Thermal Management
Pre-Applied Underfill

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(GE-Toshiba Silicones)

TOSHIBA

Presentation for-

- **Thermal Management**
- **Pre-Applied Underfill**

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Apr. 26. 2005
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LI-82-05247

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GE Advanced Materials

GE Is a Diversified Company, with 11 Major Businesses in Services, Manufacturing and Technology

Advanced Materials
Commercial Finance
Consumer and Industrial
Consumer Finance
Equipment Services
Energy
Healthcare
Infrastructure
Insurance
NBC-Universal
Transportation

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GE Advanced Materials

Silicones

Global*

Coatings and silanes

Elastomers

RTV products

Specialty Fluids

Urethane Additives

*includes GE Bayer in Europe,
GE Toshiba Silicones in Pacific,
OSi Specialties

Pacific

Electronics material/GEMTC

Plastics

Engineering Plastic -- resins

- LNP – custom compounding

Structured Products – sheet and film

Polymershapes – distribution of rod, film, sheet and tube

Quartz

High purity quartz materials

Advanced ceramic materials and products

- Advanced Ceramics

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GE Advanced Materials

Organization for Technology Development

GE GRC
R&D

GEMTC
Japan

GE TOSHIBA SILICONES

GE SILICONES
Americas

GE Bayer
SILICONES

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Introduction to Silicone

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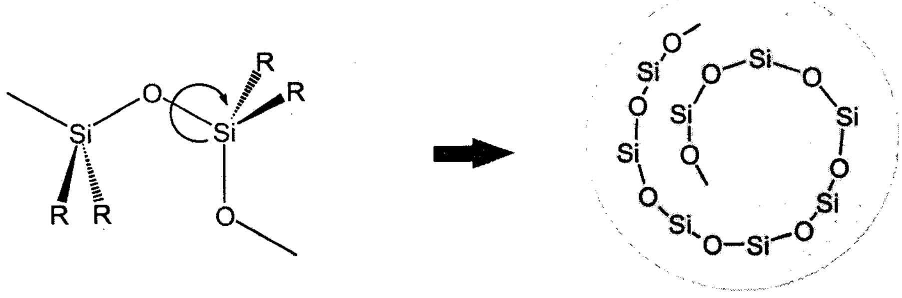
Introduction - Silicone

Organopolysiloxane

Polysiloxane with Organic Substituent on Si

Common Name : Silicon<u>e</u>



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Introduction - Silicone

Physical Characteristics of Organopolysiloxane

Good Cold Resistance	Low Tg (ca.-120℃)
Small Temperature dependance of Viscoelasiticity	
Large Compressibility	
Large Gas Permeability	
Large Thermal Expansion Coefficient but Low stress	
Low Moisture Absorption	

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Introduction - Silicone

Advantages of Silicone

Thermal Resistance	Over 150℃
Low Temperature Durability	Below -50℃
Mechanical Properties	Relatively Strong at High Temperature Comparing with Organic Rubber
Electrical Properties	High Insulation Stable at High Temperature
Weatherability	Excellent
Flame Retardancy	Non-halogen system

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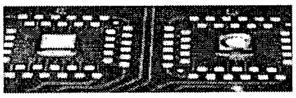
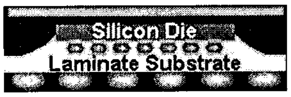
Electronic Materials Portfolio

