



Consumer Solutions



DOWSIL™ TC-4525 Gap Filler

DOWSIL™

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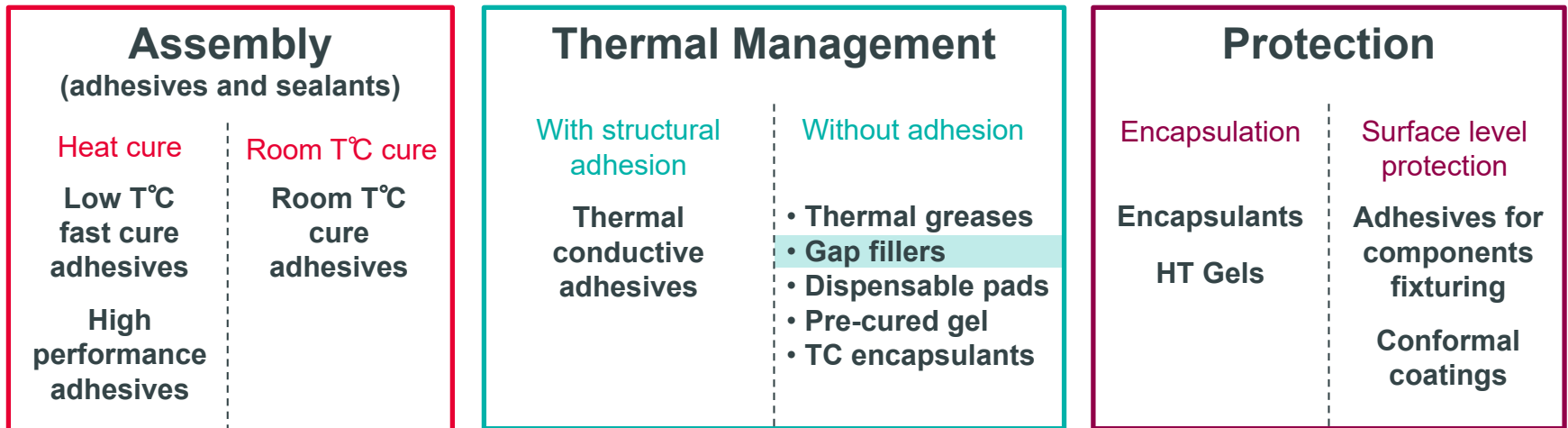
DOWSIL™ TC-4525 Gap Filler – Highlights

- **DOWSIL™ TC-4525 Gap Filler (and DOWSIL™ TC-4525 GB Gap Filler)** are the first Dow Consumer Solutions thermal gap fillers for PCB system assembly applications
 - A stepping stone in Dow's desire to penetrate the gap filler market and develop a solid portfolio
- **Advantages over competition:**
 - Improved properties:
 - Optimized reliability: **better stability of properties** during aging (thermal, modulus)
 - Optimized **dispensability** (minimized abrasion, improved rheology)
 - Optimized assembly process: better compressibility/spread-ability
 - **Faster RT cure** to reduce process costs
 - **Competitive market pricing**
- **Key messages (value proposition) and objective:**
 - DOWSIL™ TC-4525 Gap Filler is the first gap filler provided by Dow targeting PCB system assembly applications, requiring 2.5 W/mK TC and providing, better dispensability and secure supply at competitive market price.

Market, Strategy and Positioning

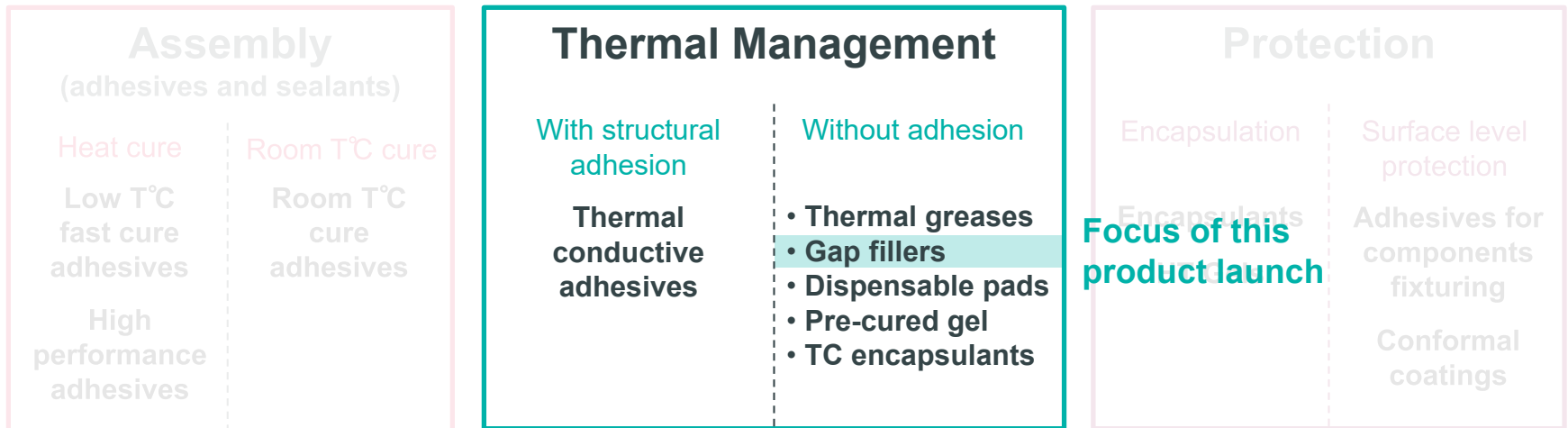
Main Trends, Drivers and Segments

- Transportation macro-trends:
 - Vehicle efficiency (xEV, lower weight/cost/form factor)
 - Increased safety
 - Better comfort and entertainment
 - Main drivers are:
 - Improve materials performance – heat dissipation, adhesion, protection, mechanical,...
 - Lower cost of ownership – faster cure, cheaper, lighter, easier to handle/dispense/store...
- ➔ **Key needs** for which silicones bring a **high value** at **low cost-of-ownership** in automotive PCB modules are:

