JSR Micro

MATERIALS INNOVATION

JSR Spin-on dielectrics

JSR LKD-5109

Low k Challenges Beyond 100 nm

NCAVS-TFUG

October 16, 2002

Contents

- Roadmap
- Properties of JSR LKD-5109
- Integration of LKD-5109
  - Challenges
  - ISMT product line
  - ISMT result highlights
- Summary

Low-k Challenges for CMP

Crystal ball beyond 100 nm (k= 1.9 - 2.5)

- Does *conventional abrasive-based* CMP work?

  Yes, and it requires **only process optimization**

  Reduced head pressure (1-3 psi)

  Optimized head design, ***pad, slurry****, ...*

JSR can address these issues through its **material technology**

- Why so?

  CMP is not the only process requiring mechanical integrity of low-k

  containment of copper migration under heat and current

  stress caused by the packaging and application of chips

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Slipping roadmap for low-k

Roadmap		Year of First Product Shipment	1997	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1997		Technology Node	250 nm	180 nm		150nm		130 nm			100 nm			70 nm			50 nm				
	NA	Interlevel metal insulator—effective dielectric constant (k)	3.0 - 4.1	2.5 - 3.0		2.0-2.5		1.5 - 2.0			1.5 - 2.0			≤ 1.5			≤ 1.5				
1998 Update		Technology Node	250 nm	180 nm			130 nm			100 nm			70 nm			50 nm			35		
	NA	Minimum interlevel metal insulator—effective dielectric constant (k)	3.0 - 4.1	2.5 - 4.1			1.5 - 2.0			1.5 - 2.0			≤ 1.5			≤ 1.5					
1999				180 nm			130 nm			100 nm			70 nm			50			35		
	MPU	Interlevel metal insulator—effective dielectric constant (k)		3.5-4.0	3.5-4.0	2.7-3.5	2.7-3.5	2.2-2.7	2.2-2.7	1.6-2.2			1.5			<1.5			<1.5		
	SOC	Interlevel metal insulator—effective dielectric constant (k)		3.5-4.0	3.5-4.0	2.7-3.5	2.7-3.5	2.2-2.7	2.2-2.7	1.6-2.2			1.5			<1.5			<1.5		
	DRAM	Interlevel metal insulator—effective dielectric constant (k)		4.1	4.1	4.1	3.0-4.1	3.0-4.1	3.0-4.1	2.5-3.0			2.5-3.0			2.0-2.5			2.0-2.3		
2000 Update				180 nm		130 nm			90 nm				60 nm			40			30		
	MPU	Interlevel metal insulator—effective dielectric constant (k)		3.5-4.0	3.5-4.0	2.9-3.5	2.9-3.5	2.2-2.9	2.2-2.9	1.6-2.2			1.6			<1.6			<1.3		
	MPU	Interlevel metal insulator—BULK dielectric constant (k)		2.9	2.9	2.7	2.7	2	2	1.3			1.3			<1.3			1.1		
	SOC	Interlevel metal insulator—effective dielectric constant (k)		3.5-4.0	3.5-4.0	2.7-3.5	2.7-3.5	2.2-2.7	2.2-2.7	1.6-2.2			1.5			<1.5			<1.5		
	DRAM	Interlevel metal insulator—effective dielectric constant (k)		4.1	4.1	4.1	3.0-4.1	3.0-4.1	3.0-4.1	2.5-3.0			2.5-3.0			2.0-2.5			2.0-2.3		
2001				180 nm		130 nm			90 nm				60 nm			40			30		
	MPU	Interlevel metal insulator—effective dielectric constant (k)				3.0-3.7	3.0–3.7	2.9–3.5	2.5–3.0	2.5–3.0	2.5–3.0	2.0–2.5			2			1.9			1.7
	MPU	Interlevel metal insulator (minimum expected) —bulk dielectric constant (k)				2.7	2.7	2.7	2.2	2.2	2.2	1.7			1.6			<1.6			1.5
	DRAM	Interlevel metal insulator—effective dielectric constant (k)				4.1	3.0–4.1	3.0–4.1	3.0–4.1	2.5–3.0	2.5–3.0	2.5–3.0			2.5-3.0			2.0-2.5			2.0-2.3

Classification of Low k Dielectrics

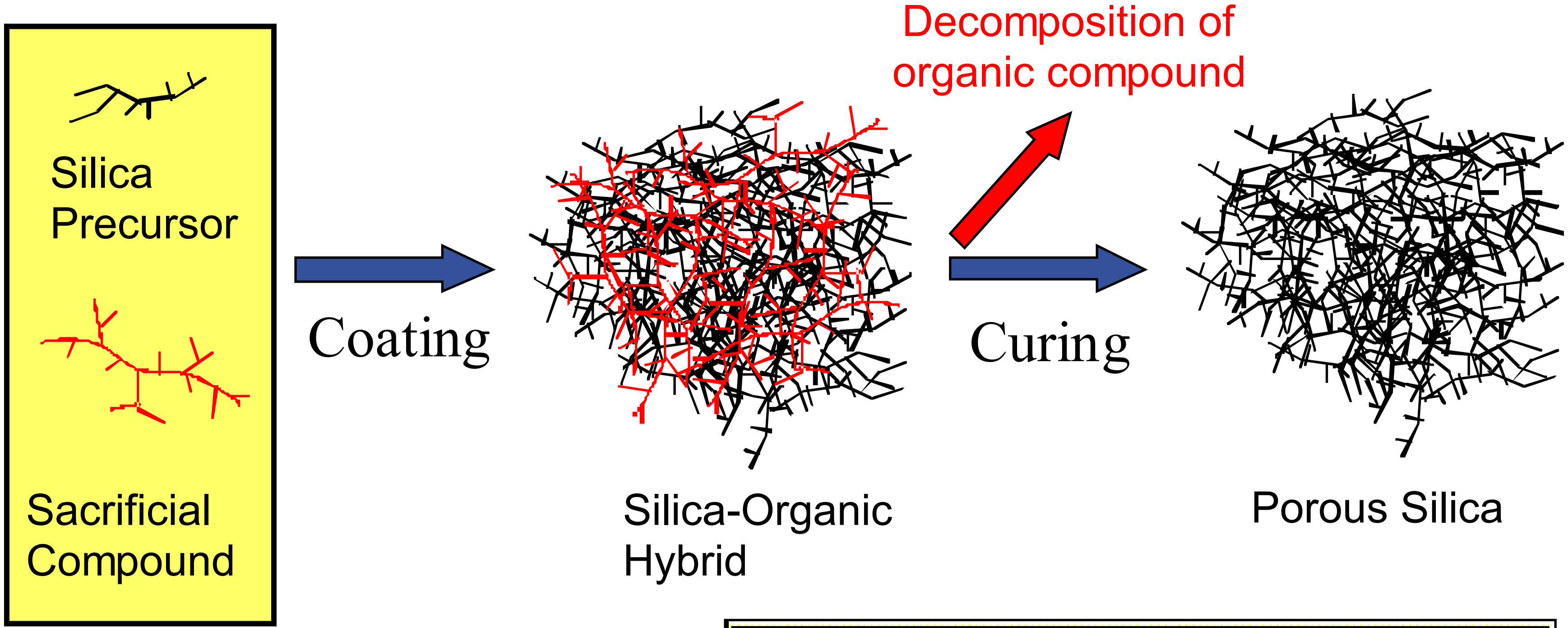
Material	k=4.1	k=3.5	k=2.6 - 3.2	k=2.0 - 2.5	Process	Vendor
Inorganic	SiO2				CVD	-
		F-SiO2			CVD	-
			FOx	XLK	Spin-on	Dow Corning
Hybrid			**LKD-2020**	**LKD-5109**	**Spin-on**	**JSR**
			IPS2.5	uPLK	Spin-on	CCIC
			HOSP	Nanoglass-E	Spin-on	Honeywell
				PPSZ-M	Spin-on	Clariant
				ALCAP-S	Spin-on	Asahi Chemical
			HSG RZ26	HSG 6210	Spin-on	Hitachi Chemical
			OCD	OCL	Spin-on	Tokyo Ohka
				Zircom	Spin-on	Shipley
			BlackDiamond	BlackDiamond 2	CVD	Applied Materials
			CORAL	POLA	CVD	Novellus
			FlowFill	Orion	CVD	Trikon
Organic			SiLK	Nautilus	Spin-on	Dow Chemical
				?	Spin-on	Sumitomo Bakelite
			FLARE	FLARE GX3	Spin-on	Honeywell

From JSR Seminar, 2001 December

Typical Curing Sequence of JSR LKD

Tool	Process	Condition
SOD Coater	Spin Coat	2000 - 3000 rpm
SOD HP	Prebake	Evaporation of solvent 80°C x 60 sec in Air
SOD HP	Softbake	Crosslink of polymer 200°C x 60 sec in Air
Vertical Furnace	Final Cure	420°C x 30 min Ambient Pressure in N_2

Conventional method of p-MSQ

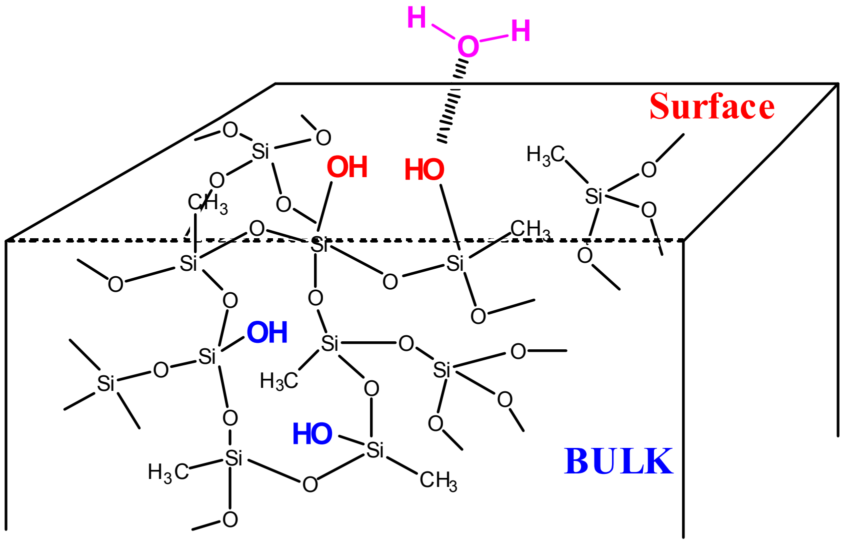


Control of k value

Sacrificial content ⟺ **Porosity of Silica film**

Hedrick, J. L. et al., Adv. Mater. (1998), 13(10), 1049
Stucky, G. D. et al., Adv. Mater. (1998), 10(16), 1380
Brinker, J. C. et al., Nature (1997)

