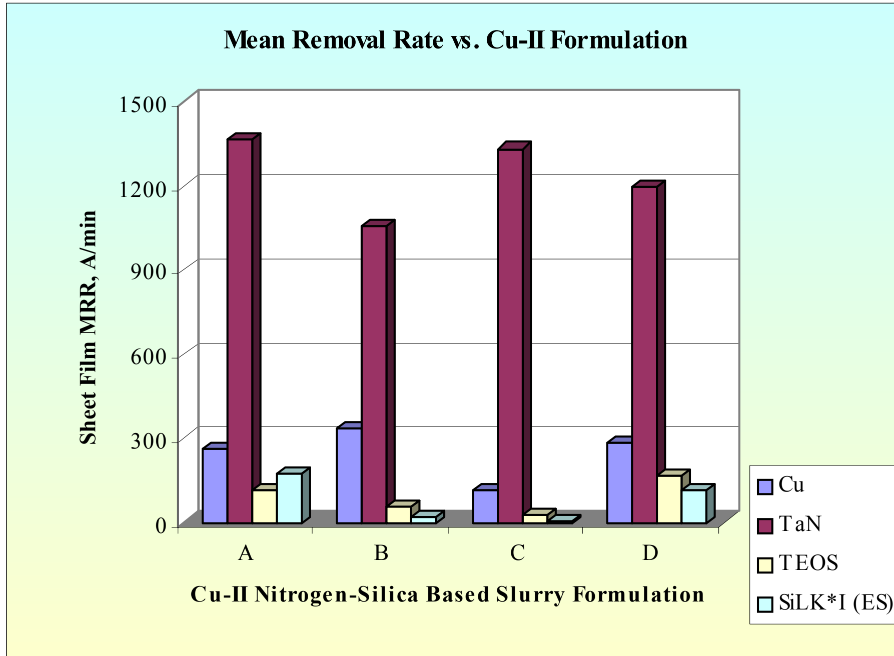
Silica Based Slurry for High Selectivity Application



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 (A)	
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

IPEC 472 Polisher / Politex Embossed Pad

Process:

