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Electrografted insulator layer as copper diffusion barrier for TSV interposers

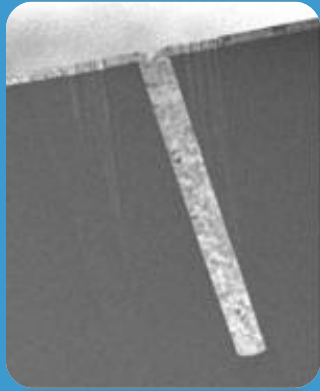
V. Mevellec, D. Suhr, T. Dequivre, P. Blondeau, L. Religieux and F. Raynal

Scottsdale/Fountain Hills
March 12-14, 2013



MOLECULES TO BUILD ON

3D Packaging / TSV

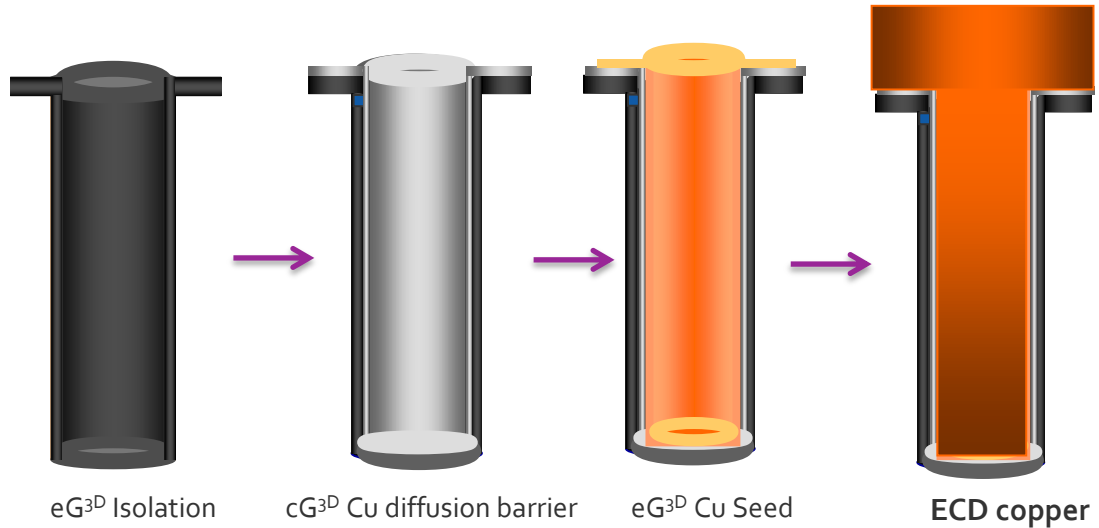


- eG^{3D} Isolation
- cG^{3D} Cu diffusion barrier
- eG^{3D} Cu Seed
- eG^{3D} Cu Fill

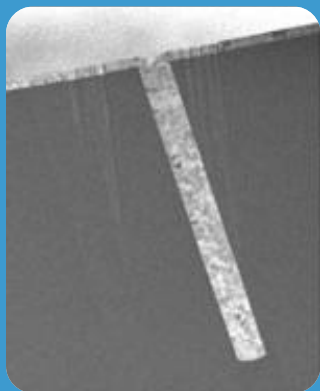
Wet alternatives technologies

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1st Process flow for TSV interposer metallization



3D Packaging / TSV

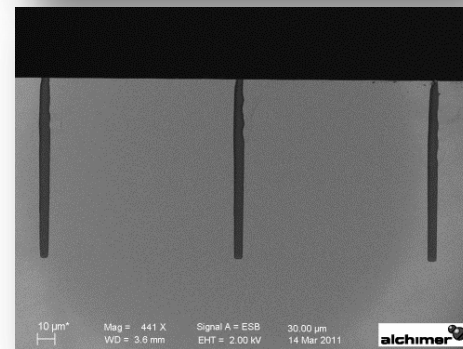
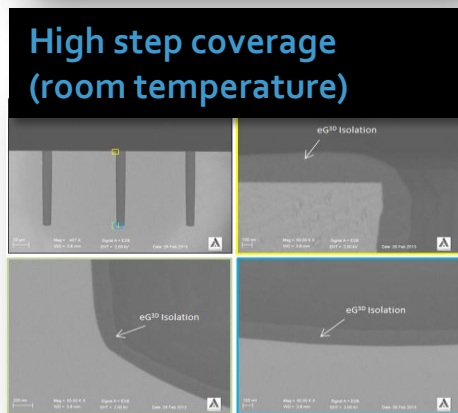
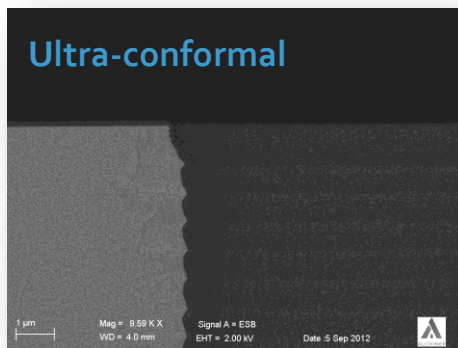


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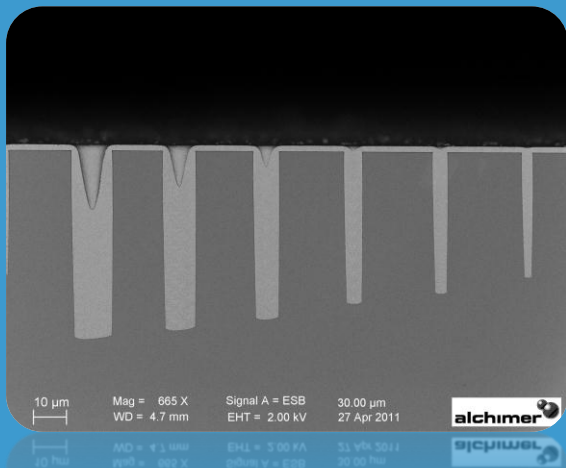
Wet alternatives technologies