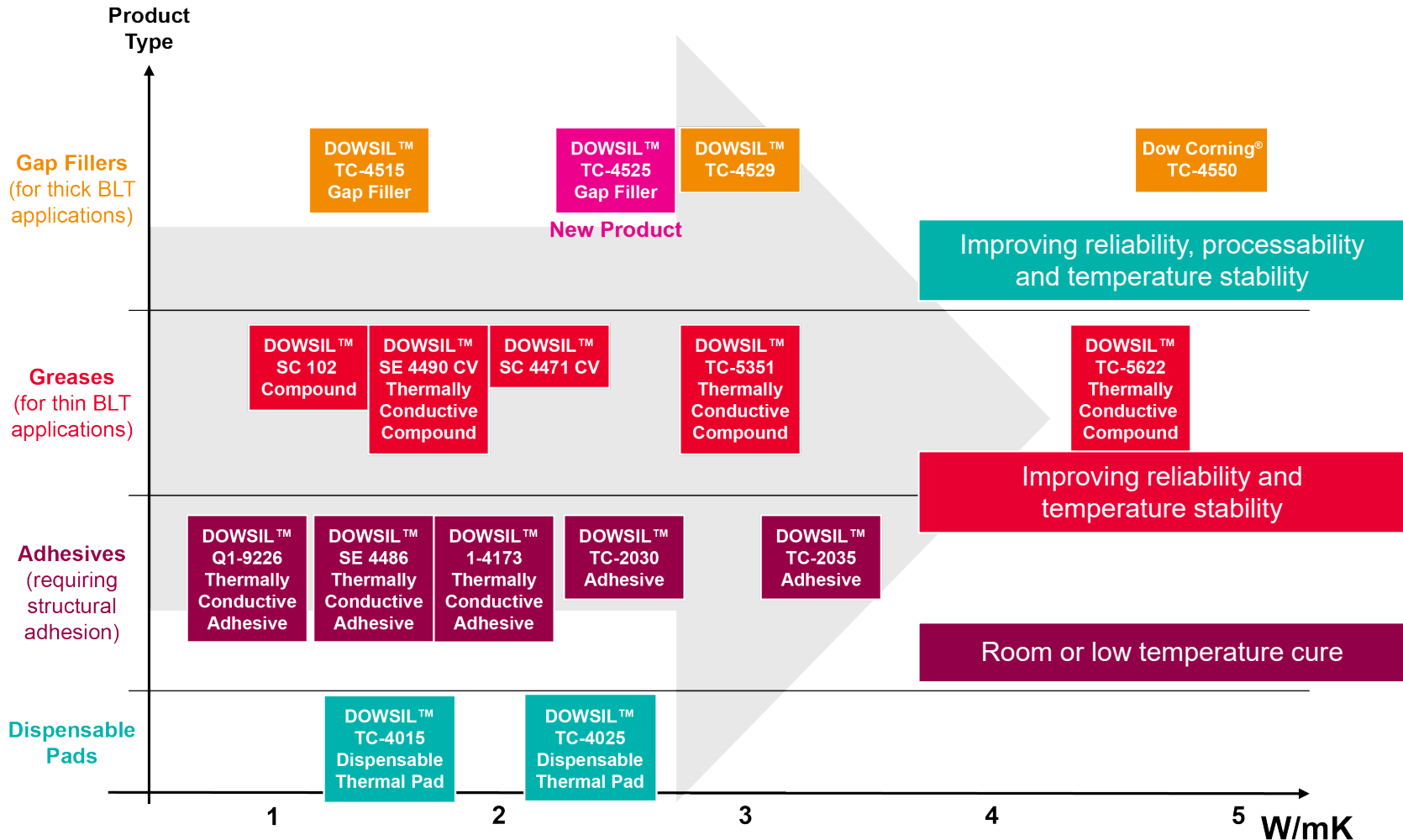


Main Trends, Drivers and Segments

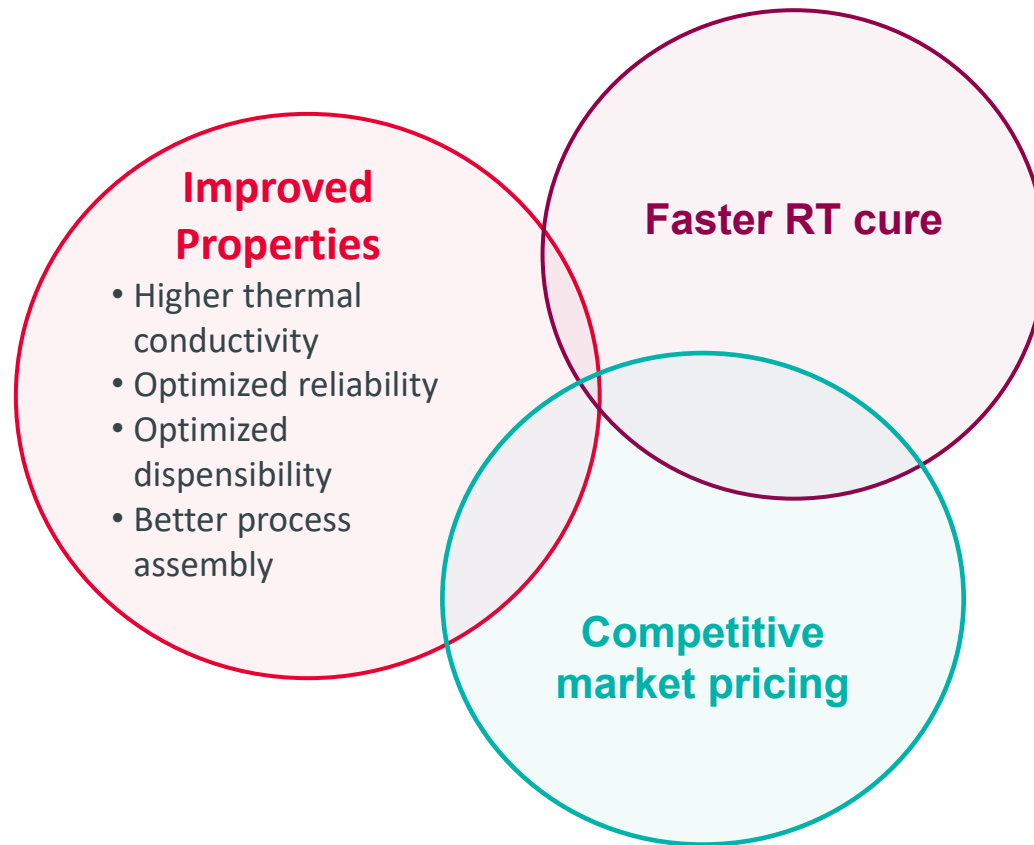
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Expanded Portfolio of Advanced Thermally Conductive Materials



Key Value Proposition of DOWSIL™ TC-4525 Gap Filler



DOWSIL™ TC-4525 Gap Filler proposes improved properties, reduced cure time (@ RT), at competitive market price; to increase customers' modules performance and lower total cost of ownership.

— Technical Part

■ To Read Cautiously...

- The product presented here is in the **early stages of commercialization** and therefore only **limited numbers of batches have been tested**. While we believe the following data is representative of how this product perform, **exact property values and cure times/temperatures may change somewhat as we gain further production experience and history**.
- The data reported is provided per the measurement methods and test conditions mentioned above. The data is representative only of the batches tested and should not be used to set specifications. Please test under your use conditions to confirm that the material performance satisfies your requirements. Specifications will be set after formulation is locked and successful production is achieved and will be represented as a range of values and not a specific number.
- Reliability: reliability and stability testing are in progress, if results are negative formulation changes to optimize the reliability could be made. This optimization could slightly alter other properties.