3 psi polishing pressure, 50 70rpm platen speed

55 75rpm carrier speed, 200 ml/min slurry flow

no conditioning in between

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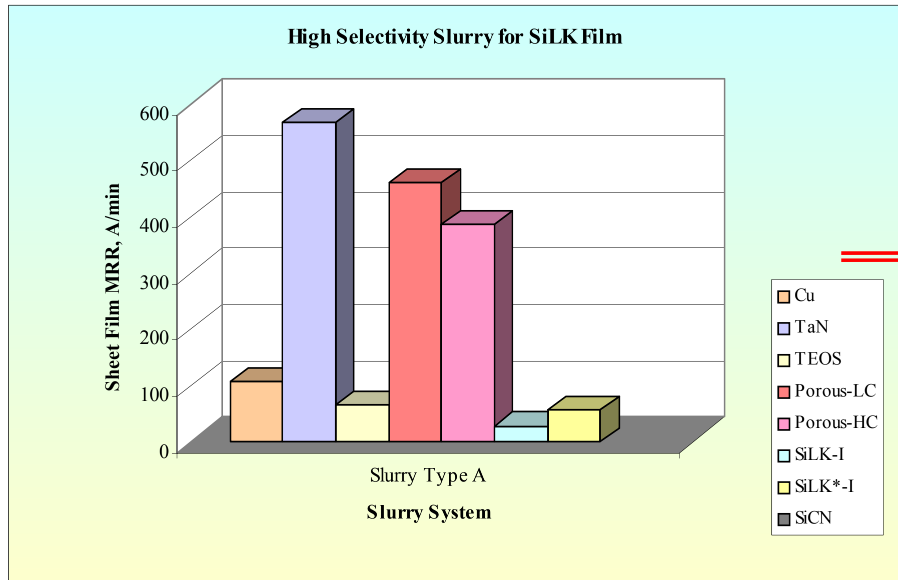
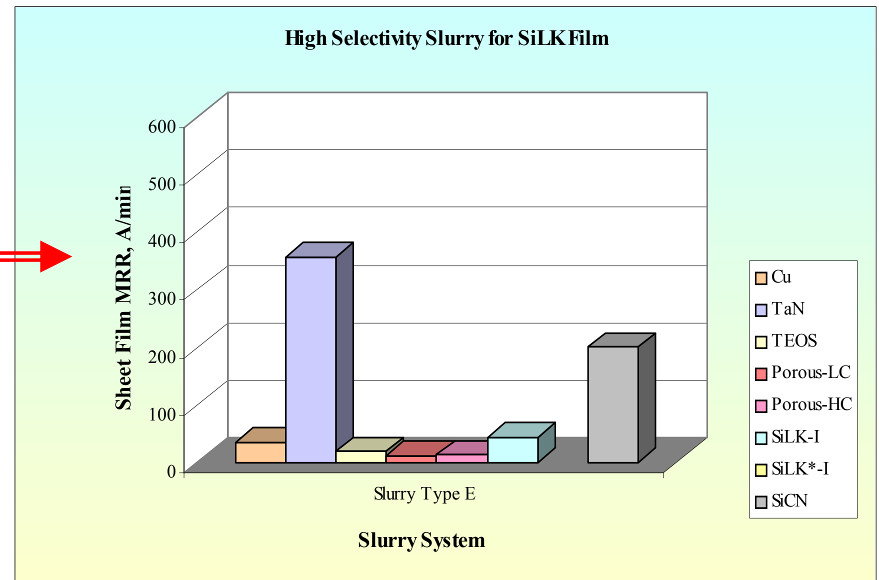
Silica Based Slurry for High Selectivity Application





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.

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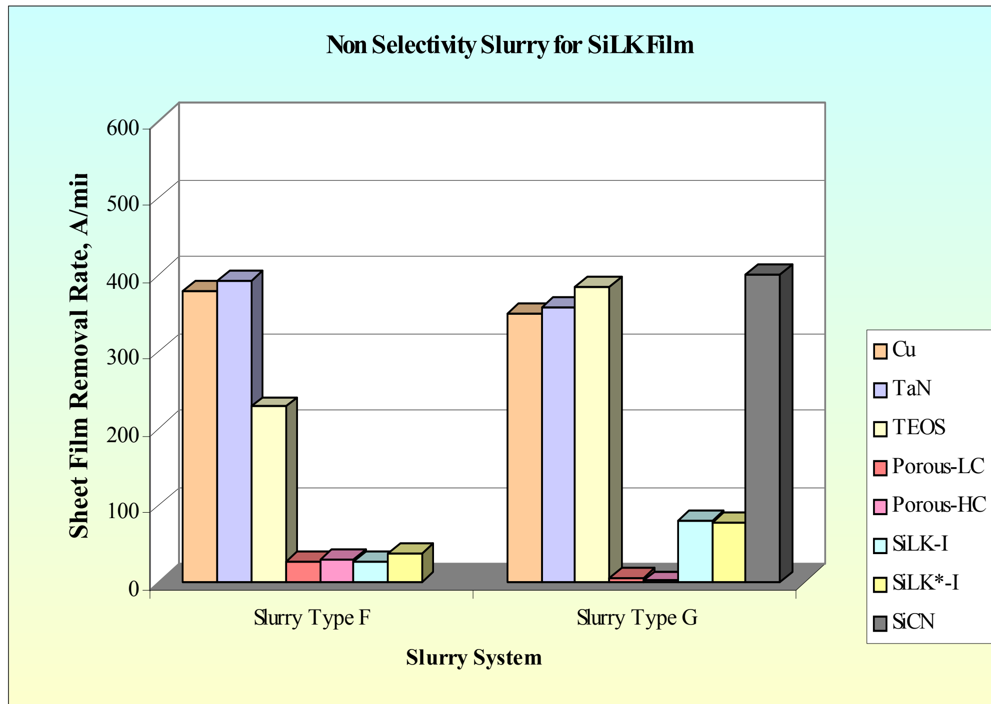
Silica Based Slurry for Low/Non Selectivity