1st Process flow for TSV interposer metallization

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3D Packaging / TSV

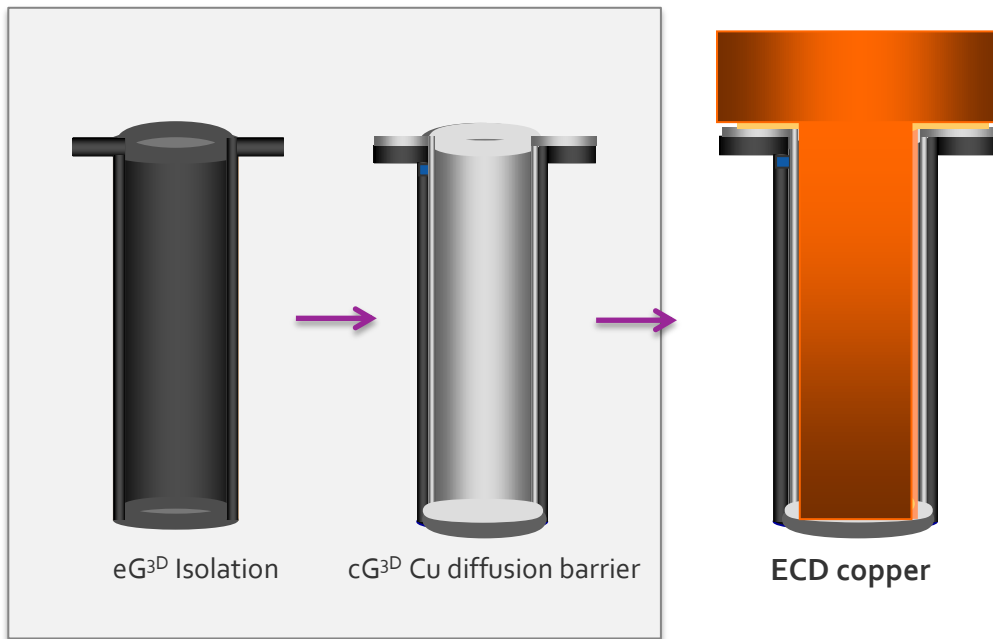


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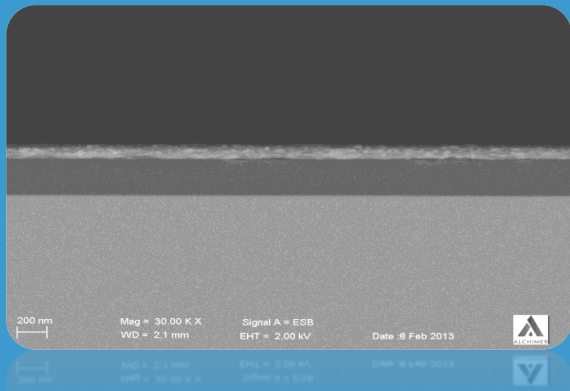
Wet alternatives technologies

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2nd Process flow for TSV interposer metallization



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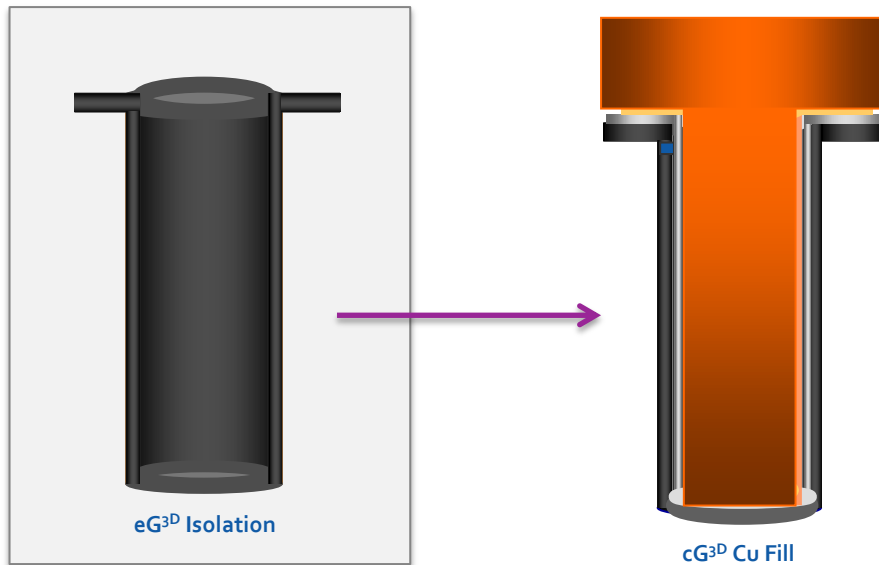


- eG^{3D} Isolation
- cG^{3D} Fill

Wet alternatives technologies

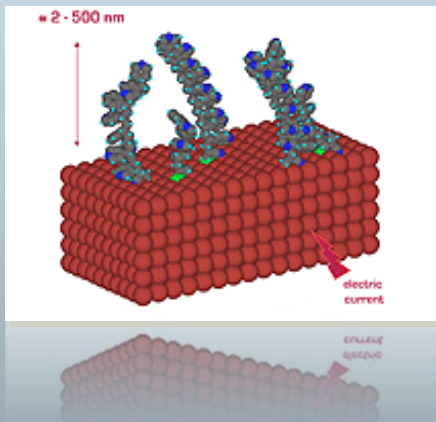
3rd Process flow for TSV interposer metallization

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Under Development

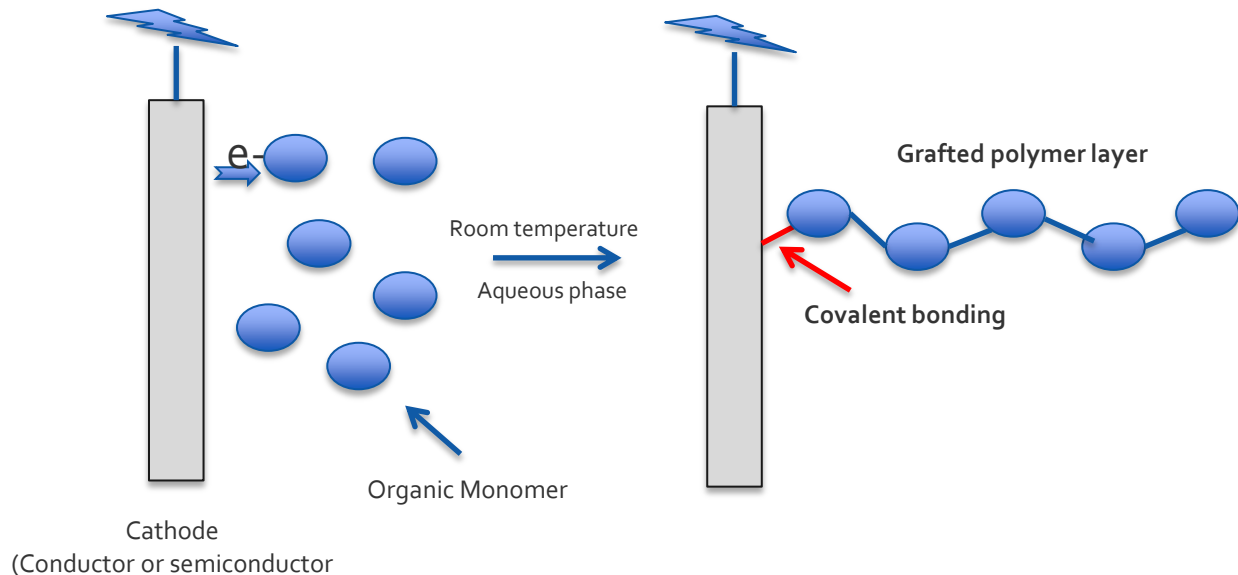
Polymer Electrografting (eG)