Schematics of P-MSQ

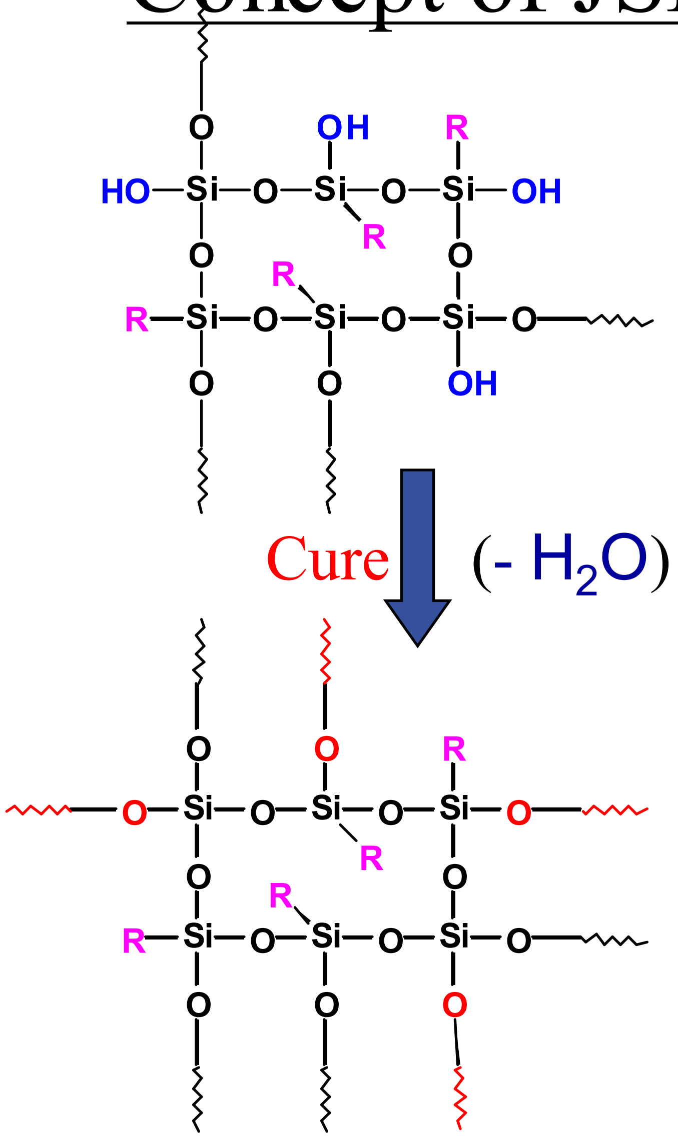


- **Doness of cure depends on residual free Si-OH**
- **Correct indicators of cure need to be chosen.**

  Detect residual Si-OH groups and moisture uptake.

  ⇔ n, k, IR, outgassing, etc.

Concept of JSR LKD (Polymer Design)



Precursor (Soluble)

SiO: Partially crosslinked silsesquioxane
(High heat resistance)

OH: Heat-curable group

R : Hydrophobic group
(Methyl, Phenyl, etc)

Low k Film (Insoluble)

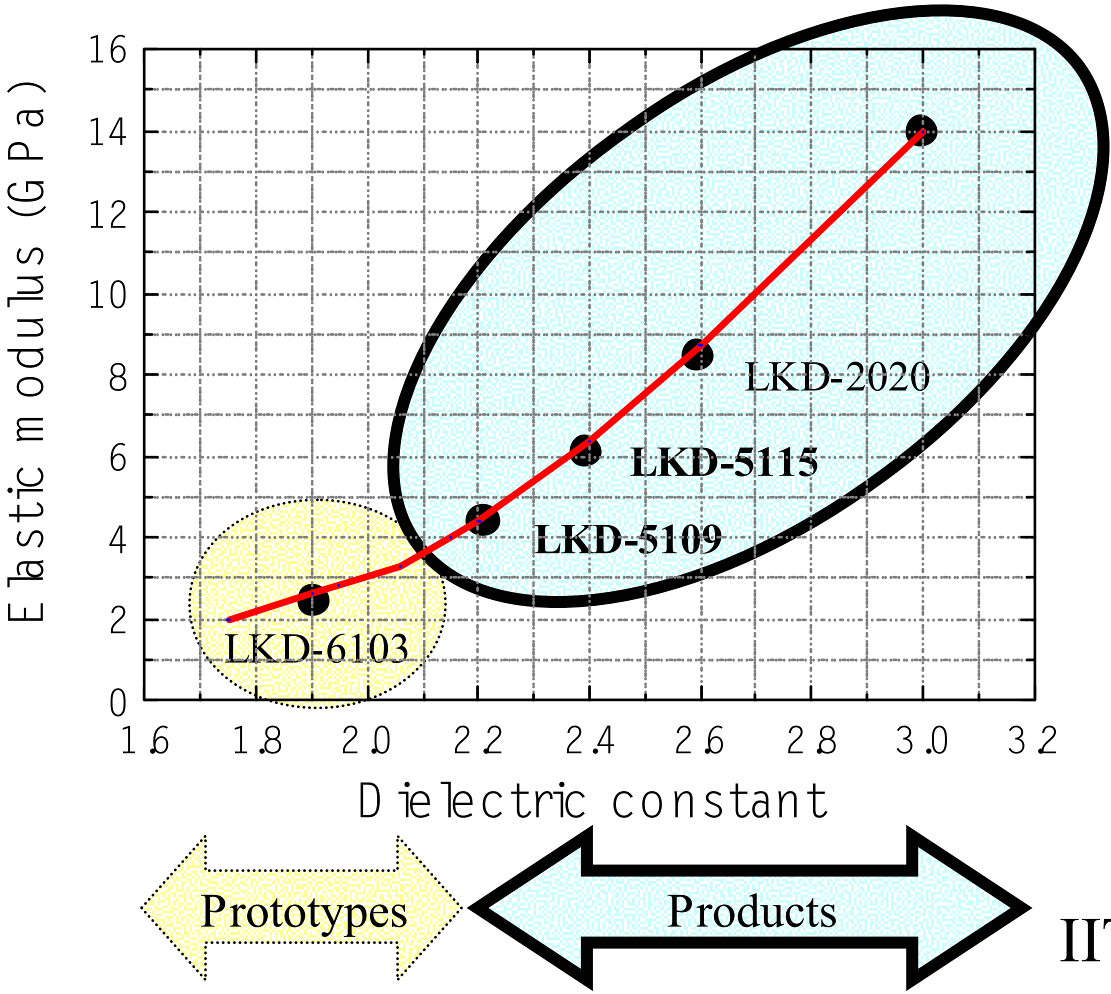
Fully crosslinked silsesquioxane
without hydroxyl group

Control of k value ⟺ **Density of Silica film**

LKD-5109 offers ...

- Superior material properties
  - Low dielectric constant, high modulus, Small CTE, ...
- Successful integration
  - Baseline process information through industry consortium
    - *Sematech, IMEC, Selete, Leti, ...*
  - Commercial Cu/LKD-5109sample availability
    - *Sematech wafer service*
- Readiness for the commercial use
- Extendibility of ILD technology
  - Keeping eye also on k <2.0 ranges

JSR Research Activity toward Ultra Low-k



IITC 2002 poster

JSR LKD Line Up

Sematech/IMEC
focus on LKD5109

	ULK		ELK		VLK
Cure method	Thermal	Special	**Thermal**	**Thermal**	**Thermal**
Product name	LKD-6103	LKD-6102	**LKD-5109**	**LKD-5115**	**LKD-2020**
Product stage	R&D	R&D	**Product**	**Product**	**Product**
Final Cure Temp.	420 C	**350 C**	**420 C**	**420 C**	**420 C**
Dielectric constant: K	**1.91**	2.01	**2.20**	**2.34**	**2.55**
Refractive index	1.201	1.226	**1.248**	**1.279**	**1.316**
Modulus: E (GPa)	2.1	3.4	**4.5**	**6.4**	**8.0**
Thermal conductivity			**0.235**	**0.247**	**0.301**
Specific Gravity	0.82	0.90	**0.93**	**1.00**	**1.13**