Packaging

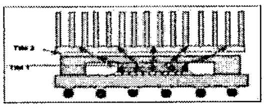
Die Attach/Die coating



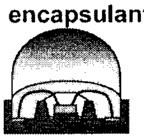
Pre Applied Underfill



Thermal Interface Material

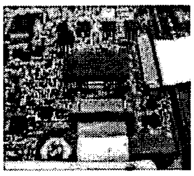


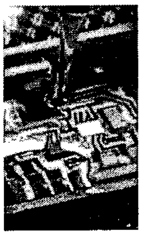
LED encapsulant/Lens



Board Mounting

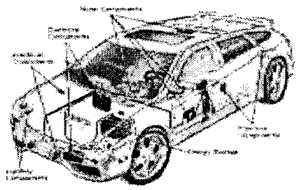
Adhesive for Passive/ Package, Potting



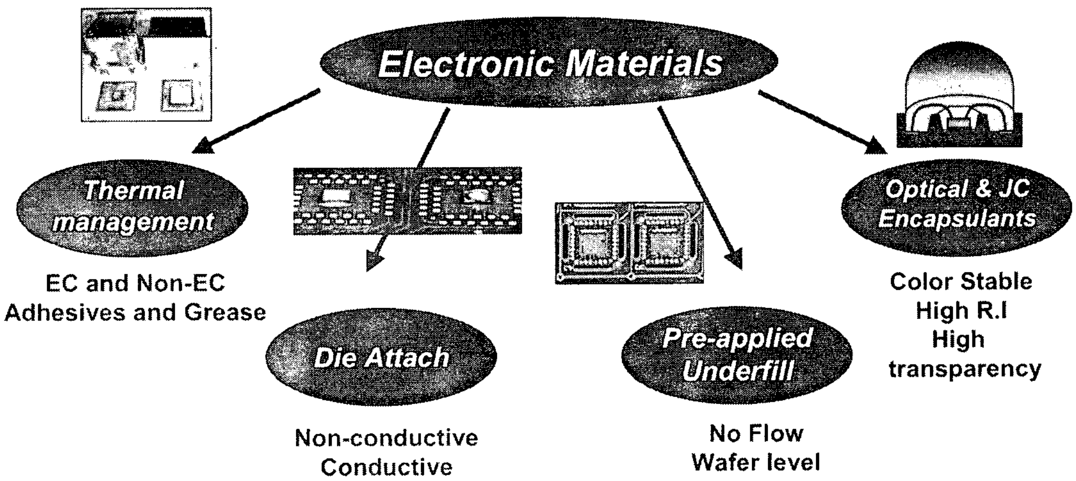


Final Assembly

Adhesive/Gels Grease



Micro-Electronics Focus Areas



Thermal Interface Materials

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SilCool™ Thermo-Conductive Materials

Insulating Type Adhesives
TSE 3281G
TSE 3282G
LTR3291
LTR3292
TSE3286G(Exp)
XE13-C1822(Exp)

Electro-Conductive Type Adhesives
SDC5000 (New)