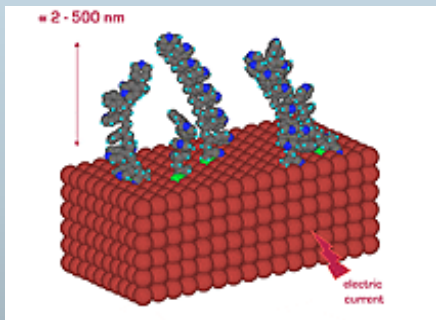
- Fundamental
- Mechanism

Concept of electrografting

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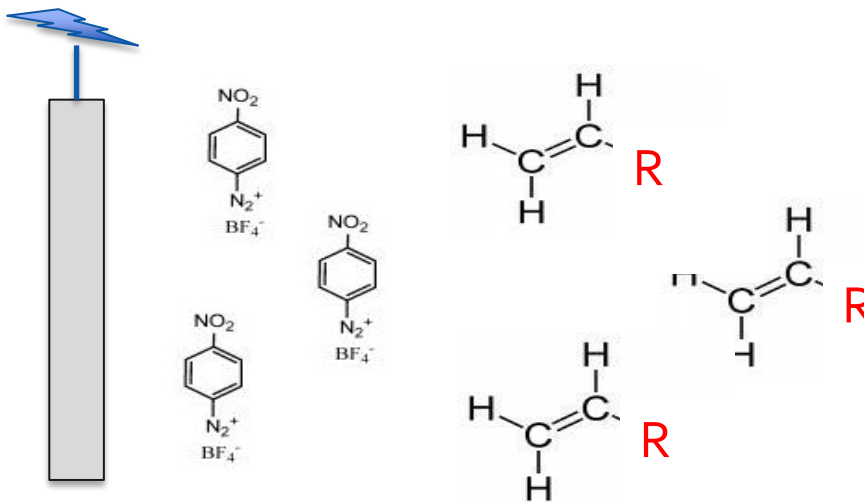
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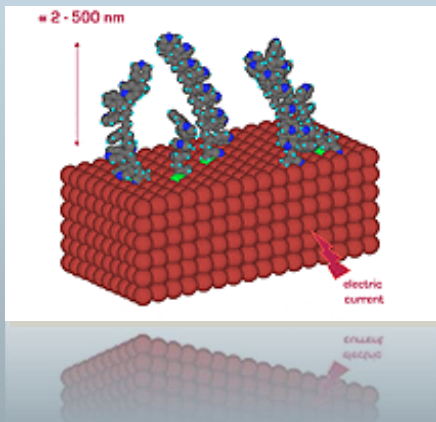
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Concept of electrografting Radical polymerization electro-initiated