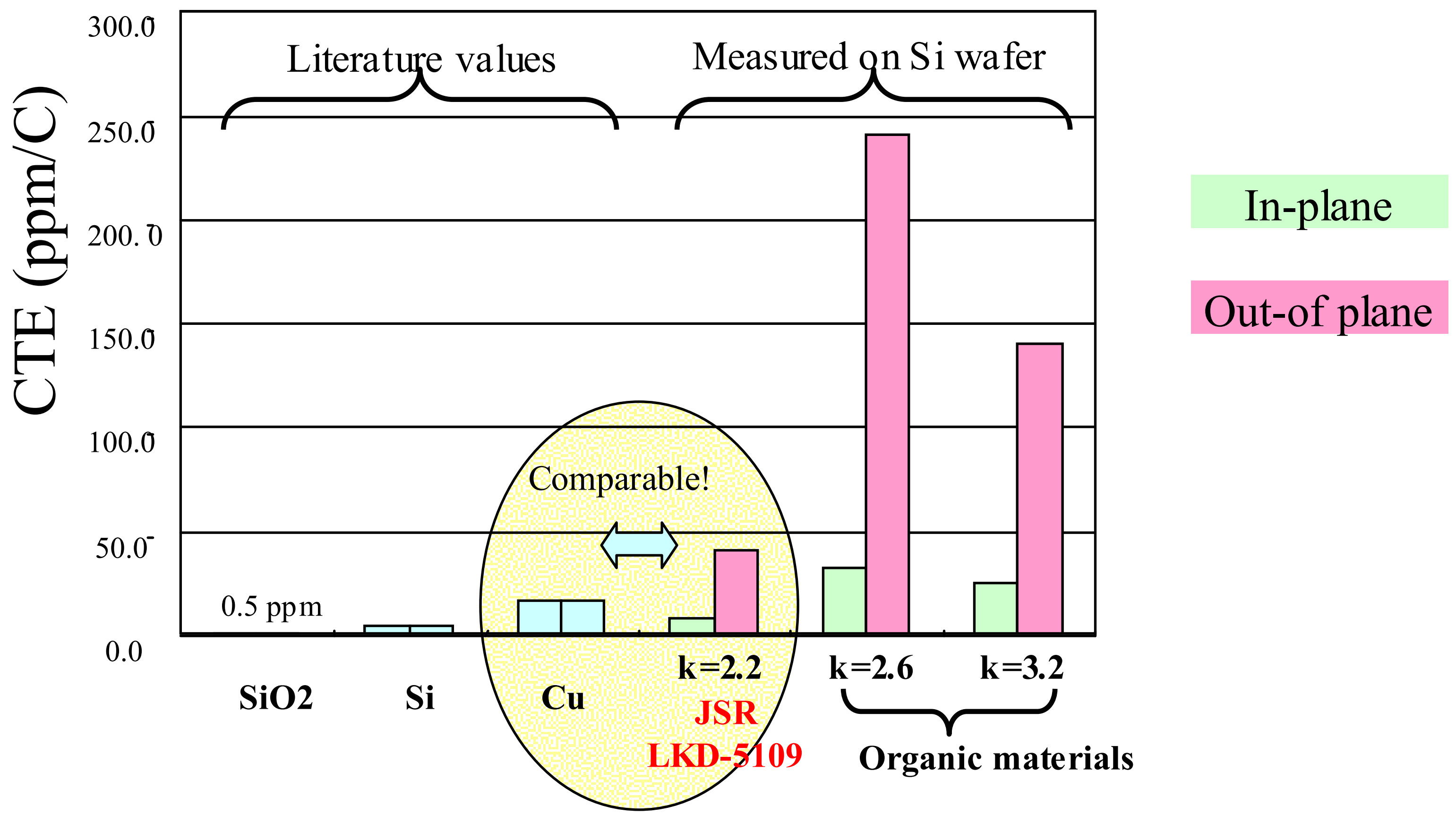
All of these JSR LKD products can be described generically as (porous-)MSQ material

IITC 2002 poster

CTE Advantage

LKD-5109 (MSQ based Low-k) has CTE comparable to Copper

MSQ = **Inorganic** back bone polymer



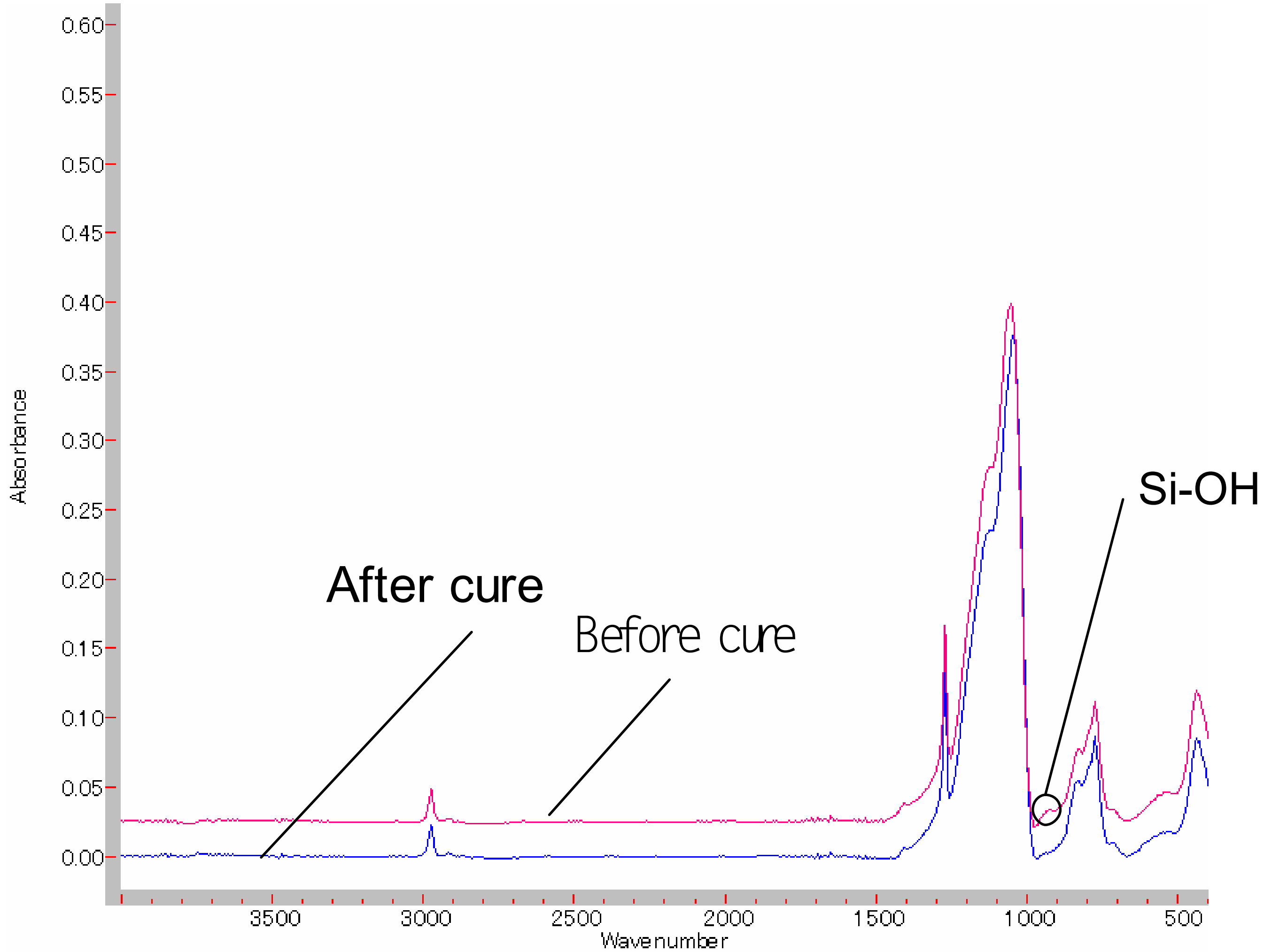
Chemical Compatibility of JSR LKD

Chemical		pH	Etch Rate (nm/h)	Si-CH3 Retation (%)	k value increase
HF	0.05%	<1.0	-1.6	99	0.02
Etch Clean A	NH4F base	1.0	-2.4	99	-0.01
Etch Clean B	Organic acid base	1.0	-8	100	0.02
CMP Slurry A	Neutral	6.0	-1.1	102	0.00
Etch Clean C	Solvent base	6.6	-3	100	0.02
CMP Slurry B	Amine base	10.4	-8	100	0.03
Etch Clean D	Organic amine base	12.4	-7	100	0.00
HA	PR Devlopper	13.4	0	80	0.12

Exposure : 25C / 20 min

JSR LKD have a good chemical compatibility over a wide range of pH. Incompatibility can be seen in HF base solutions and Hydroxyamine base solutions

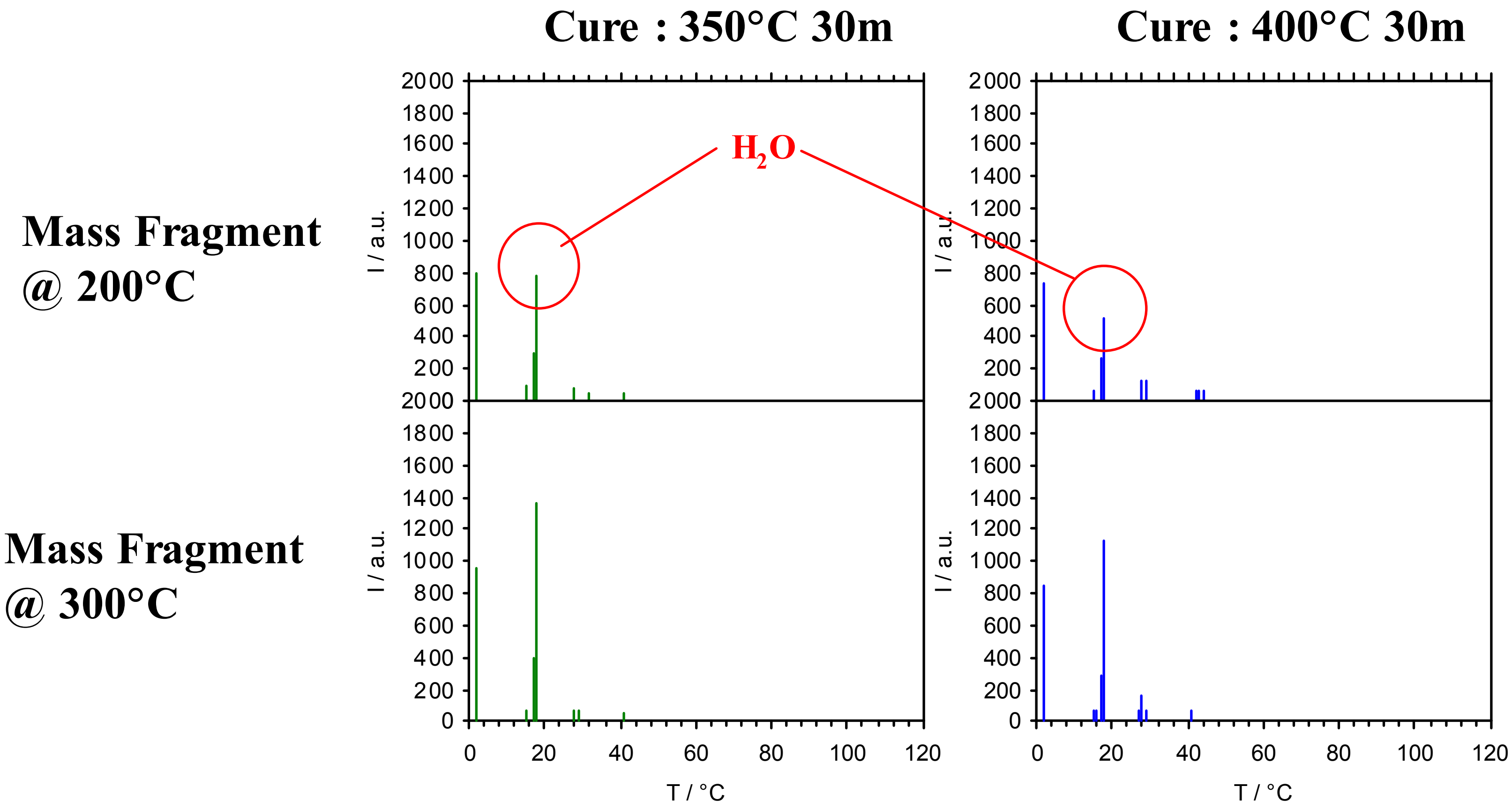
FT-IR Spectra



Hydrophobicity

- Why we measure it?
  - Degradation of k value
  - Blistering etc during heat cycle
- How we measure?
  - Screening test can use:
    - *FTIR*
  - Success criteria should include:
    - *k value and $\Delta k = k(25C) - k(200C)$*
    - *TDS (MS)*