Thermal Conductive Interface Material

1. Thermal Conductive Adhesive

| Material | T°C (W/m.K) | Part | Cure Conditions |
|---|-------------|--------|-----------------|
| DOWSIL™ TC-2035 Adhesive | 3.3 | 2 Part | 30 min @ 125°C |
| DOWSIL™ TC-2030 Adhesive | 2.6 | 2 Part | 60 min @ 130°C |
| DOWSIL™ 1-4173 Thermally Conductive Adhesive | 1.9 | 1 Part | 20 min @ 150°C |
| DOWSIL™ SE 4486 Thermally Conductive Adhesive | 1.5 | 1 Part | RTV 48hrs @ RT* |
| DOWSIL™ Q1-9226 Thermally Conductive Adhesive | 0.7 | 2 Part | 30 min @ 150°C |

2. Thermal Conductive Grease

| Product | T°C (W/m.K) | TR @ 40 psi (C.cm ² /W) – ASTM D5470 |
|--|-------------|--|
| DOWSIL™ TC-5622 Thermally Conductive Compound | 4.3 | 0.06 |
| DOWSIL™ SE 4490 CV Thermally Conductive Compound | 1.9 | 0.77 |
| DOWSIL™ TC-5351 Thermally Conductive Compound | 2.9 | |
| DOWSIL™ SC 102 Compound | 0.9 | 0.6 |

*Cure time for moisture cure adhesives depends on many factors including, ambient temperature, material thickness and relative humidity of cure environment.

Thermal Conductive Interface Material

3. Thermal Conductive Dispensable Pad

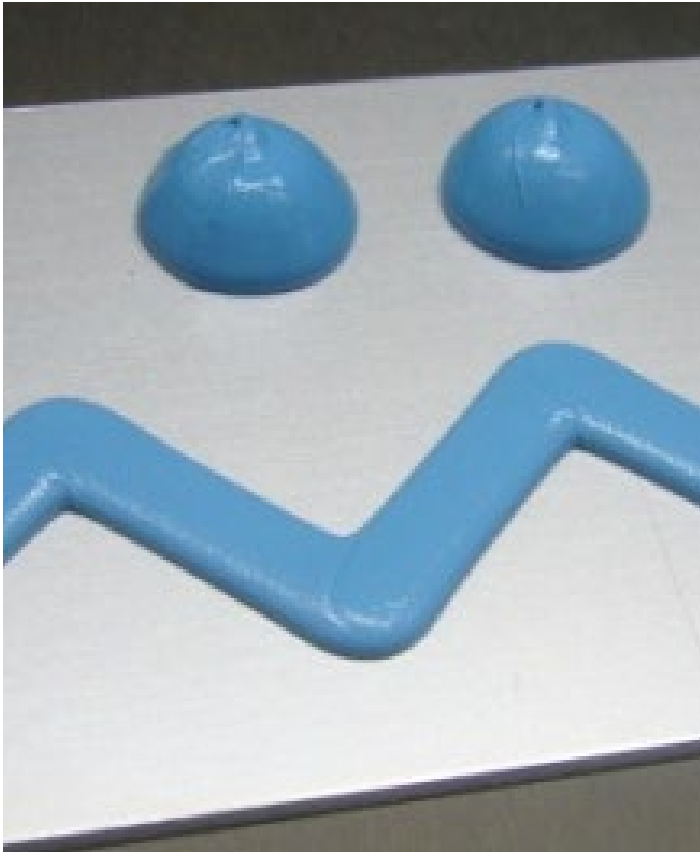
| Material | TC (W/m.K) | Part | Cure Conditions |
|---|------------|--------|-----------------------------|
| DOWSIL™ TC-4025 Dispensable Thermal Pad | 2.2 | 2 Part | 5h @ 25°C or 30 min @ 120°C |
| DOWSIL™ TC-4015 Dispensable Thermal Pad | 1.5 | 2 Part | 5h @ 25°C or 30 min @ 120°C |