Silicone Grease / Compound
TIG 2000 (Exp)
TIG 4000 (New)*
TIG 5000 (New)*

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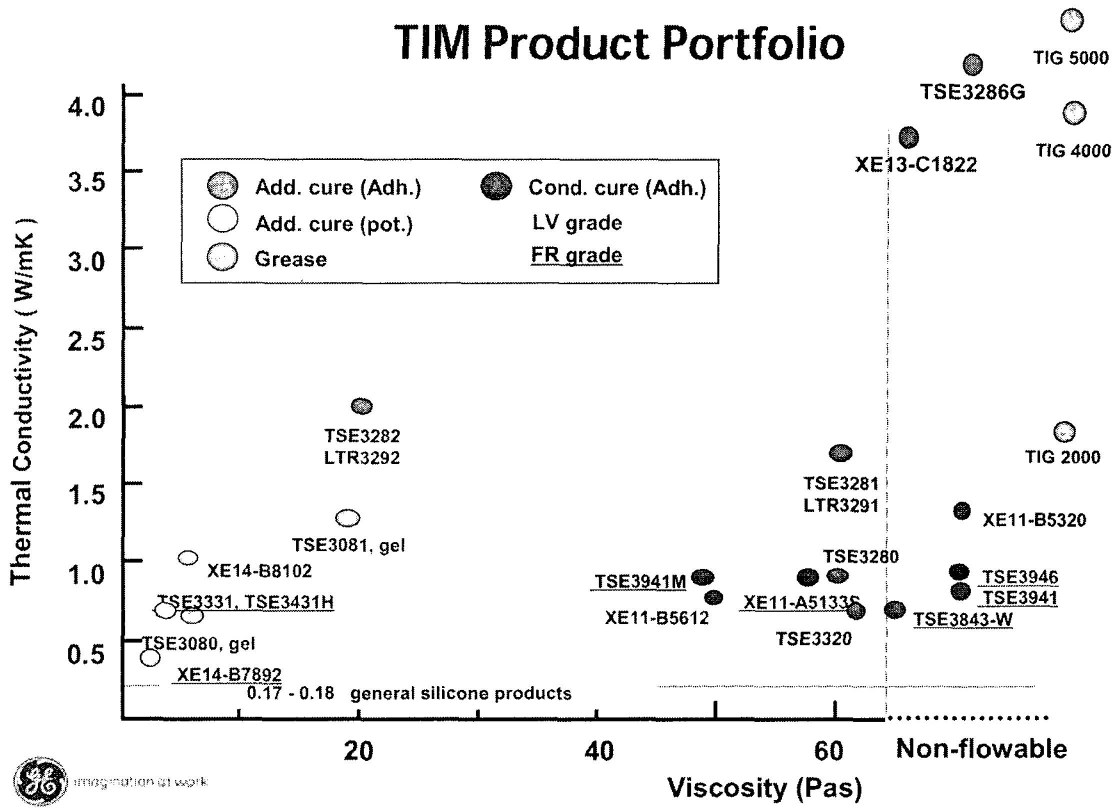
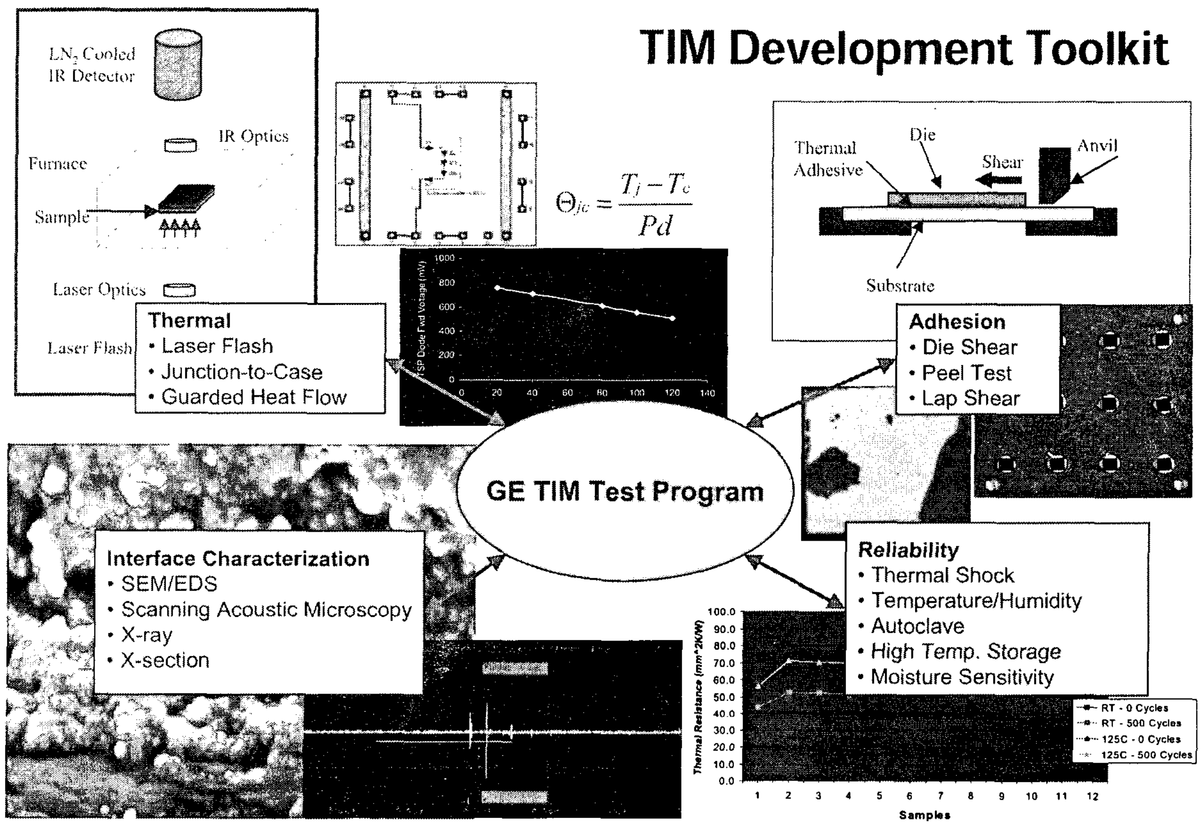
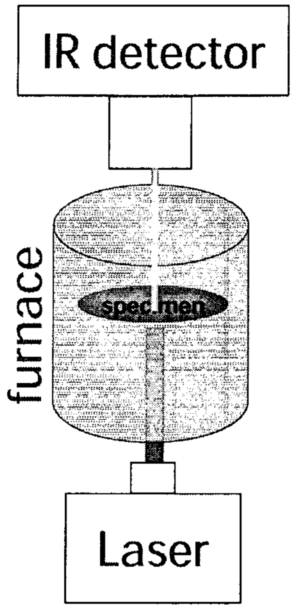