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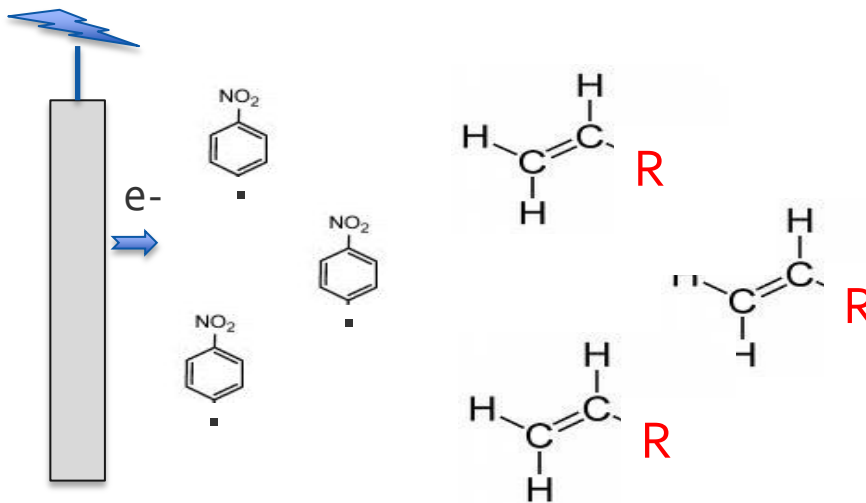
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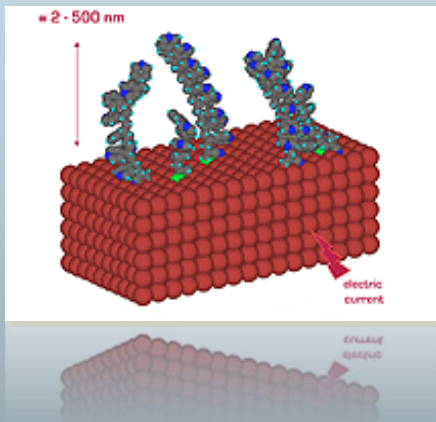
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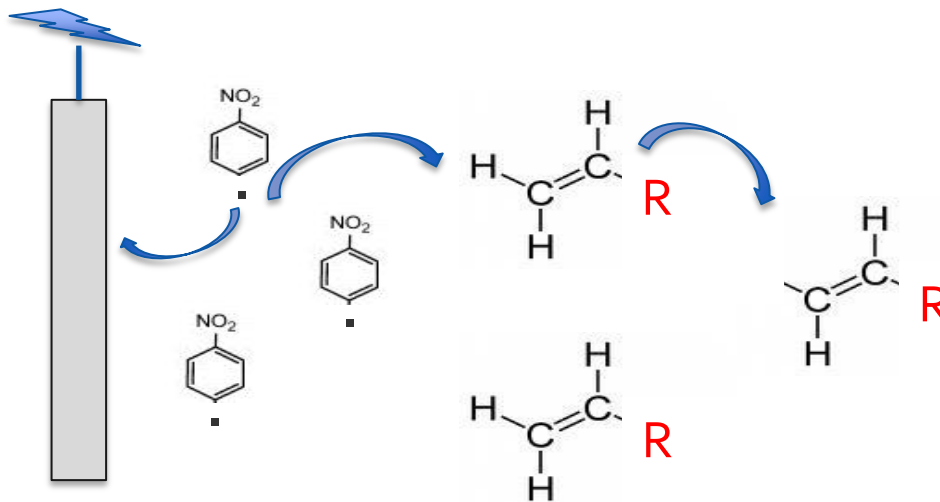
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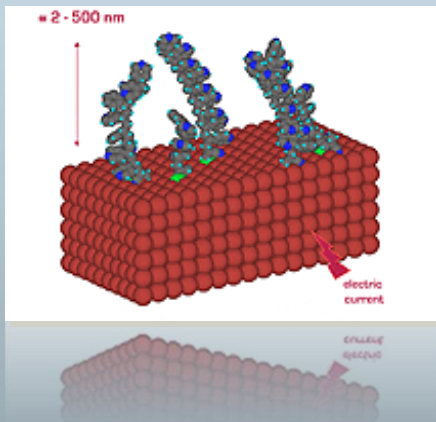
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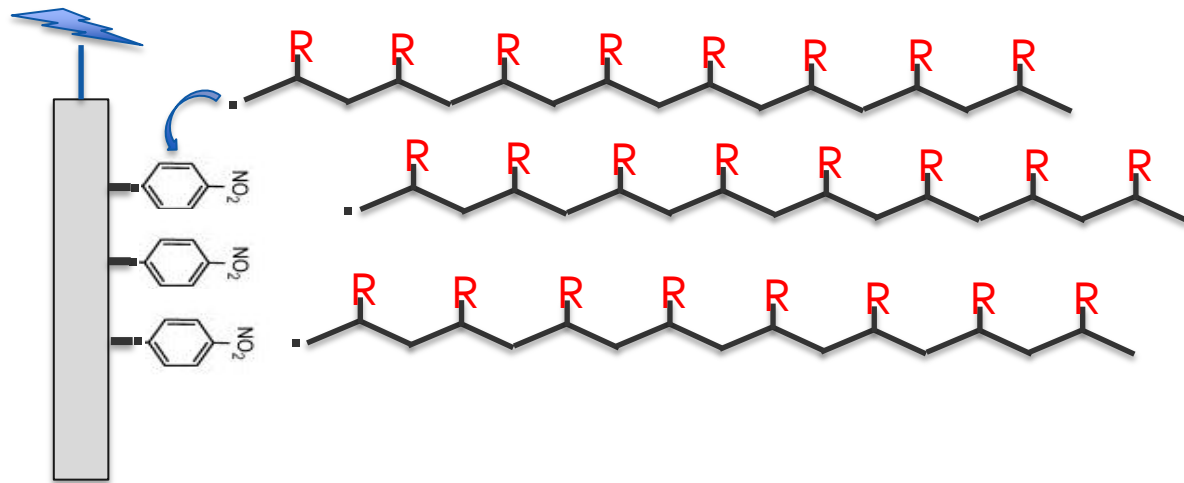
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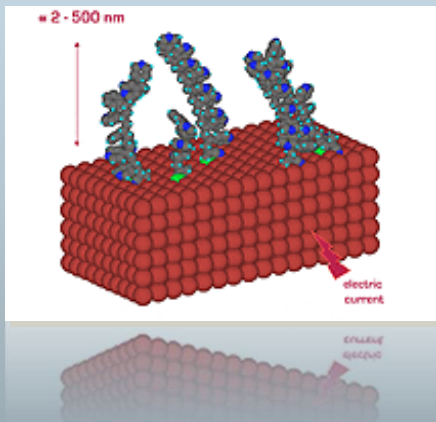
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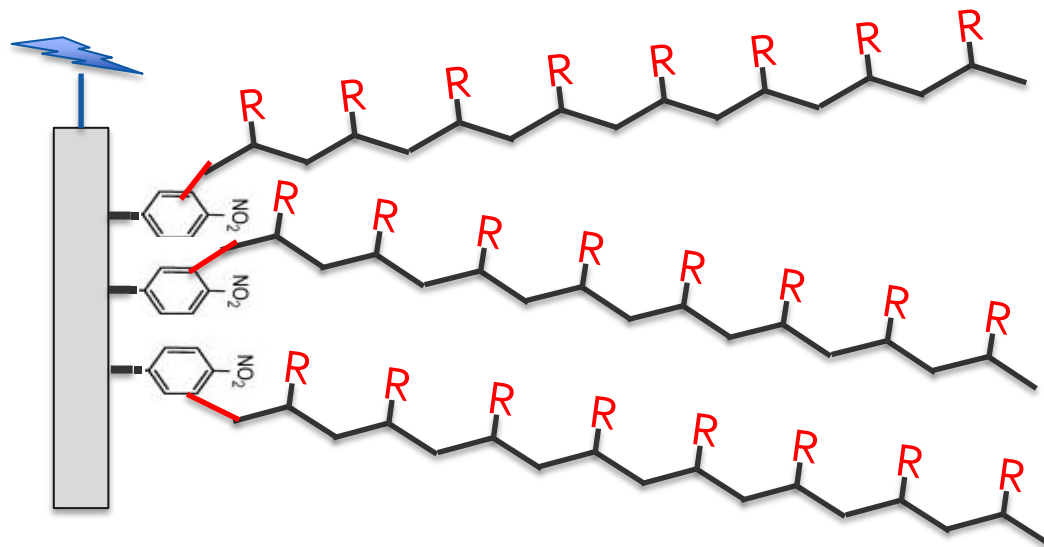
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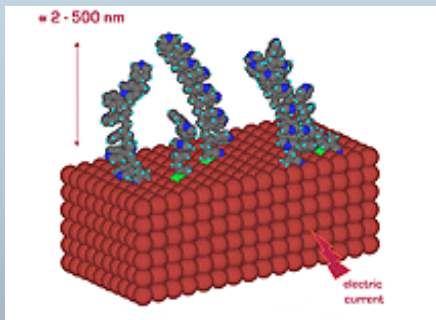
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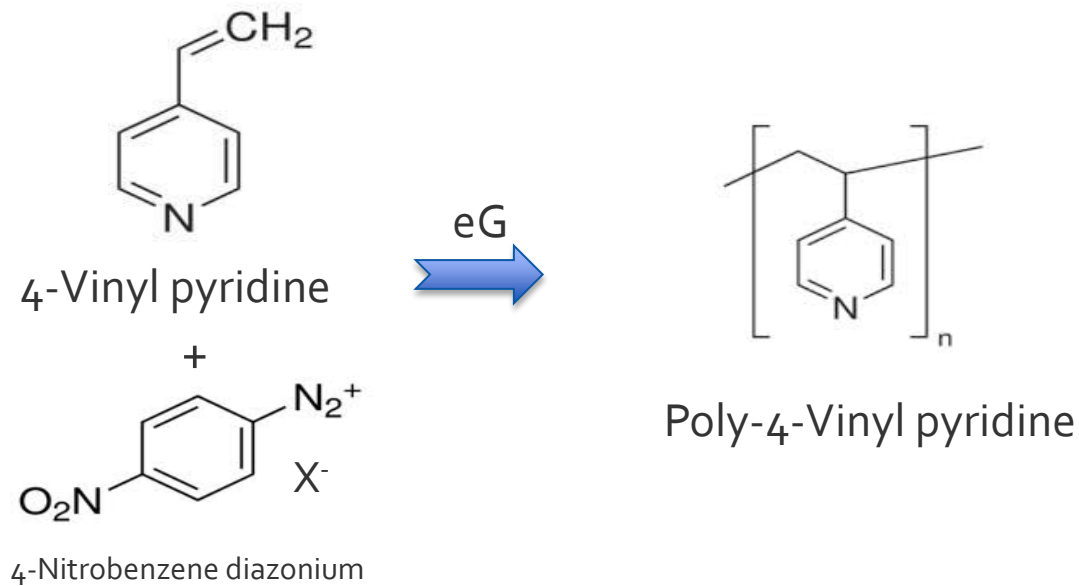
Polymer Electrografting (eG)