4. Thermal Conductive Gap Filler – New!

| Material | TC (W/m.K) | Part | Cure Conditions | Commercial Status |
|----------------------------|------------|--------|-------------------------------|-----------------------------------|
| Dow Corning® TC-4550 | 5.0 | 2 Part | 2h @ 25°C or 10 min @ 80°C | Front End Development |
| DOWSIL™ TC-4525 Gap Filler | 2.5 | 2 Part | 2h @ 25°C or 10 min @ 80°C | Launch in Q1 2015 – Commercial |
| DOWSIL™ TC-4515 Gap Filler | 1.5 | 2 Part | 2h @ 25°C or 10 min @ 80°C | Development – Launch Q1 2016 |

Thermal Dispensable Pad vs. Gap Filler

Thermal Gap Filler

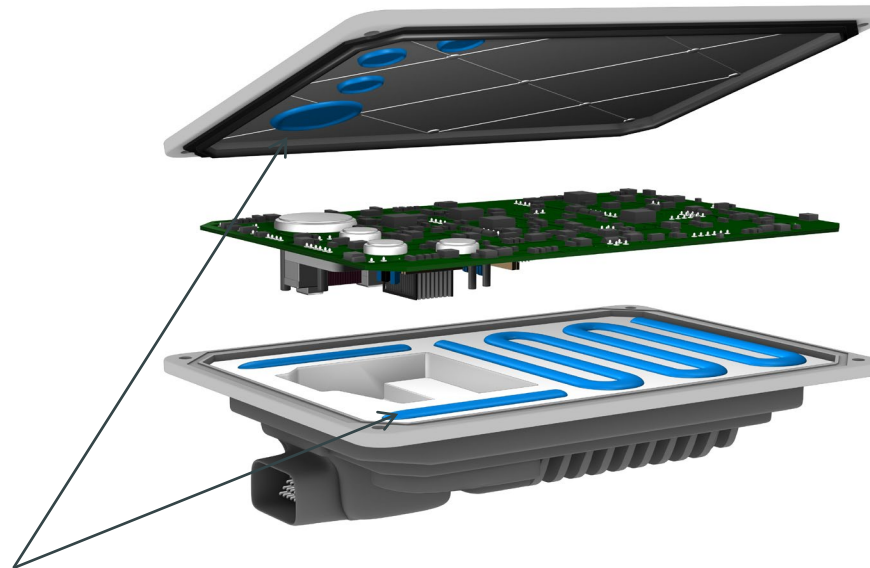


Thermal Dispensable Pad



Gap Filler Definition

- A soft and compressible material able to dissipate the heat from the heat source (typically Printed Circuit Board) to the cold source (typically aluminum housing acting as a heat sink)
- Typical thickness: above 150 μ up to 5 mm



Thermally Conductive Gap Filler

Figure 1: Engine Control Unit (ECU)

Examples of Possible Gap Filler Application in Automotive Electronics

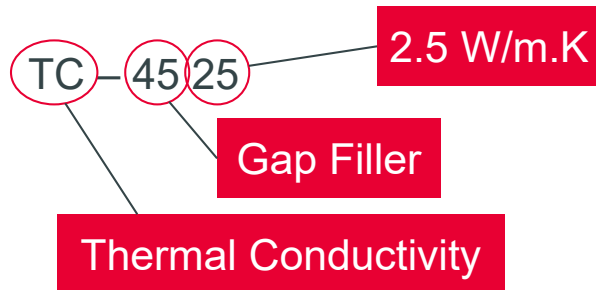
- Where? – Large assembly requiring heat dissipation
Few examples:
 - Engine Control Unit (ECU)
 - Anti-lock braking/electronic stability control (ABS/ESP) – safety system
 - DC/DC converter of HEV vehicle
 - ADAS (Advanced Driver Assistance Systems) – i.e. Distance control
 - High temperature sensors
 - Transmission Control Unit (TCU)
- Why? – Reliability of the module during service life
 - Heat transfer
 - Vibration dampening: A gap filler compressed between a PCB and housing can significantly reduce the risk of failure caused by mechanical vibration. In assemblies like under the hood modules in passenger cars, vibration can, over time, cause the failure of solder joints or wires bonding and thus operating failure of the module itself.