TIM Product Portfolio
Add. cure (Adh.)
Add. cure (pot.)
Grease
Cond. cure (Adh.)
LV grade
FR grade
Thermal Conductivity (W/mK)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
TIG 5000
TSE3286G
TIG 4000
XE13-C1822
TSE3282
LTR3292
TIG 2000
TSE3281
LTR3291
XE11-B5320
TSE3081, gel
XE14-B8102
TSE3280
TSE3941M
TSE3946
TSE3941
TSE3331, TSE3431H
XE11-B5612
XE11-A5133S
TSE3843-W
TSE3320
TSE3080, gel
XE14-B7892
0.17 - 0.18 general silicone products
20
40
60
Non-flowable
Viscosity (Pas)


TIM Development Toolkit
LN2 Cooled IR Detector
IR Optics
Furnace
Sample
Laser Optics
Laser Flash
$\Theta_{jc} = \frac{T_j - T_c}{Pd}$
Thermal
• Laser Flash
• Junction-to-Case
• Guarded Heat Flow
Thermal Adhesive
Die
Shear
Anvil
Substrate
Adhesion
• Die Shear
• Peel Test
• Lap Shear
GE TIM Test Program
Interface Characterization
• SEM/EDS
• Scanning Acoustic Microscopy
• X-ray
• X-section
Reliability
• Thermal Shock
• Temperature/Humidity
• Autoclave
• High Temp. Storage
• Moisture Sensitivity
RT - 0 Cycles
RT - 500 Cycles
125C - 0 Cycles
125C - 500 Cycles
Samples