TDS Fragment
Cure Temp. Dependency



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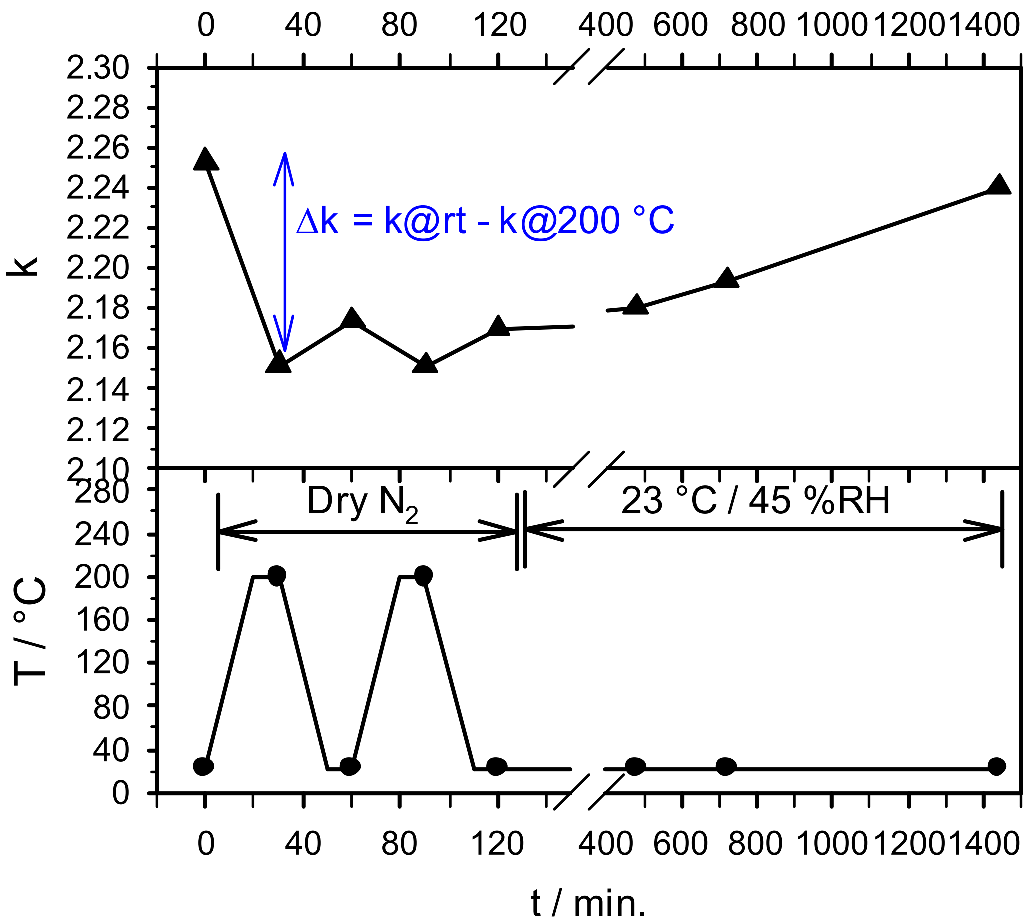
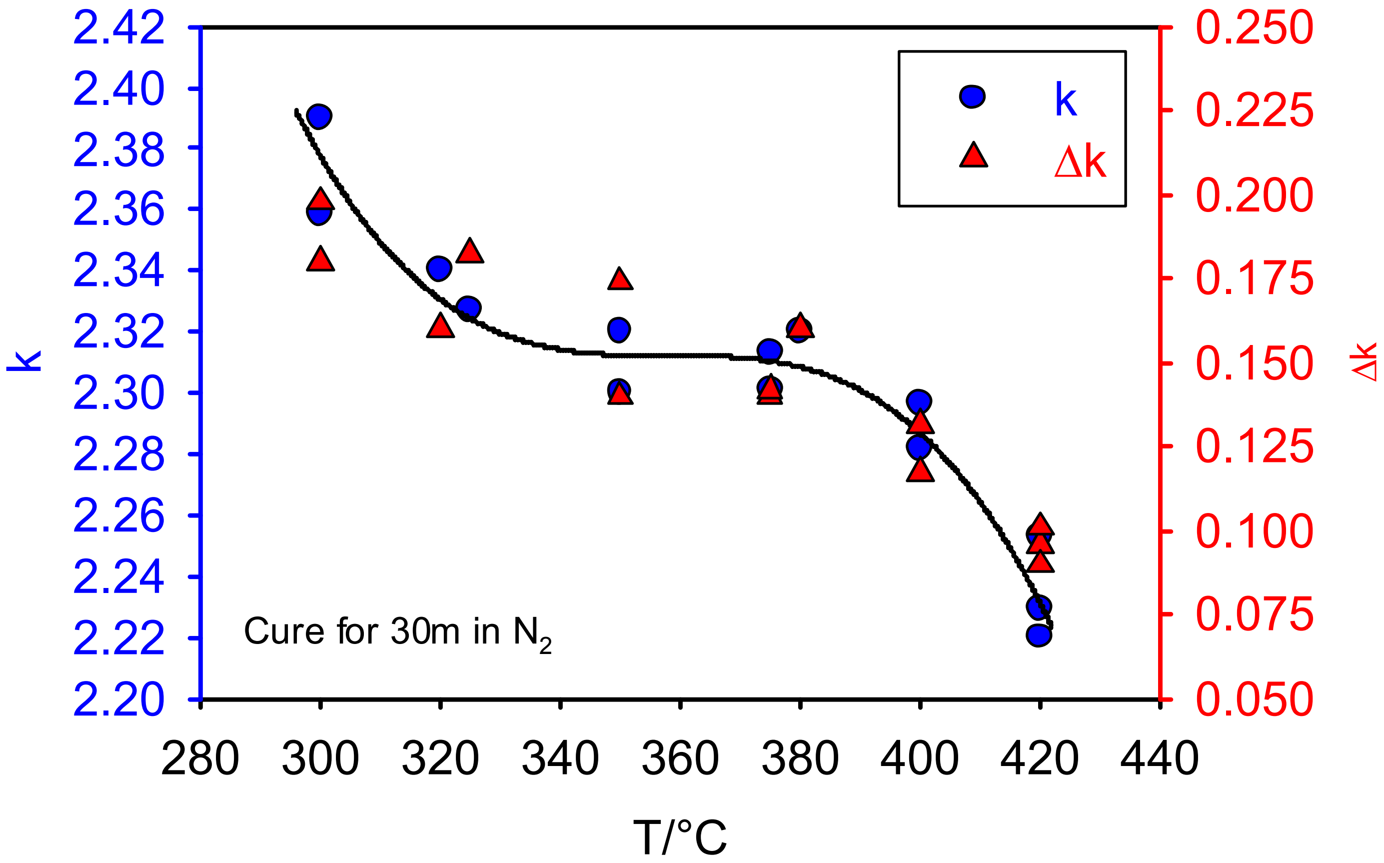
Delta k Measurement



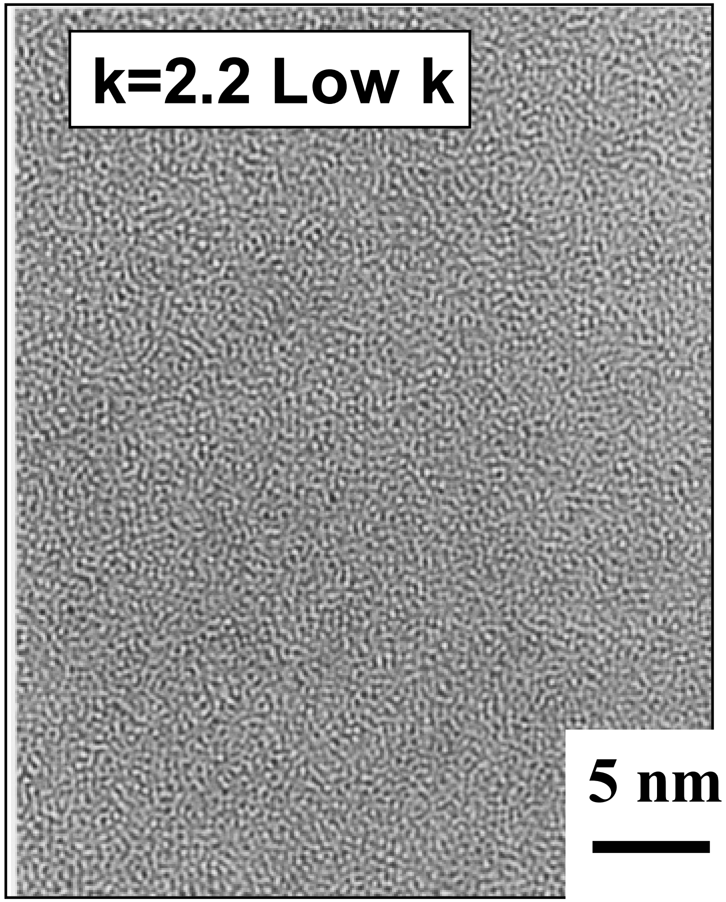
k measurement at 200 °C is to eliminate moisture effect in k value.