DOWSIL™ TC-4525 Gap Filler – Properties Outlook

- Thermal conductivity: 2.5 W/m.K
- 2 part low modulus (soft material)
- Working time at room temperature: 40 minutes
- Cure time at room temperature: 2 hours
- Cure time at 80°C: 10 minutes
- Mixing ratio (weight or volume): 1/1
- Storage at room temperature
- UL 94 V0 flame retardant



Nomenclature



| Properties | Unit | Measure |
|----------------------------------|-------------------|---------|
| Appearance (part-A) | - | White |
| Appearance (part-B) | - | Blue |
| Viscosity (part-A) | Pa · s | 207 |
| Viscosity (part-B) | Pa · s | 193 |
| Viscosity (mixed) | Pa · s | 217 |
| Density (cured) | g/cm ³ | 2.88 |
| Hardness (Shore 00) | - | 55 |
| Thermal Conductivity (transient) | W/mK | 2.6 |
| Dielectric Strength | kV/mm | 18 |

Improve Process Experience

An important criteria for Dow is to enhance customer material processing experience with a positive impact on the total cost of ownership. This is applicable to each new material development project initialization.

DOWSIL™ TC-4525 Gap Filler ✓

DOWSIL™ TC-4525 Gap Filler

2.5 w/m.K

2 Part

2 hours @ 25°C or
10 min @ 80°C

Process optimization

- Energy saving ✓
- Minimize substrates preparation ✓
- Reduce equipment maintenance ✓

Optimize product processing

- Storage ✓
- Shelf life ✓
- Dispensing ✓
- Assembly and cure ✓

Improve product robustness

- Bubble free
- Vertical holding ✓
- Cure
- Adhesion ✓

■ DOWSIL™ TC-4525 Gap Filler – Formulation

Optimization of thermal and processing properties thanks to a suitable selection of fillers adding to a proper filler treatment

- Achieve 2.5 W/m.K by a Tri-modal distribution of Alumina
- Enhance thermal management by reducing thermal interface resistance and lowering viscosity thanks to filler treatment
- Drastically reduce abrasiveness due to a precise selection of filler
- Control and fast cure thanks to the Pt catalyst supporting the hydrosilylation cure system

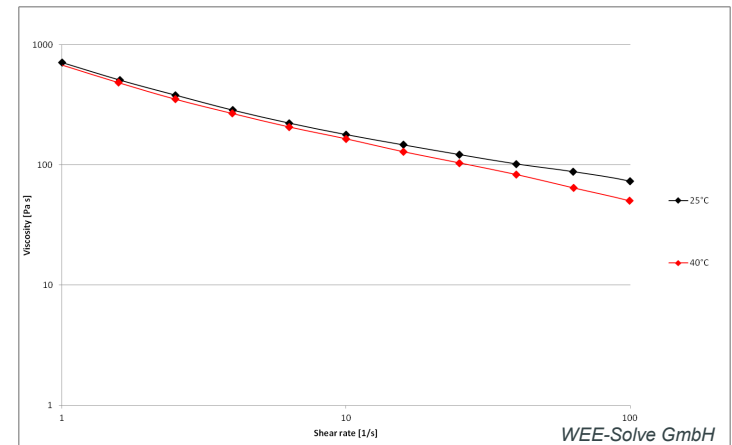


— Product Key Attributes

Rheology

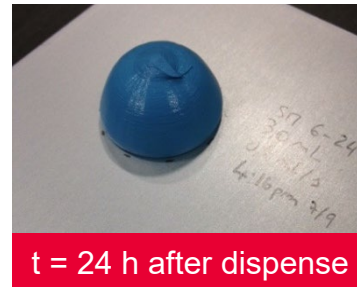
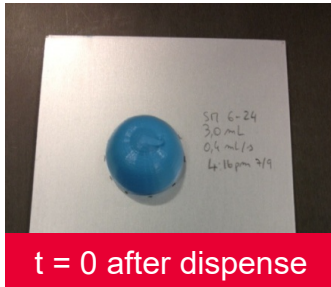
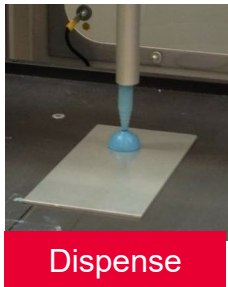
- The thixotropic nature of the material made it:
 - Easy to dispense by meter mix system with a high throughput
 - Easy to wet on the substrate
 - Does not flow once dispensed driving to a good accuracy of the pattern
- Thixotropic index ($1 \text{ s}^{-1}/10 \text{ s}^{-1}$ – Steady shear): 4.3
- The material is not flowing on the substrates after needle dispensing and this in an uncured state up to the cured stated

Flow curves of DOWSIL™ TC-4525 Gap Filler mixed at 25 and 40°C



Dynamic viscosity in function of shear rate.

*Note: at higher shear rates the gap is emptying.
The data is only reliable below 60 1/s.*



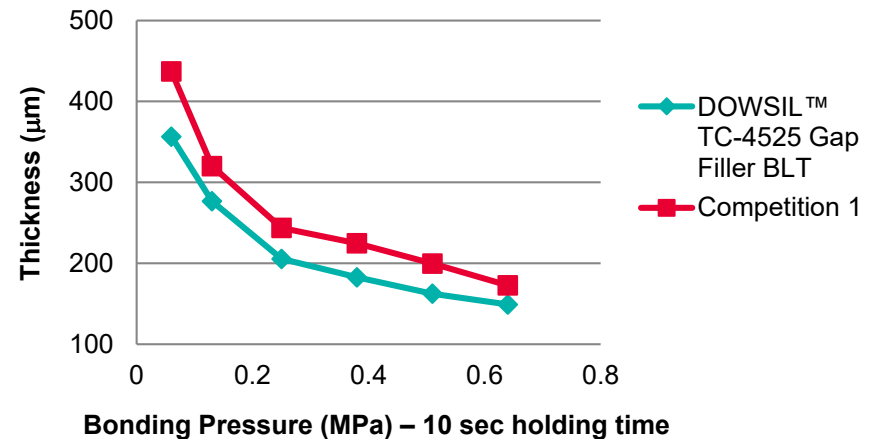
Test Method:

- Rotational measurements:
 - UDS Anton Paar, MP30
- PP 25 (25 mm plate),
 - Gap: 200 micron
 - T: 25 and 40°C

Excellent Material Spreadability at Low Pressure

- The lower pressure requested to spread the material and reach the targeted bondline thickness has a positive impact on module reliability
 - Minimize stress during assembly on the substrates
 - Improve module life time (reliability)
- Excellent spreadability at low assembly pressure
 - The reduced pressure used to spread the material freshly mixed minimizes the risk of the dies/PCB cracks
 - Improve the fatigue life of a PCB

BLT vs. Bonding Pressure



| | |
|-------------------------------|-------|
| BLT (10 s @ 0.13 MPa) | 277 µ |
| Minimum BLT (10 s @ 0.64 MPa) | 139 µ |

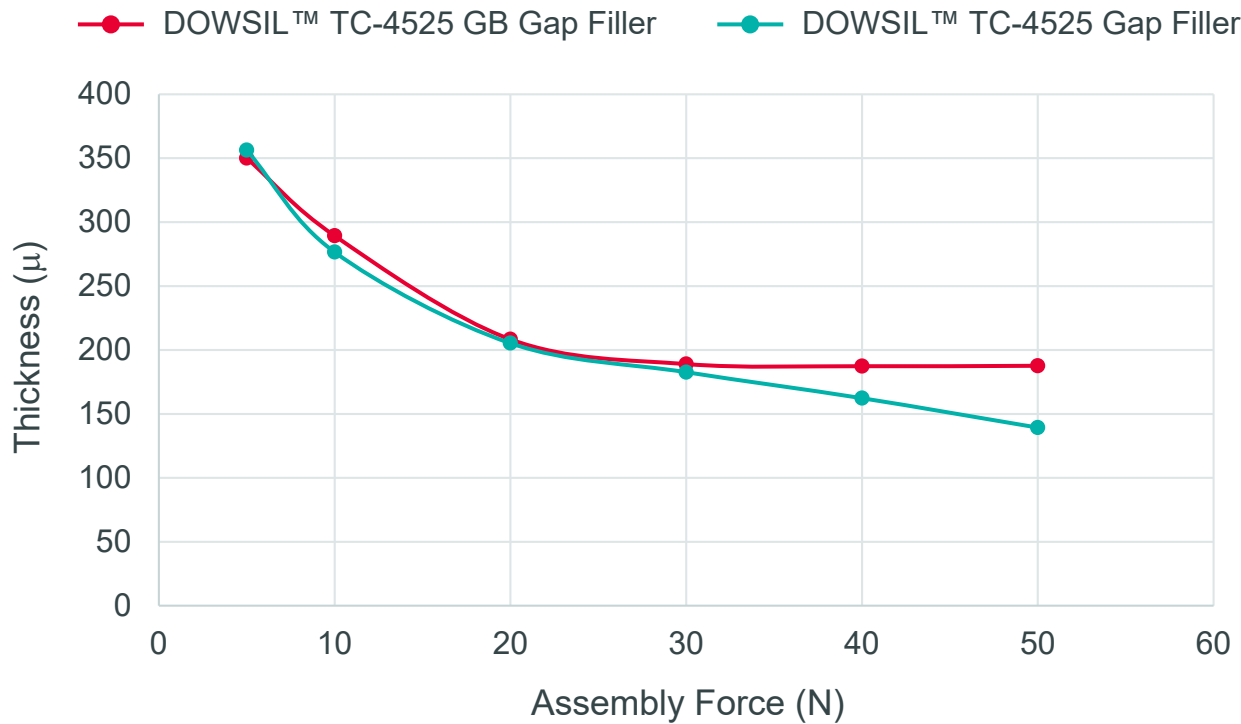
Simulate the pressure finger assembly

Test Method:

- Texture Analyzer
- BLT vs. Pressure
 - Pressure: 5 N to 20 N
 - 10 sec holding time
- Probe diameter: 1 cm

Control BLT Independently of Substrate Flatness

- Glass bead option: DOWSIL™ TC-4525 GB Gap Filler
- Particle size distribution in the range of 150 to 180 micron



BLT vs. Pressure (10 s holding time)

Fast Cure Rate

Rheology

Evolution of the complex viscosity with time at 25, 40 & 80 °C

Table 1: Complex viscosity plateau as function of temperature

| Time to reach a η Plateau | DOWSIL™ TC-4525 Gap Filler | Competition 1 |
|--------------------------------|----------------------------|-------------------------|
| 25°C | 100 min | < 120 min (not reached) |
| 40°C | 20 min | < 60 min (not reached) |
| 80°C | 2 min | 20 min |

At isothermal conditions DOWSIL™ TC-4525 Gap Filler has an evolution of the viscosity (and G') quicker than Competition 1. The complex viscosity rises with time and reached a plateau (Table 1).