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

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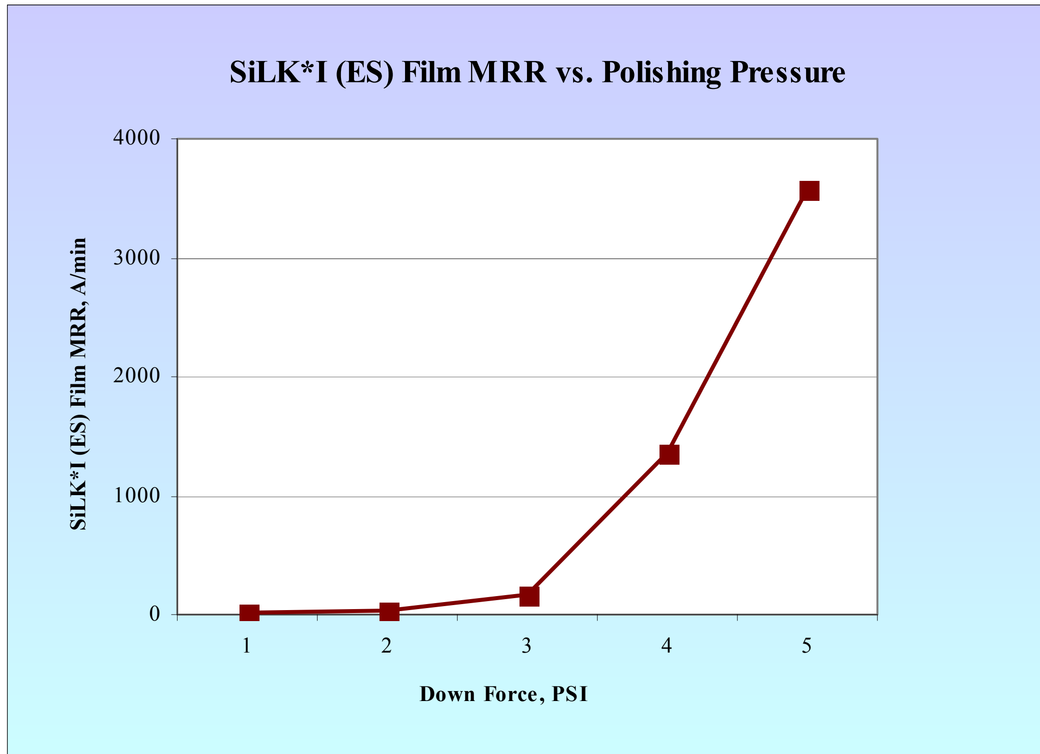
SiLK*I (Ensemble) Film MRR vs. Polishing Pressure



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.