Thermal Resistance

Laser flash machine



$\lambda = \alpha \rho Cp$

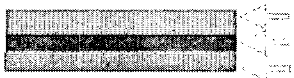
λ : thermal conductivity

α : thermal diffusivity

ρ : density

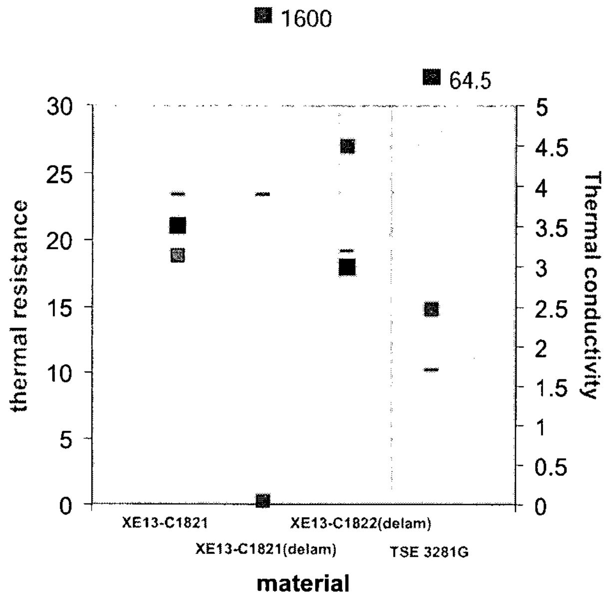
Cp:Specific heat

Thermal resistance=thickness/ λ

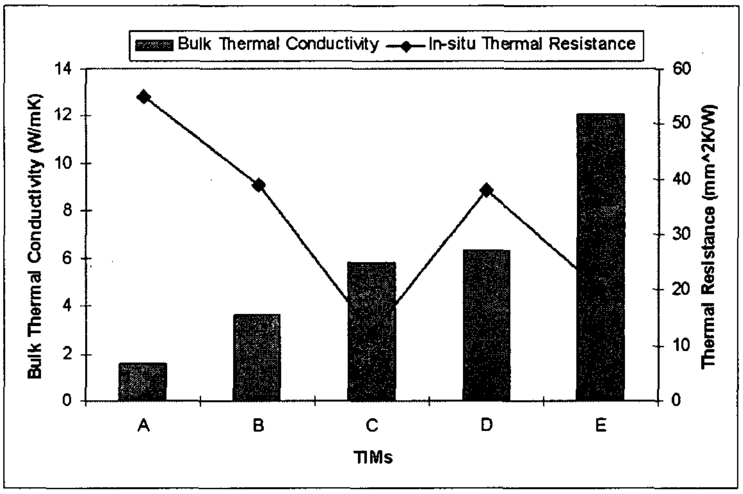


Thermal Resistance

Thermal resistance is a important factor to simulate thermal performance of packages



Thermal Resistance vs. Bulk Conductivity



Bulk Thermal Conductivity is not an accurate predictor of in-situ performance

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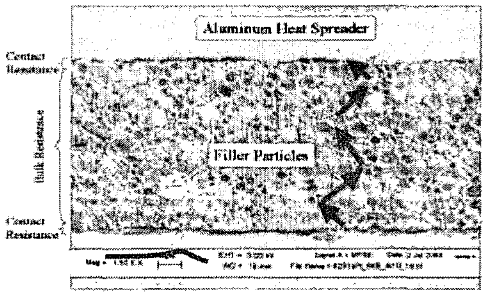
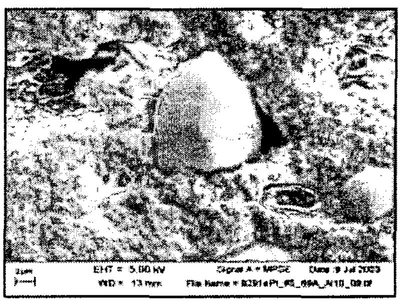
TIM: Design Challenges





SEM Showing Void at Alumina Filler–Silicone Matrix Interface

Acoustic Microscopy Images of TIM Samples Showing Extensive Voiding

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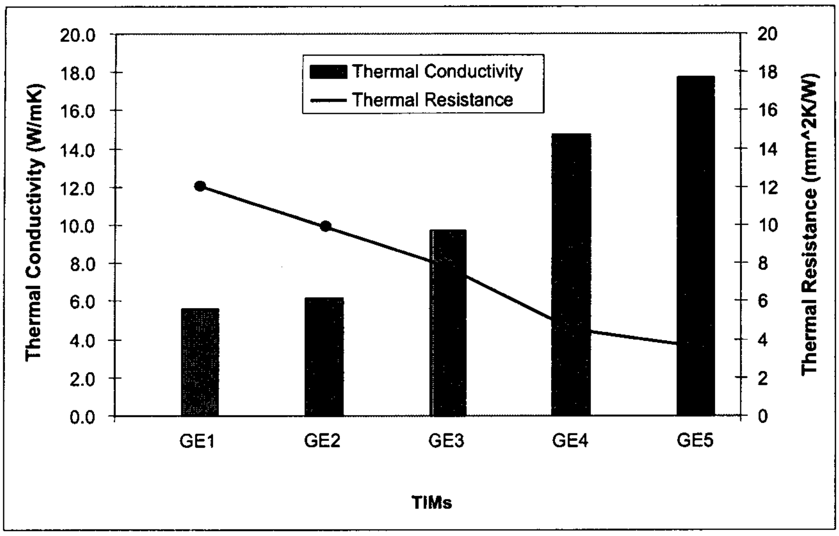
Image from Advanced Packaging