- Fundamental
- Mechanism

Concept of electrografting Polymer used for TSV applications

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Insulating properties

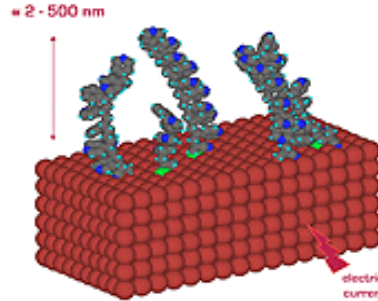
$$C_{ox} = \frac{\epsilon_0 * \epsilon_r * A}{t}$$

- Breakdown voltage
- Leakage current
- Dielectric constant
- Capacitance density

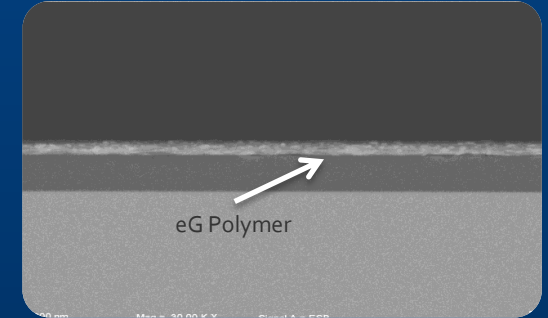
Thermo-mechanical properties

- E-modulus
- CTE
- TGA

Electrografted polymer layer



Cu barrier effect



- SEM cross section
- TOF SIMS depth profile
- Breakdown voltage shift

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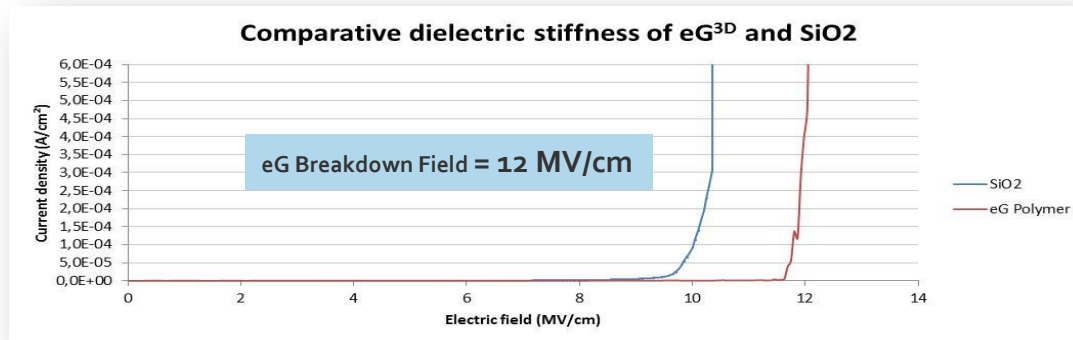
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Breakdown voltage

Thickness : 200 nm for SiO₂ and eG polymer

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Leakage current At 0,25 MV/cm

SiO ₂	10 nA/cm ²
eG Polymer	15 nA/cm ²

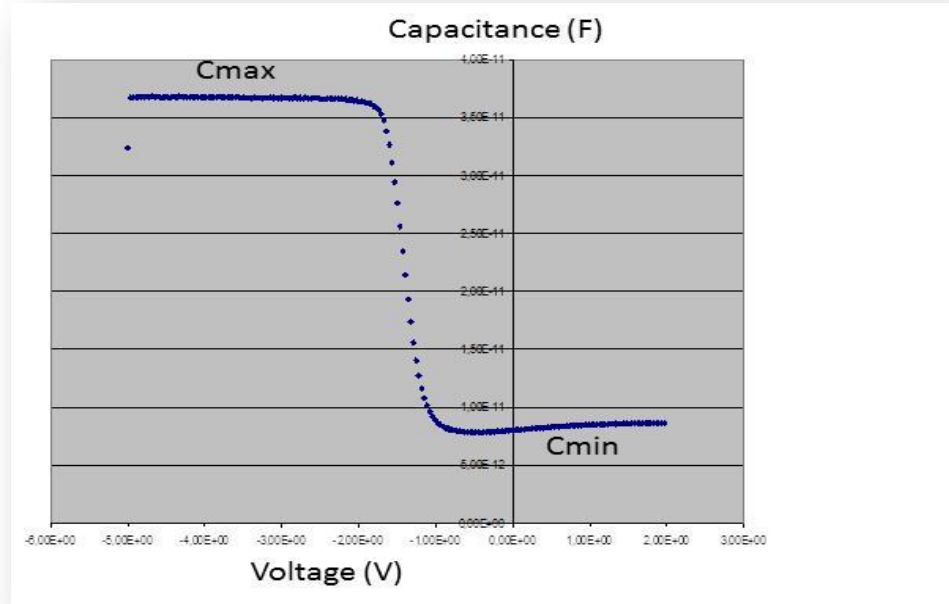
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Dielectric constant

$$\epsilon_r = (3.7 \cdot 10^{-11} \cdot 200 \cdot 10^{-9}) / (8.85 \cdot 10^{-12} \cdot 2.82 \cdot 10^{-7}) = 2.96$$