Cure Temperature Dependency of k and Δk
in JSR LKD-5109

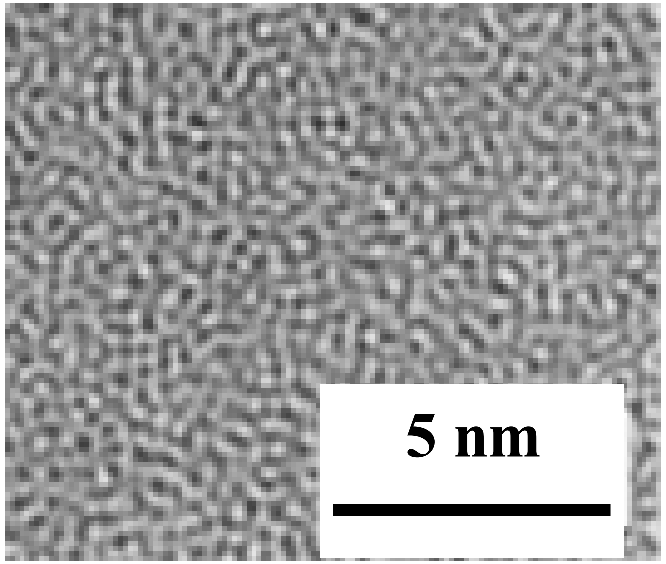


Increase in k value as lowering cure temperature is mostly due to moisture absorption.

TEM Observation of LKD-5109



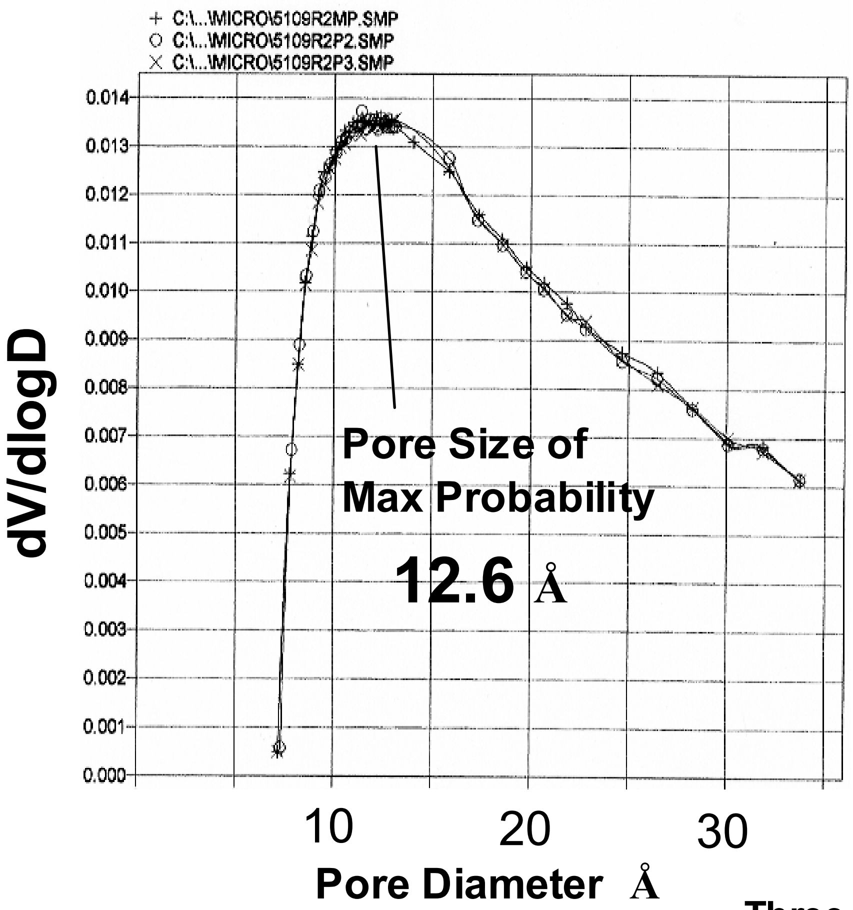
No pore structure is observed.
Low density film structure.



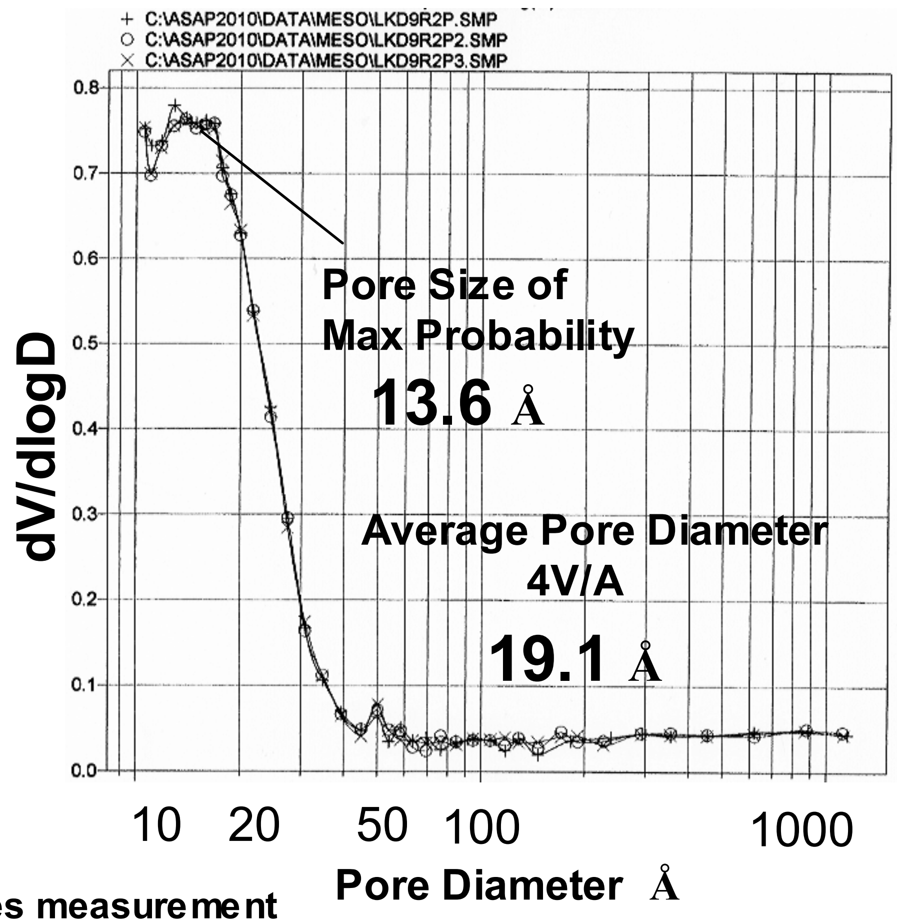
Pore Size Distribution & Porosity of LKD5109

Sample : Powder

Micropore(Ar)



Mesopore(N2)



Three times measurement

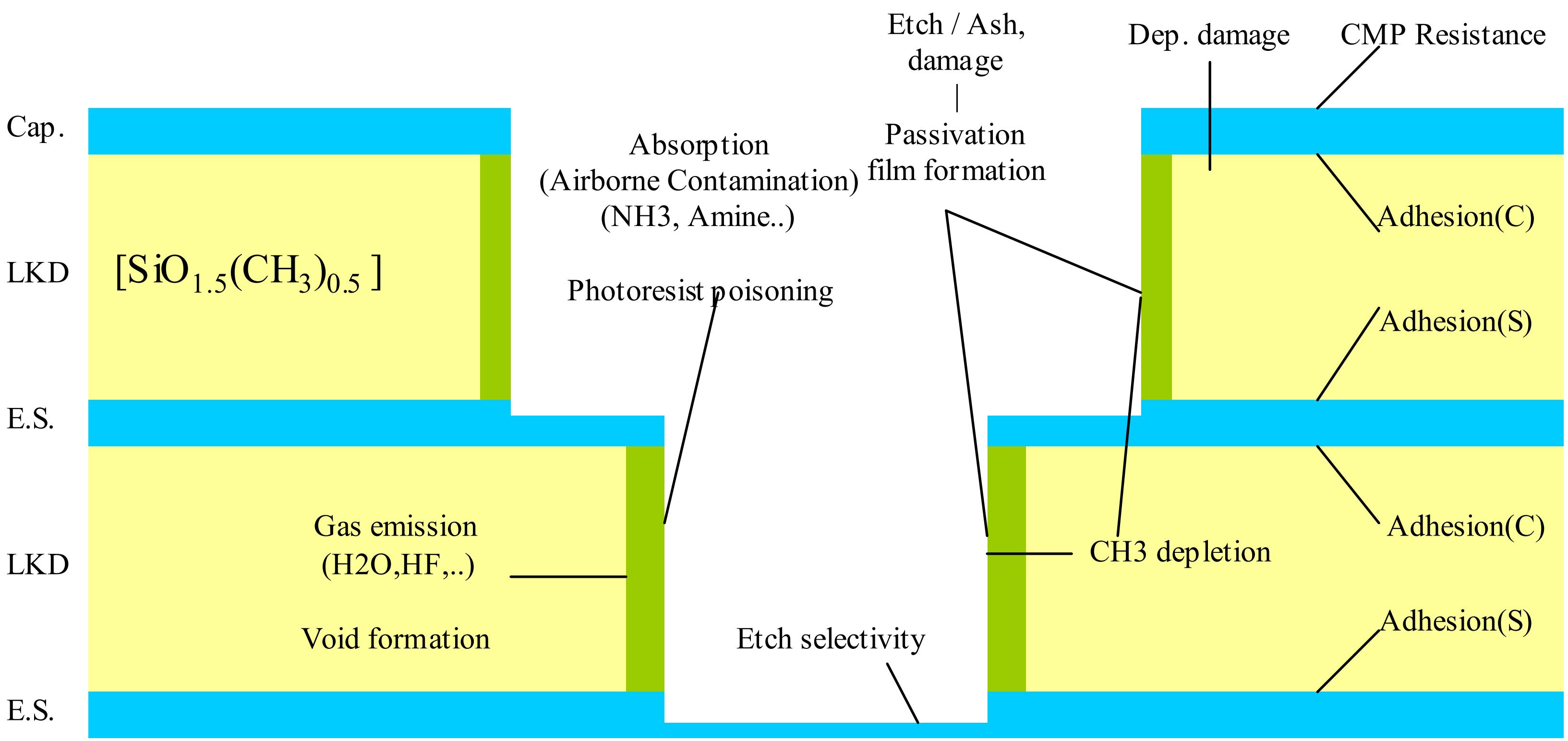
Integration Challenges of JSR LKD

Known integration issues for JSR LKD

- Side wall damage (Etch / Ash)
  Degas, Increase dielectric constant.
  Adhesion to BM.
- Void formation
- Chemical Corrosion (Stripper)
- Photoresist poisoning
- Delamination, scratch, ... (CMP)