Next-Gen TIM Materials



- New Greases with thermal resistance values as low as 4 mm2 K/W
- High thermal conductivities
- Class leading pump-out / bleed performance

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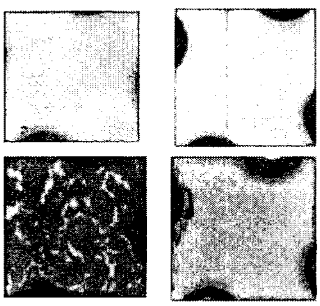
Next-Gen TIM Greases

High Temperature Storage

Time Zero

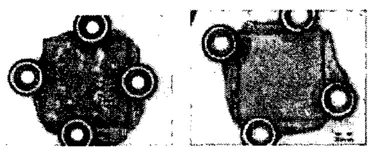
150 hrs at 150°C



Best in Class – 1   GE

Thermal Shock (-40 to 125C)

1000 Cycles



Best in Class – 1   GE

GE Materials Significantly Better in Reliability Tests

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Pre Applied Underfill

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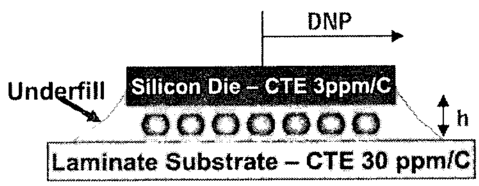
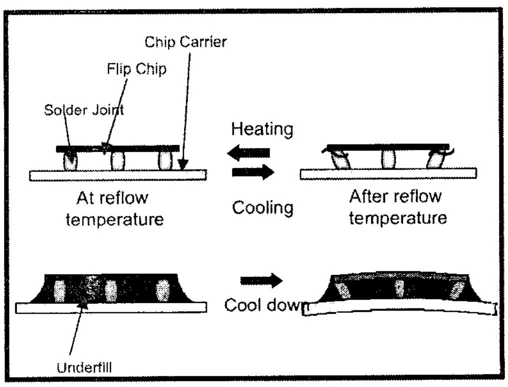
Underfill Mechanism

- **CTE mismatch between silicon and chip carrier**
  - > Solder interconnect is subjected to shear strain during thermal excursions

$$\gamma_{Outer\,C4\,Solderjoint} = \frac{DNP[(\alpha_A - \alpha_B)(T_{max} - T_{min})]}{H}$$



- **Chip carrier and flip chip are interlocked by underfill material**
  - > Underfill compensates shear strain solder joints
  - > Joint is compressed and protected by underfill



- **Underfill materials greatly increase the fatigue lifetime of solder joints in flip chip packages**

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Underfill Technologies

- Types of underfill technologies:
  > Capillary
  > No-Flow
  > Wafer Level
- Packages Applicable for Underfill:
  > Flip Chip, CSP, BGA

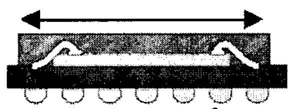

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Image from
Adamson, GlobalTRONICS 2002

Capillary Underfill

- **Underfill is applied after interconnection of the device**
- **Comprised of filled liquid polymer**
  > **Most common is silica filled epoxy**
- **Line dispensing is typically on one side of the chip, or L-shape to prevent entrapment of air**
- **Surface tension forces draw material under the chip**
- **Post curing is done which is below the melting temperature of solder**