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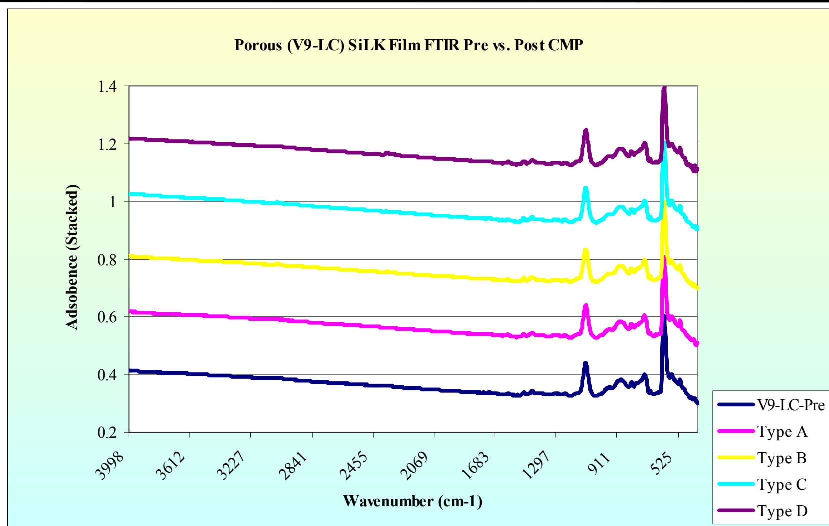
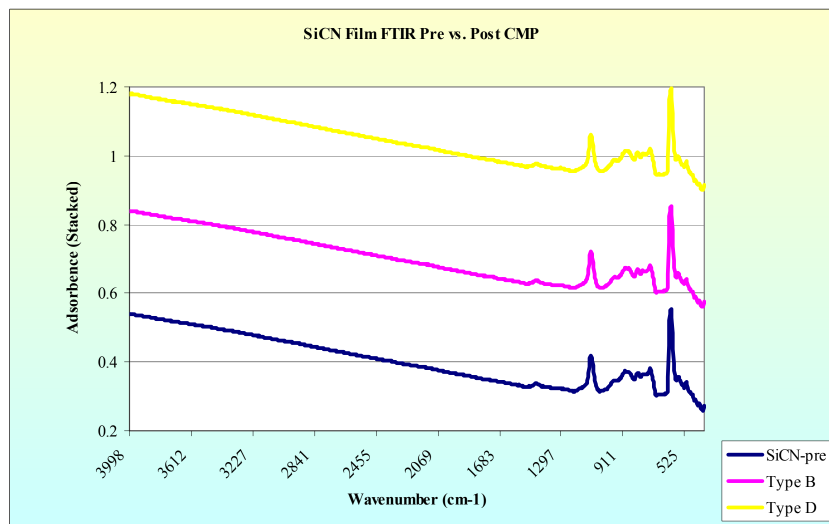
SiLK Surface FTIR Before and After CMP