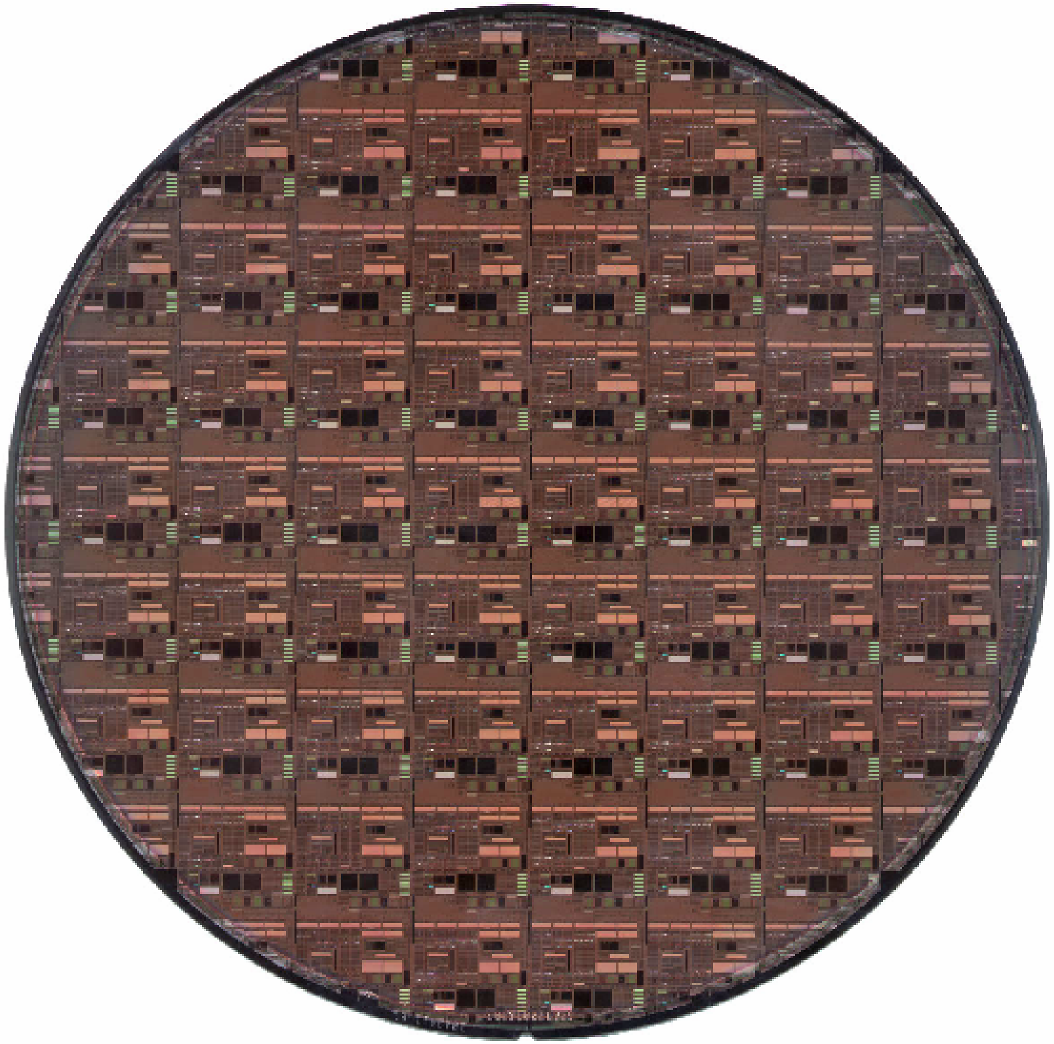
Possible Integration Interactions of JSR LKD

After Patterning, Etch, Ash, ...

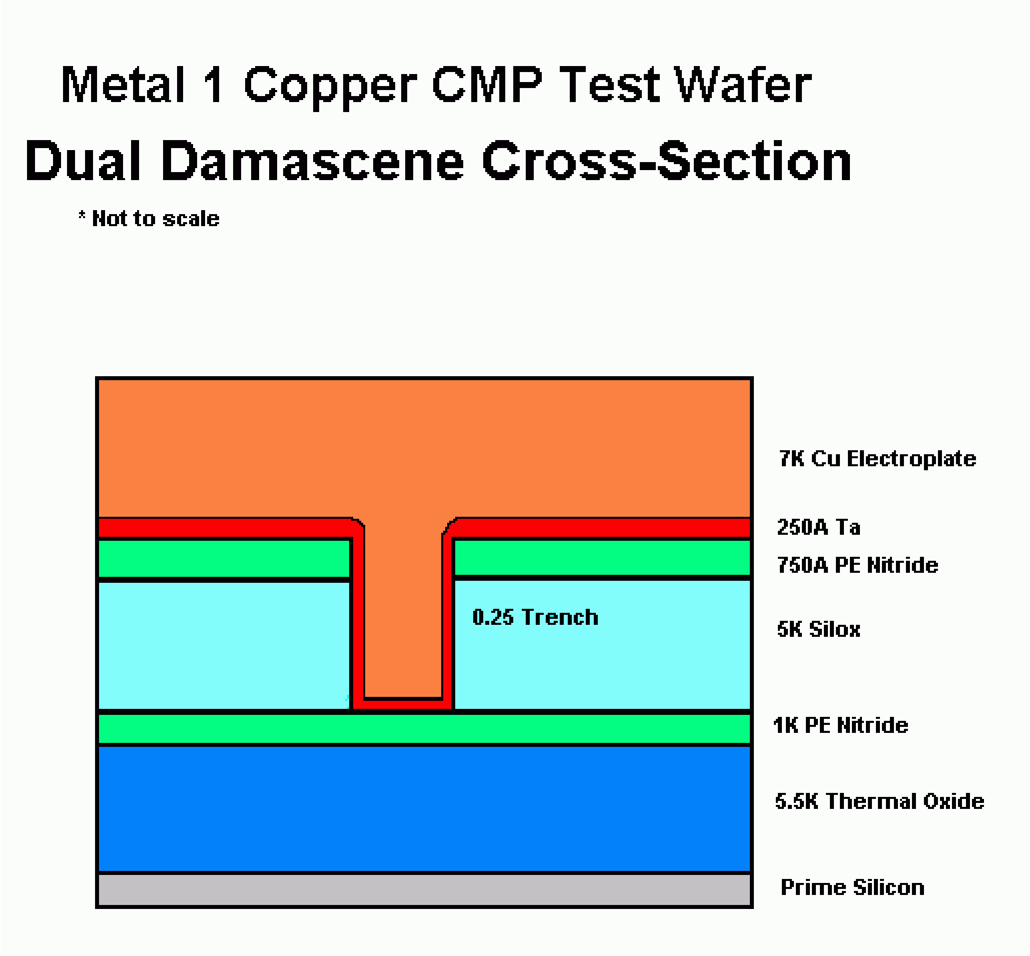


Ash damage and Photoresist poisoning can be avoided by dual H.M. scheme.
Etch and Dep. damages are still present even with dual H.M. scheme.

ISMT LKD Test Wafer with 800AZ Mask

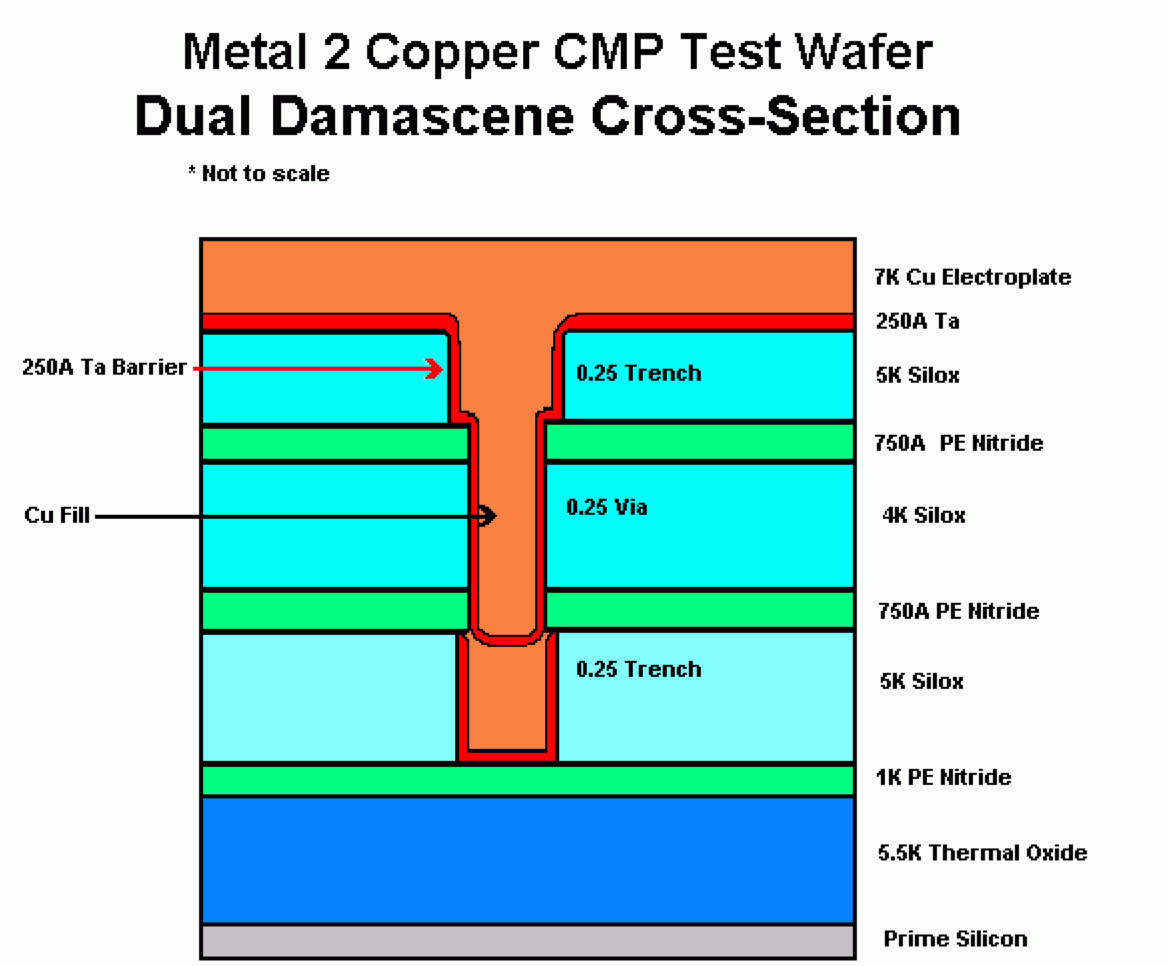


ISMT LKD Test Wafer with 800AZ Mask



Example of available structure (Source www.sematech.org)