Hardness

Cure profile

2 h @ 25°C
10 min @ 80°C

Shore 00

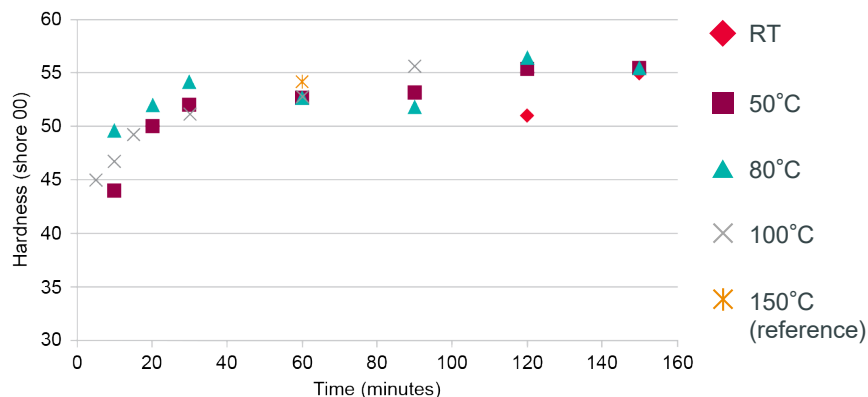
Room Temperature cure within 120 min, stability reached after 150 min

Heat accelerate

| Cure Schedule | Hardness (shore 00) |
|---------------|---------------------|
| 1 h @ 150°C | 55 |
| 2 h @ RT | 51 |



DOWSIL™ TC-4525 Gap Filler Cure Rate: Hardness Evolution at Different Temperatures

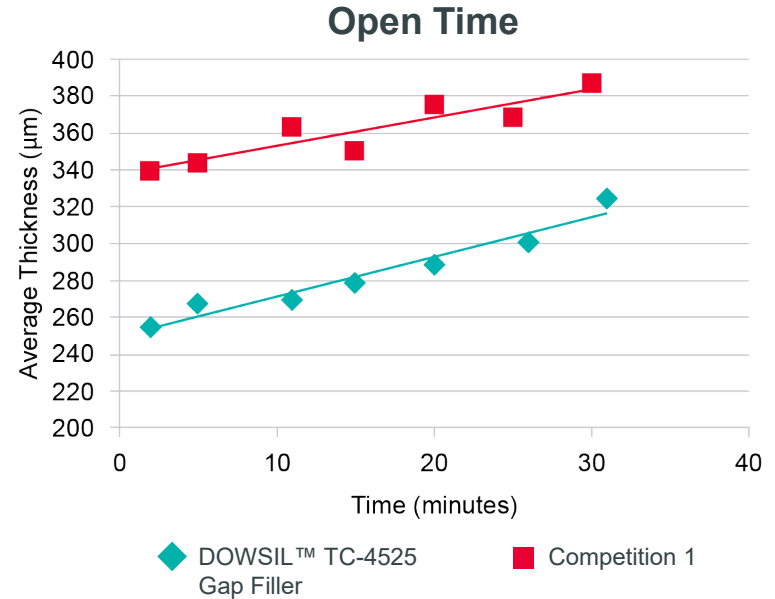
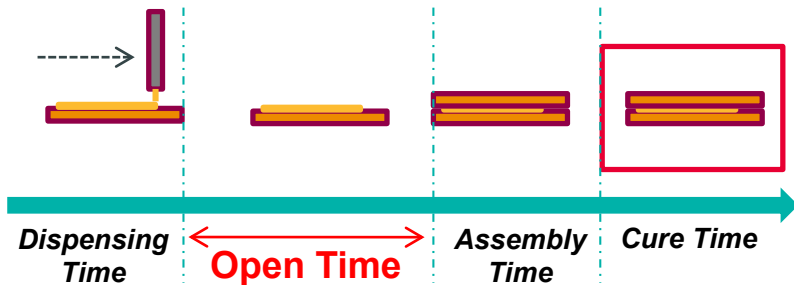


...While Managing Good Open Time

DOWSIL™ TC-4525 Gap Filler provides

- An open time of at least 10 min to reach original BLT
- Reduce risk of waste in case production flow trouble

Working Time at 25°C 40 min



Graph – Simulate the time elapsed between dispensing and assembly stations

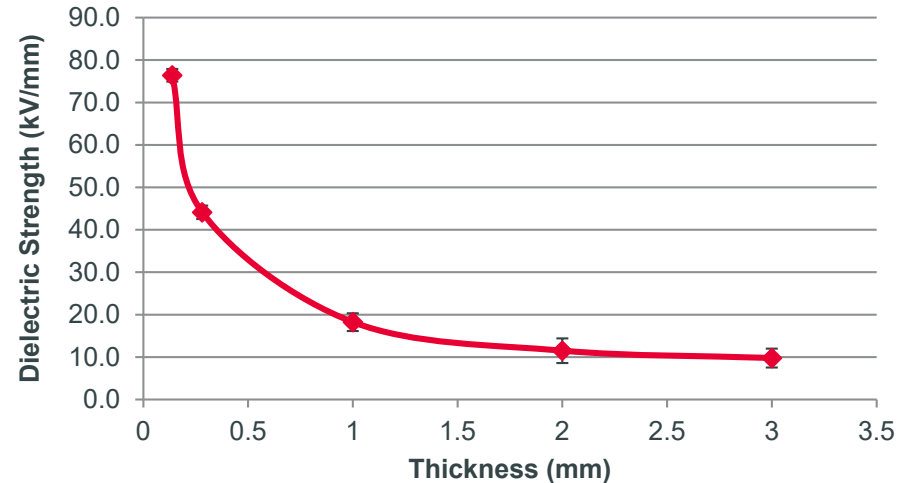
Test Method:

- Texture analyzer
- Open time:
 - Loading force: 10 N
 - 10 sec holding time
- Probe diameter: 1 cm

Dielectric Strength

- Gap Filler is designed for use at relatively thin bond-line thickness (BLT from 150 μ to 3 mm) therefore it is more accurate to present dielectric strength at the thickness it will be used in the application.
- Typically on data sheet the DS is reported at 2 mm thick (CTM), however the dielectric strength is not linear versus thickness. It is therefore interesting to report the DS value at the exact BLT it will be use for thin section.