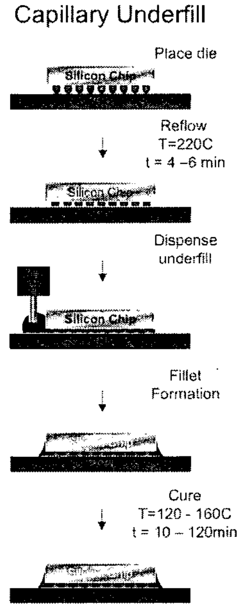

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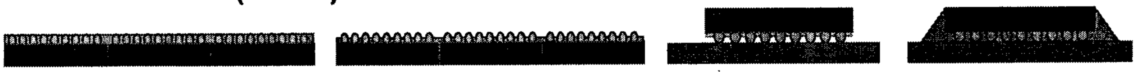
Image from
Chipscale review

Pre-Applied Underfill: No Flow & Wafer Level

No-Flow (NFU / NUF)

Apply underfill → **Place die** → **Reflow and cure** → **Postcure(160℃ , 1hr)**

Wafer Level (WLU)



Apply Underfill → **Remove Solvent** → **Dice wafer Place die** → **Reflow and cure**

GE Objective: World class reliability through low CTE, high Tg materials
GE Differentiator: Novel base resin chemistry with advanced filler technology to create class-leading materials

Advantages: Process speed, reduced cost, design freedom

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Image from Chipscale review

Pre-Applied Underfill: Advantages

Advantages of Pre-Applied Underfill

High Productivity	Remove several processes Shorten the process time
Low manufacturing cost	Material cost/Equipment cost Space saving

- Capillary Underfill Process

Apply flux → Die P&P → Reflow → Flux cleaning → Dispensing CU → CU flow → Fillet dispensing → Oven cure

- Pre Applied Underfill Process

Dispensing NFU → Die P&P → Reflow → Post cure

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Pre-Applied Underfill: Design Targets

Reliability:
- Temp. Cycle : - 50/150° C, 1000cycles
- Temp & humidity : 85%/85° C, 1000hrs
- Storage @ 150° C : 1000hrs
- MSL ≤ 3
- Solvent resistance

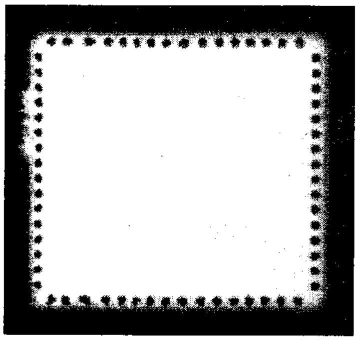
Process Compatibility:
- Std reflow profile compatibility (eutectic, leadfree)
- Rapid cure at max reflow temperature
- Short post-cure at sub-reflow temperatures
- Flux-promoting

Material Properties
- Low CTE (<50 ppm)
- High Tg (>125C)
- Low viscosity (2500 cPs)
- Moderate modulus (>2 GPa)
- High Adhesion (>3000 psi)
- Insulating Resistance (IPC) >1000MΩ
- Toughness
- Transparency (for WLU)

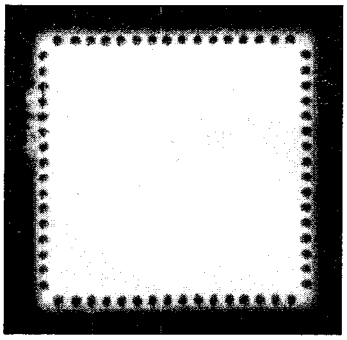
Industry Driven Performance Requirements

Pre-Applied Underfill: NFU Reliability

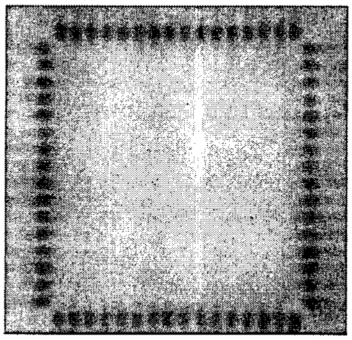
Challenge: *Thermal Cycling & Temp/Humidity Reliability*