ISMT LKD Test Wafer with 800AZ Mask

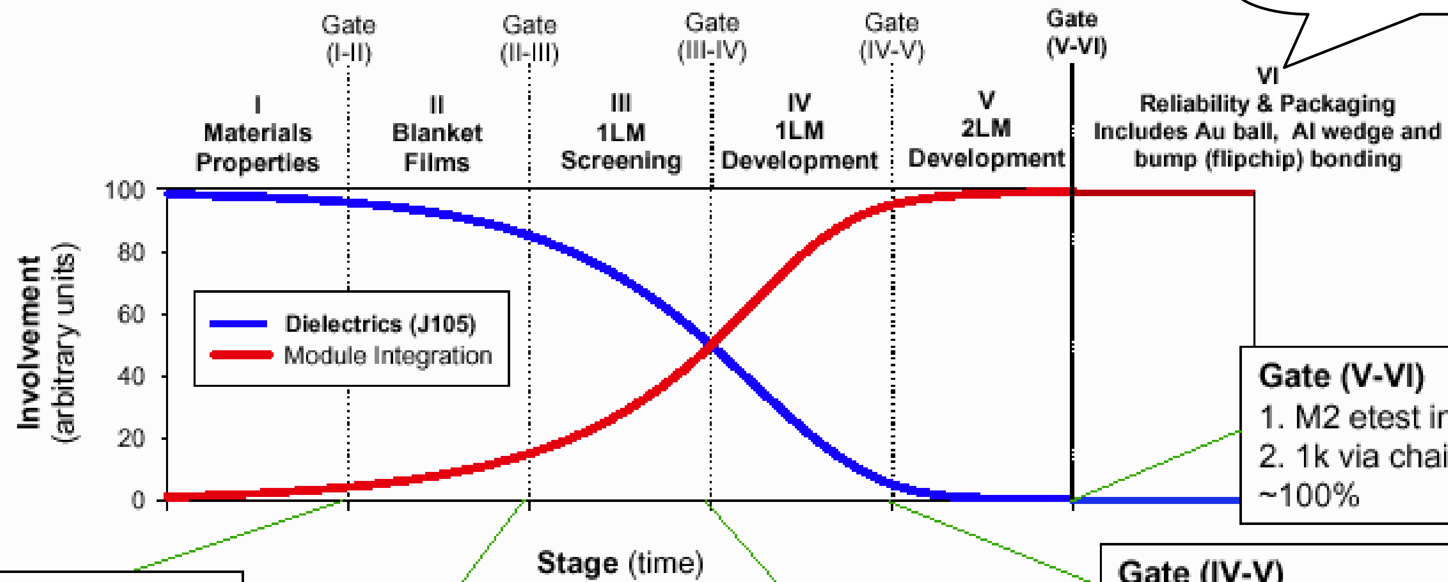


Example of available structure (Source www.sematech.org)

J105 (Dielectrics) / Integration Eval. Model

ATDF Baseline
JSR LKD5109

Schematic Representation of Project Involvement by Stage
(for any given Low κ Dielectric Material)



Gate (V-VI)

1. M2 etest in spec
2. 1k via chainyields ~100%

Gate (I-II)

1. κ<2.5 (or extendable)
2. Thermal stability
3. Adhesion

Gate (II-III)

1. 2-LVL stack anneal
2. CMP adhesion test
3. Blanket film polish rate
4. Blanket film RGA
5. Etched film RGA

Gate (III-IV)

1. X-SEMs of completed 1LM Module
2. Rev.0 module process recipe(s)
3. Adhesion issues
4. Moscap data
5. Mechanical strength
6. Etch & CMP selectivities

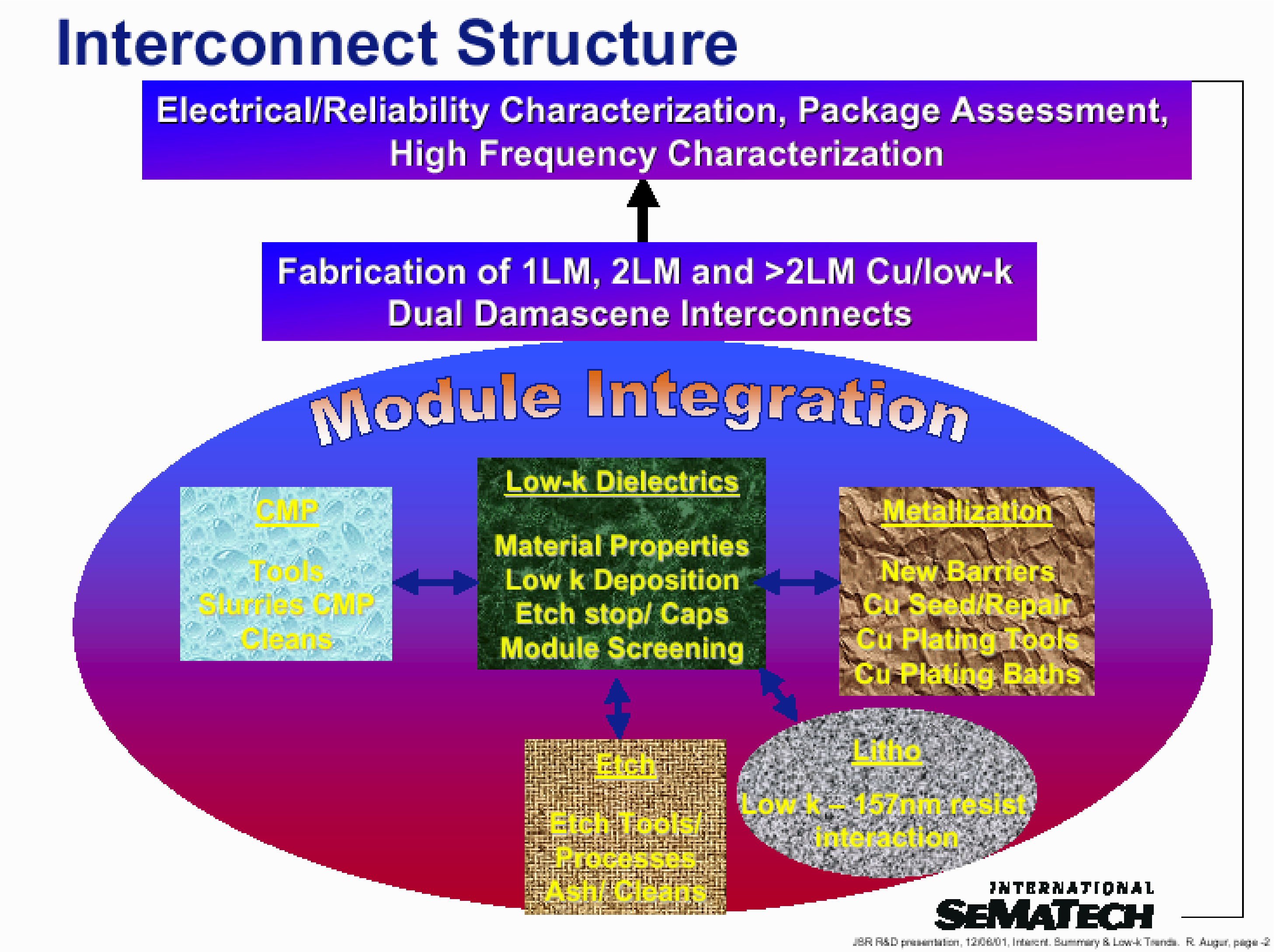
Gate (IV-V)

1. M1 etest in spec
2. Process modules in spec
3. All tools available
4. BTS data ok
5. DD etch verified
6. Multistack adhesion ok
7. Integration plan written

INTERNATIONAL SEMATECH

JSR R&D presentation, 12/06/01, Intercnt. Summary & Low-k Trends. R. Augur, page -1

Collaboration with Sematech Activity



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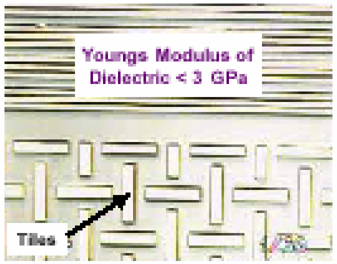
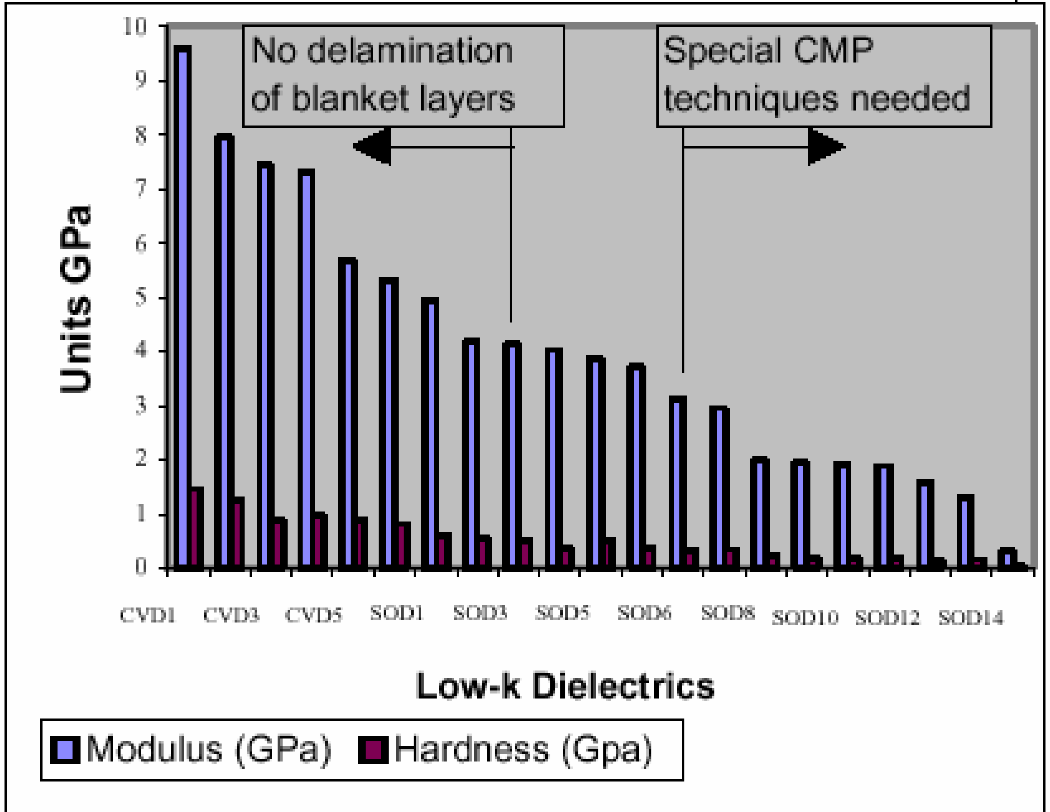
Integration Issues: Strength/Adhesion