Capacitance density

$$C_{max} / S = 3.7 \cdot 10^{-11} / 2.82 \cdot 10^{-7} = 1.3 \cdot 10^{-4} \text{ F/m}^2$$

Insulating properties

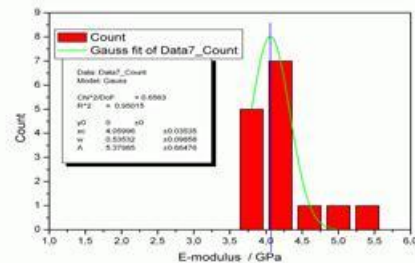
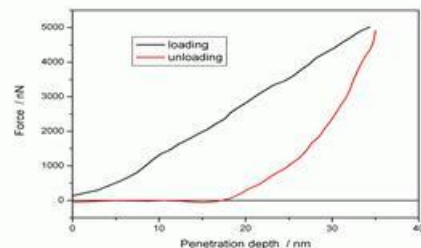
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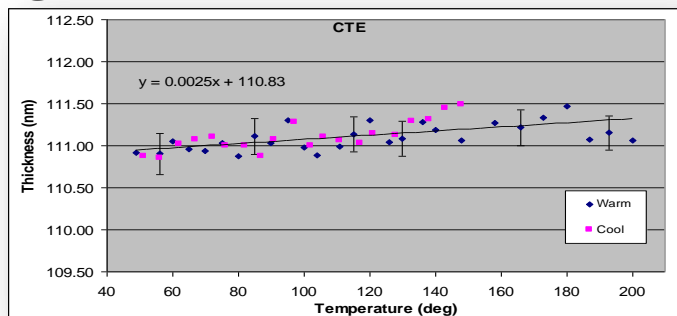
E-Modulus



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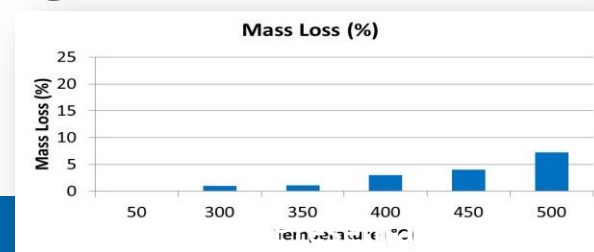
eG polymer
4.05GPa.
(SiO₂ = 107GPa)

CTE



CTE = 30 ppm/°C

TGA



< 1% mass loss at 350°C

Insulating properties

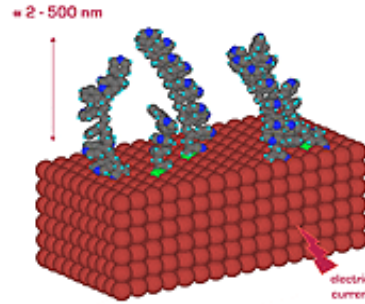
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- Breakdown voltage
- Leakage current
- Dielectric constant
- Capacitance density

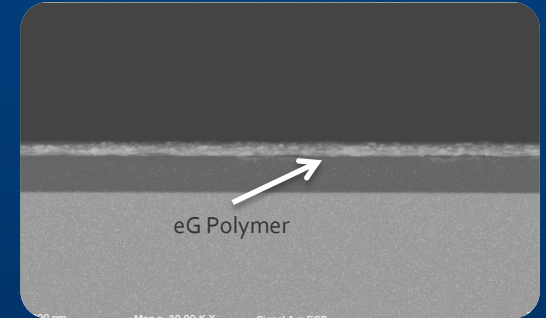
Thermo-mechanical properties

- E-modulus
- CTE
- TGA

Electrografted polymer layer



Cu barrier effect



- SEM cross section
- TOF SIMS depth profile
- Breakdown voltage shift

eG Polymer + Eless Copper

200 nm
Mag = 30.00 K X
WD = 2.1 mm
Signal A = ESB
EHT = 2.00 kV
Date :8 Feb 2013



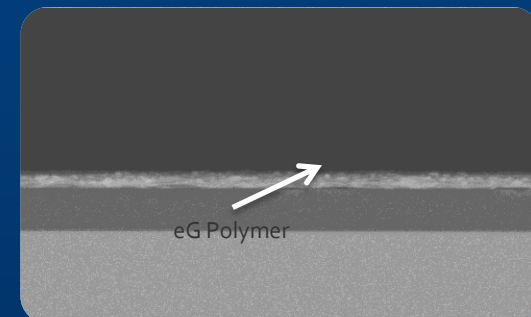
No degradation of the polymer layer

200 nm
Mag = 50.00 K X
WD = 3.2 mm
Signal A = ESB
EHT = 2.00 kV
Date :8 Feb 2013



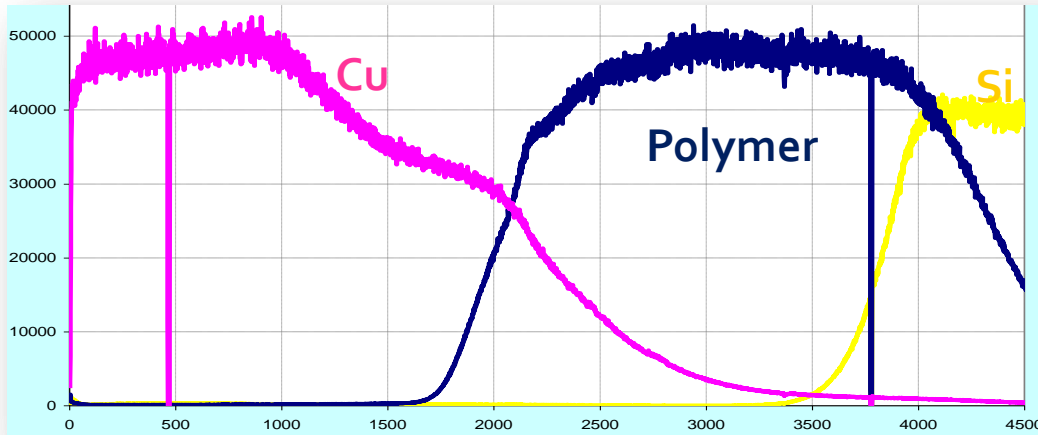
400°C/ 2h under
N₂/H₂

Cu barrier effect



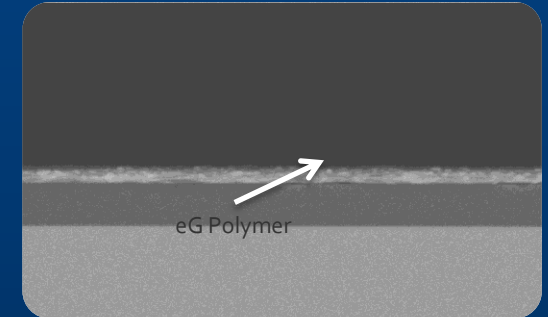
- SEM cross section
- TOF SIMS depth profile
- Breakdown voltage shift

eG polymer (200nm) + Eless copper (200 nm) after 400°C / 2H



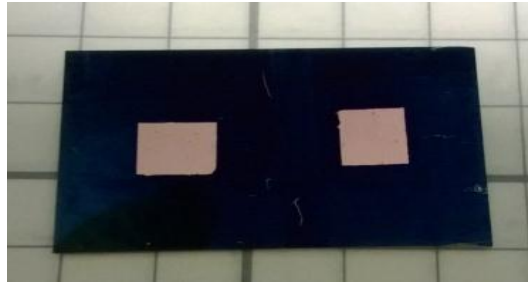
- Analysis Artefact due to ion beam “push through”
- Backside depth profile on going