C-SAM before preconditioning



C-SAM after MSL3



X-ray after MSL 3

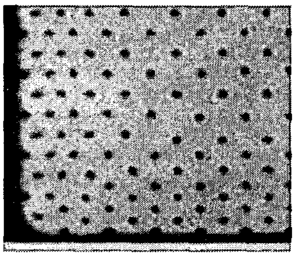
✓ Passed JEDEC MSL Level 3, 260C
- Pre-con: 192 hours @ 30C/60%RH
- 3x solder reflow

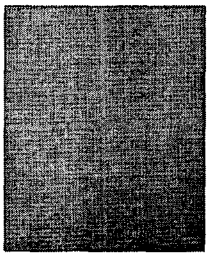
✓ 1500+ cycles AATS (-50/+150C)

✓ No fillet cracking observed, electrical connections intact

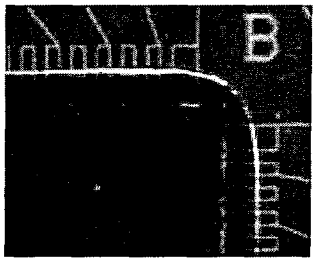
✓ Same performance demonstrated on die up to 185mm^2 (13.5x13.5)

Pre-Applied Underfill: NFU Reliability





C-SAM – die/underfill interface

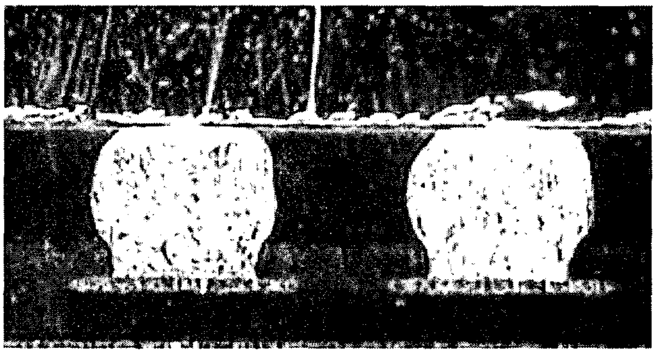


Fillet view

Full Area Array / Large Die Reliability!

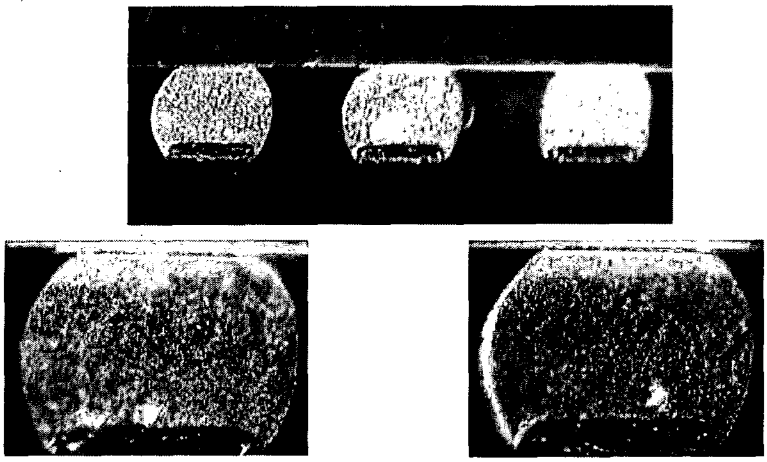
12.5 x 12.5 mm with 1064 I/O
1000+ cycles @ AATS –50C to +150C -> crack free fillets and minimal delamination

Pre-Applied Underfill: Application Compatibility



- **Eutectic bump : Available Now**
- **High-Lead Bump / Eutectic Pad : Materials Available Now, Under evaluation for yield up**
- **Lead free bump : coming soon**

Pre-Applied Underfill: Pb-free Compatible



Pb-free compatible No-Flow in development

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Thank you!

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