- Low strength and adhesion challenge CMP
- Cap loss must be avoided with porous low-k
- Alternatives to CMP
- Tiling





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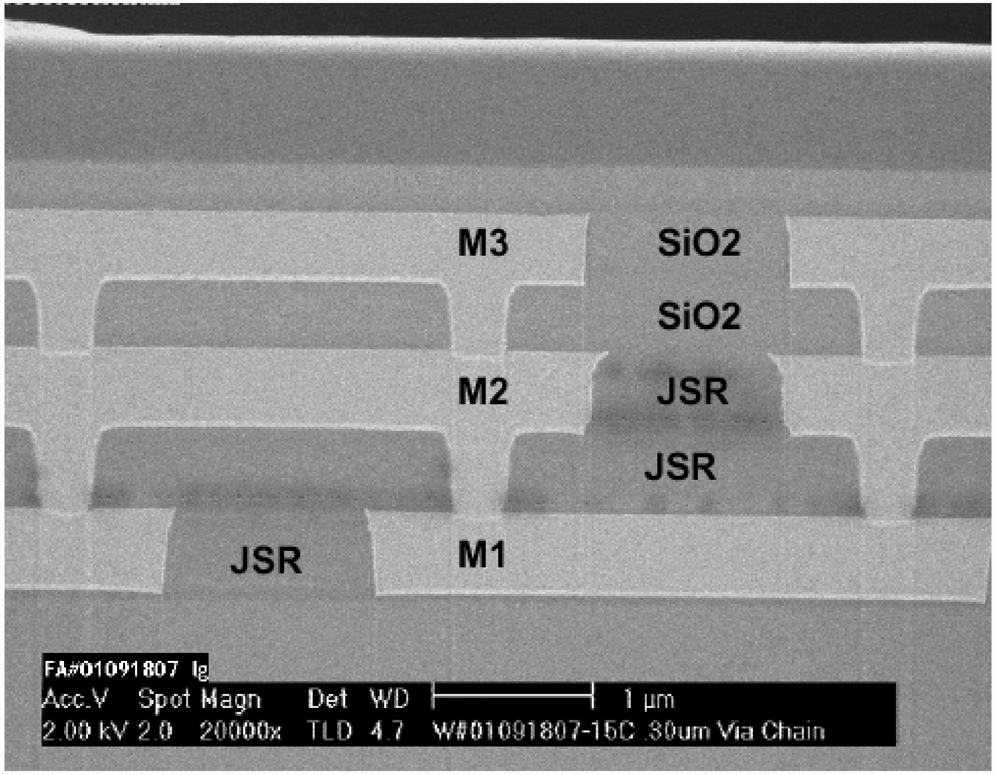
JSR Symposium, Japan. Dec 7th, 2001. R. Augur, page -6

JSR LKD-5109 Integration at ISMT

3LM Lot; 0.3 µm Via Chain

Structure to support packaging activity to mimic real-world integration.



(K. Mosig)

M3 was patterned with M2 (775 level) mask in ATDF with good overlay.

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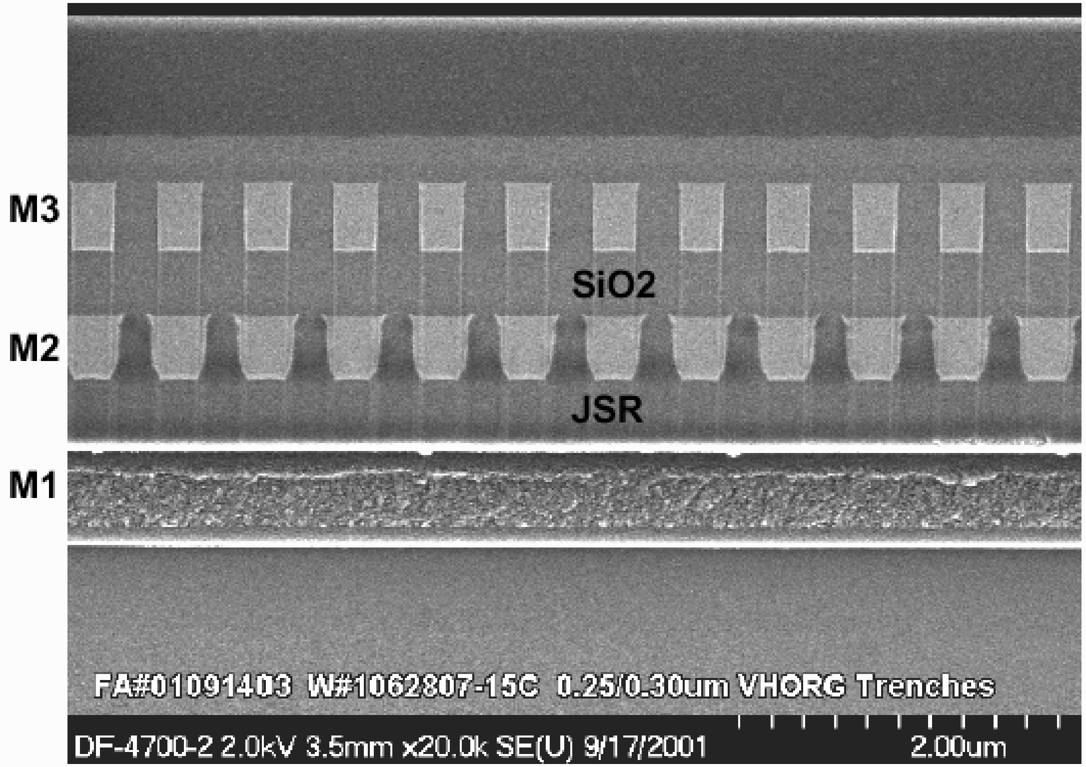
JSR LKD-5109 Integration at ISMT

M2 Long Serpentine/Comb Structure



(K. Mosig)

M1 comb runs parallel to the picture surface

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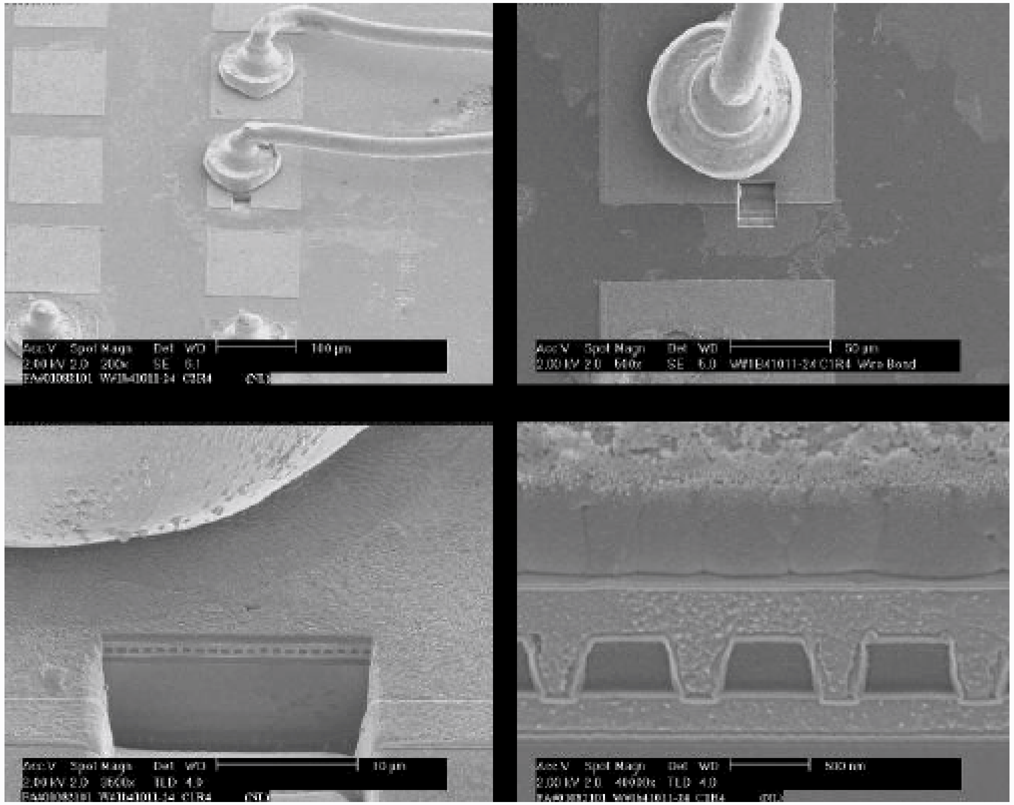
JSR LKD-5109 Integration at ISMT

Package Results; Gold Wirebond II



Successful wire bonding and solder bumping (high yield and pull/shear strengths).

(M. Rasco)

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Summary

- Momentum for the spin-on low-k material is building up rapidly.
  - Publication
    - *IITC 2002 and Semicon/West 2002 coming*
  - Commercial sample availability
    - *JSR for liquid and ISMT for wafer*
- JSR LKD-5109 technology has demonstrated extendibility beyond K < 1.9
- JSR LKD-5109 is accumulating integration knowledge at the device manufactures, tool venders, and research consortiums.