Cu barrier effect



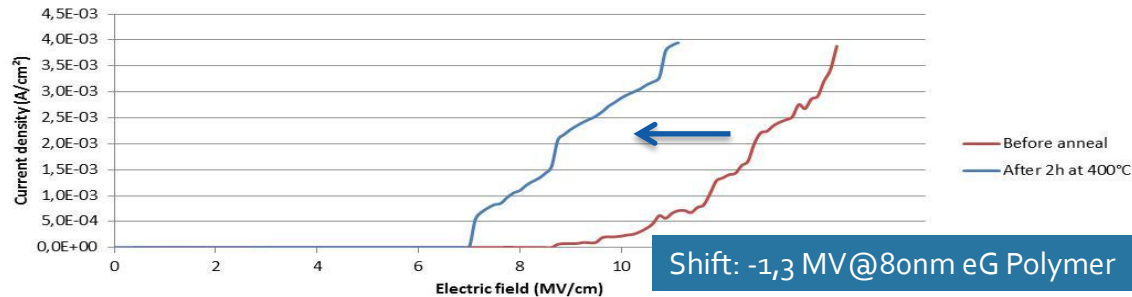
- SEM cross section
- TOF SIMS depth profile
- Breakdown voltage shift

Sample preparation:

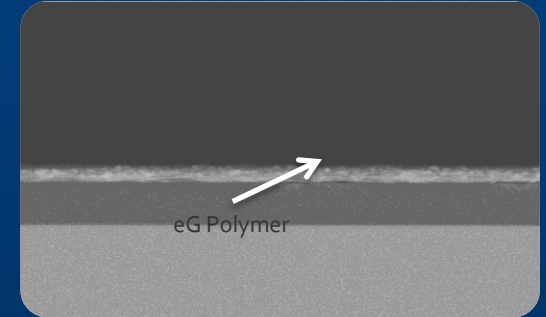


Breakdown measurement :

I/E plot - 80nm eG, 100nm electroless Copper



Cu barrier effect



- SEM cross section
- TOF SIMS depth profile
- Breakdown voltage shift

Conclusion

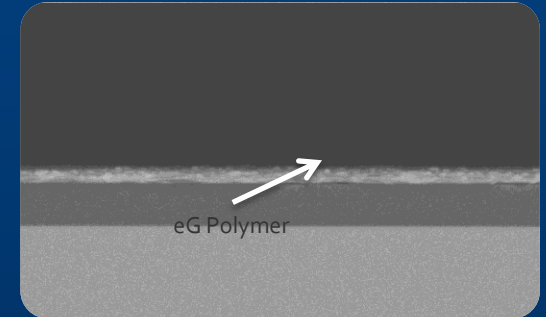
- eG Polymer shows promising results as **copper diffusion barrier**
- Additional characterizations are ongoing :
 - * **Breakdown shift for thick polymer layer**
 - * **Backside analysis using TOF-SIMS depth profile**



Optimization of the **polymer nature** can be investigated by changing the **formulation of the bath/curing step/cross linking/etc..**

What about the cost saving?

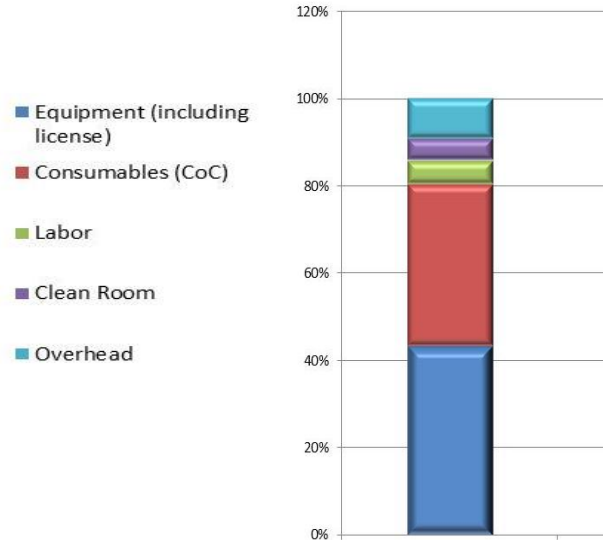
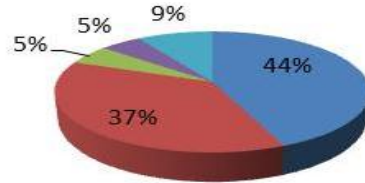
Cu barrier effect



- SEM cross section
- TOF SIMS depth profile
- Breakdown voltage shift

Cost Analysis TSV interposers metallization

Baseline (Dry)



Assumptions:

- TSV dimensions
- Wafer per month
- Wafer size
- Process yield
- Cleanroom surface ratio
- Equipment depreciation time
- Maintenance
- Cleanroom fully depreciated

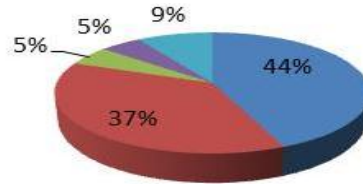
- 5*50 μm
- 7,6K
- 8 Inches
- 95%
- 2,5
- 5 years
- 3%

- **Baseline** : PECVD SiO₂ - PVD Barrier - PVD Copper - ECD Fill
- **Current Wet flow** : eG Isolation - cG Barrier - eG Fill
- **Next Wet flow** : eG Isolation - cG Fill