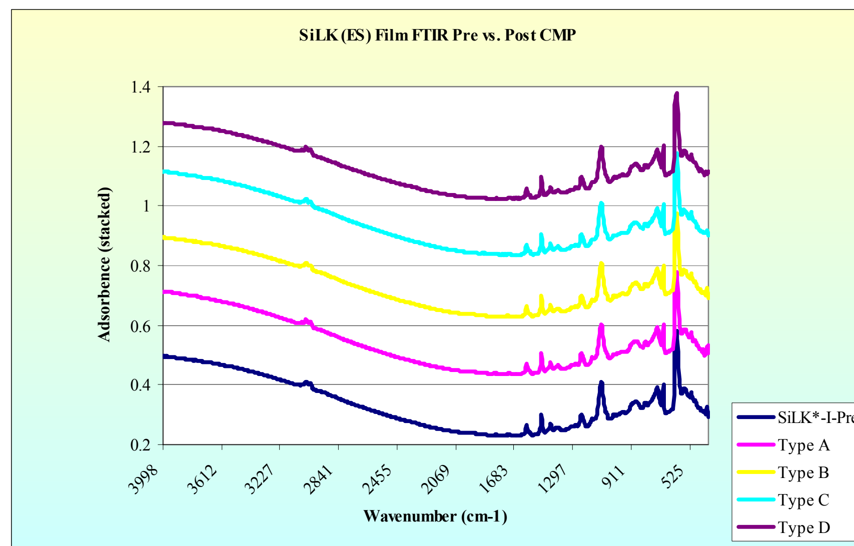




Conclusion

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



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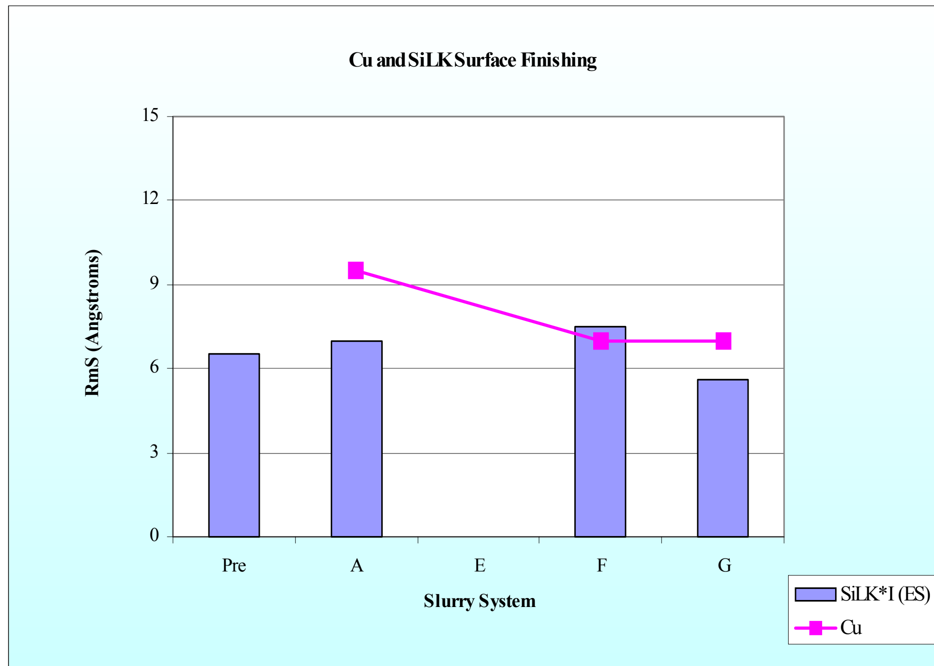
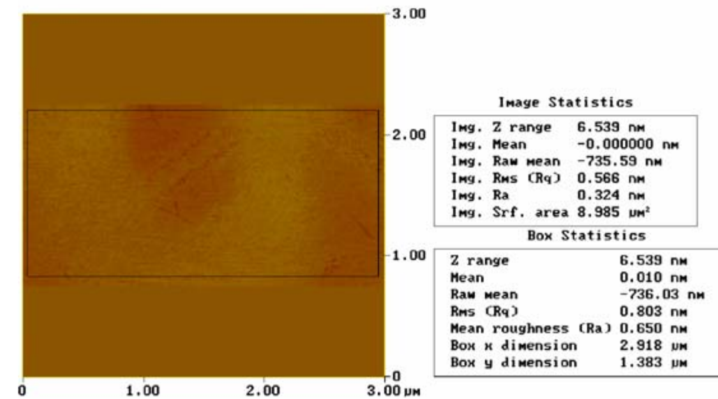
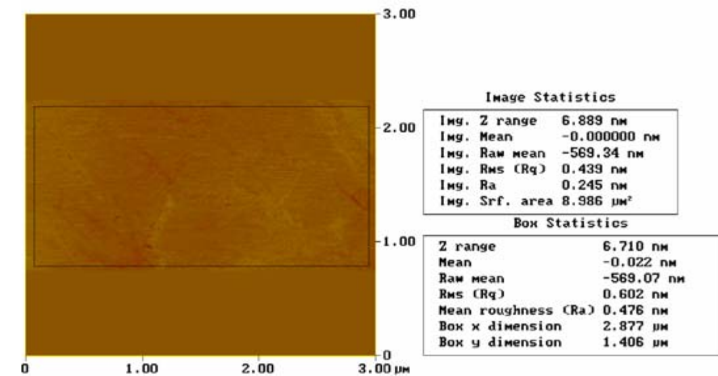
Copper and SiLK Surface After CMP







1) SiLK RmS was similar before and after CMP

2) Cu preRmS was >30 A.

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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.

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