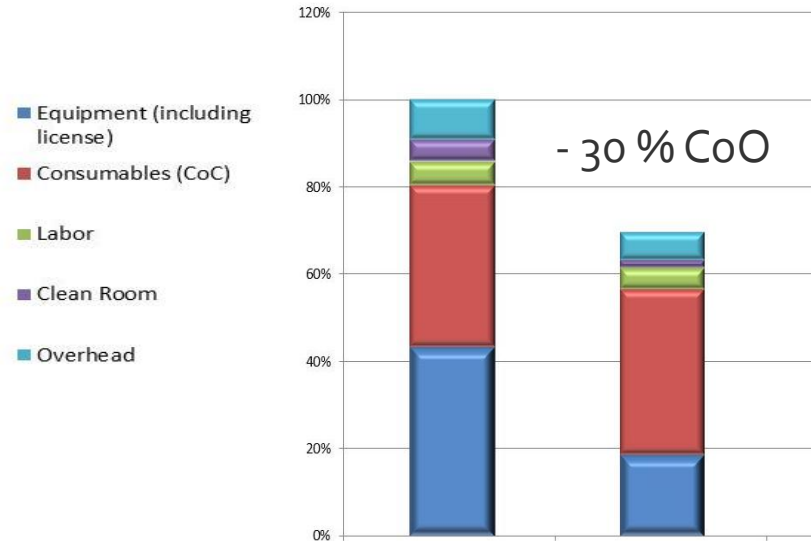
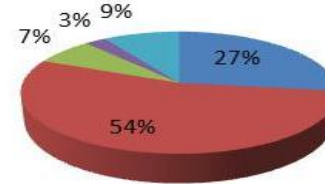
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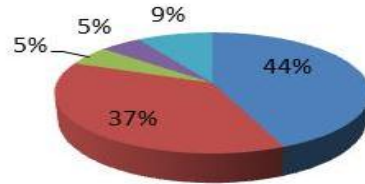


Current wet flow

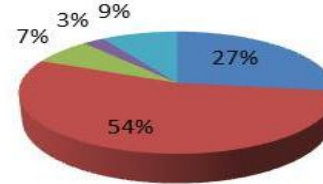


Cost Analysis TSV interposers metallization

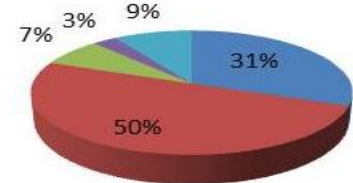
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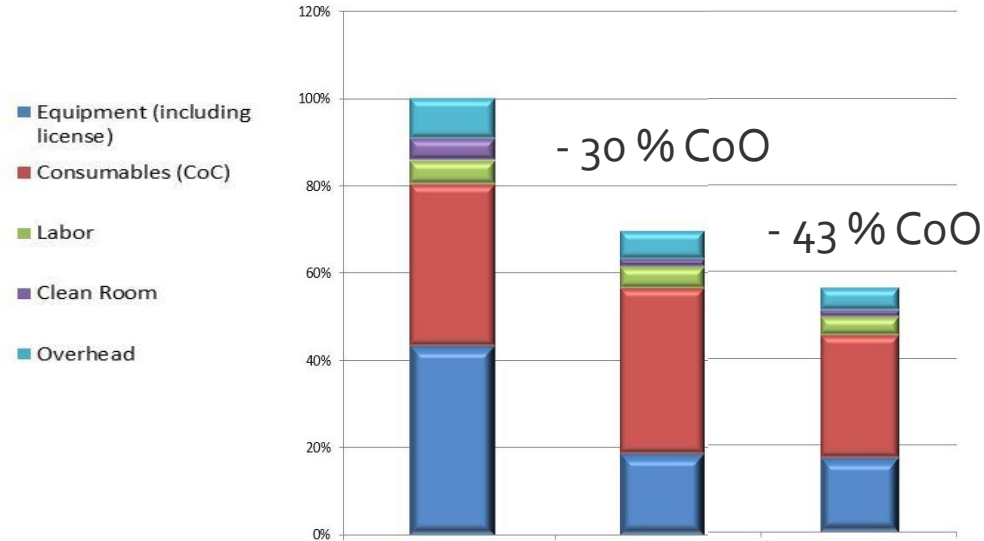
Current wet flow



















Next wet flow



- **Baseline** : PECVD SiO₂ - PVD Barrier - PVD Copper - ECD Fill
- **Current Wet flow** : eG Isolation - cG Barrier - eG Fill
- **Next Wet flow** : eG Isolation - cG Fill










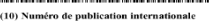



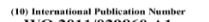

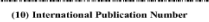

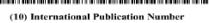
Conclusion

(19) Organisation Mondiale de la Propriété Intellectuelle Bureau international			(10) Numéro de publication internationale WO 02/070148 A1
(43) Date de la publication internationale 12 septembre 2002 (12.09.2002)	PCT		
(19) World Intellectual Property Organization International Bureau			(10) International Publication Number WO 2007/099137 A2
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(43) Date de la publication internationale 26 novembre 2009 (26.11.2009)	PCT		
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(19) World Intellectual Property Organization International Bureau			(10) International Publication Number WO 2010/108996 A1
(43) International Publication Date 30 September 2010 (30.09.2010)	PCT		
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(43) International Publication Date 17 March 2011 (17.03.2011)	PCT		
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(19) World Intellectual Property Organization International Bureau			(10) International Publication Number WO 2011/154493 A1
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- 2.5D Process flow
- Polymer barrier
- Cost reduction

- Alchimer's proprietary wet technologies enables 2.5D interposers metallization in high aspect ratio structures.
- 2.5D metallization process flow can be simplified by combining material properties
 - * Barrier + Seed
 - * Isolation + Barrier








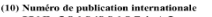

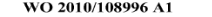






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- Alchimer's proprietary wet technologies enables 2.5D interposers metallization in high aspect ratio structures.
- 2.5D metallization process flow can be simplified by combining material properties
 - * Barrier + Seed
 - * Isolation + Barrier
- First results on the electrografted polymer layer as a copper diffusion barrier show encouraging results
- Optimization and detailed characterization are on ongoing to improve the barrier effect of the polymer layer

Conclusion

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(43) Date de la publication internationale 12 septembre 2002 (12.09.2002)	PCT		
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- 2.5D Process flow
- Polymer barrier
- Cost reduction

- Alchimer's proprietary wet technologies enables 2.5D interposers metallization in high aspect ratio structures.
- 2.5D metallization process flow can be simplified by combining material properties
 - * Barrier + Seed
 - * Isolation + Barrier
- First results on the electrografted polymer layer as a copper diffusion barrier show encouraging results
- Optimization and detailed characterization are ongoing to improve the barrier effect of the polymer layer
- By using wet technologies for TSV metallization, cost of ownership is decreased by 30% today
- New development will put the cost savings close to 45% compare to conventional dry approaches



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Thank you!

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