Dielectric Strength vs. Thickness
DOWSIL™ TC-4525 Gel Filler Cure at RT

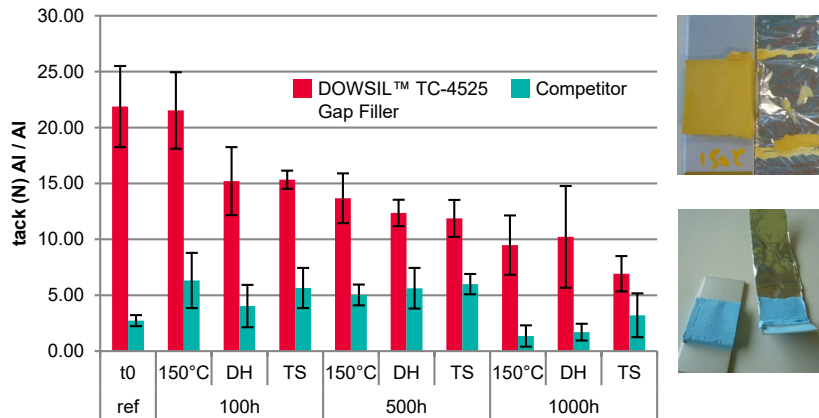
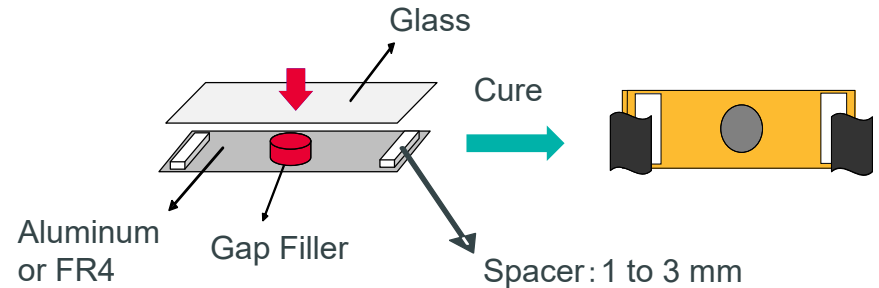


Method ASTM D 149

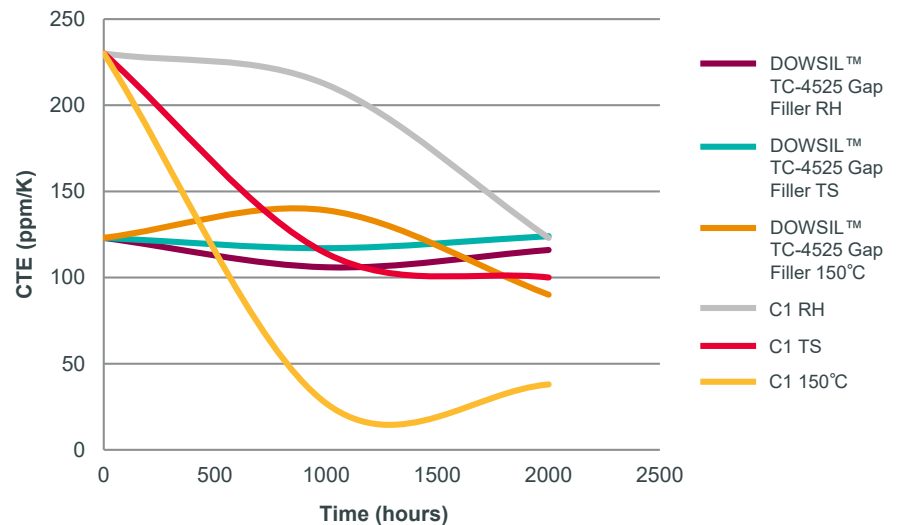
- Prepare sample at different thickness (3 mm; 2 mm; 1 mm; 150 μ m)
- Measure on the Hipotronics instrument (in fluid)

Aside the Ease of Processing, Performance In-service is Excellent...

- Hold Vertical position
 - Passing 2,000 h environmental aging up to 3 mm thick (TS, 175°C, 85%RH/85°C)
- Excellent mechanical and elastomeric stability during temperature cycling
- Maintain a good interface contact during module life to assure a stable thermal resistivity



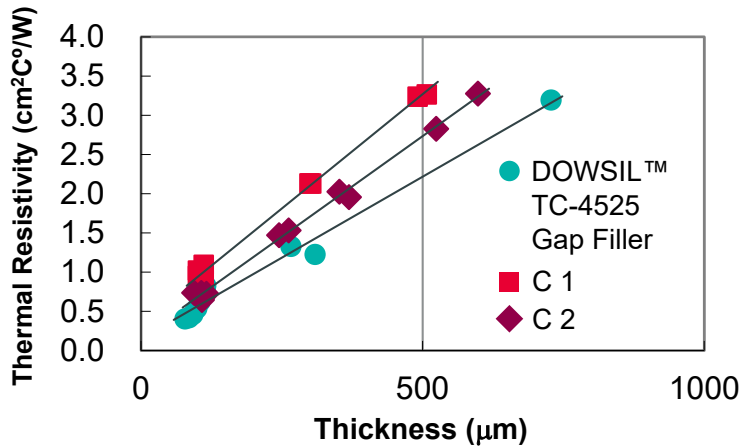
CTE versus Aging Time Test -50 to 150°C



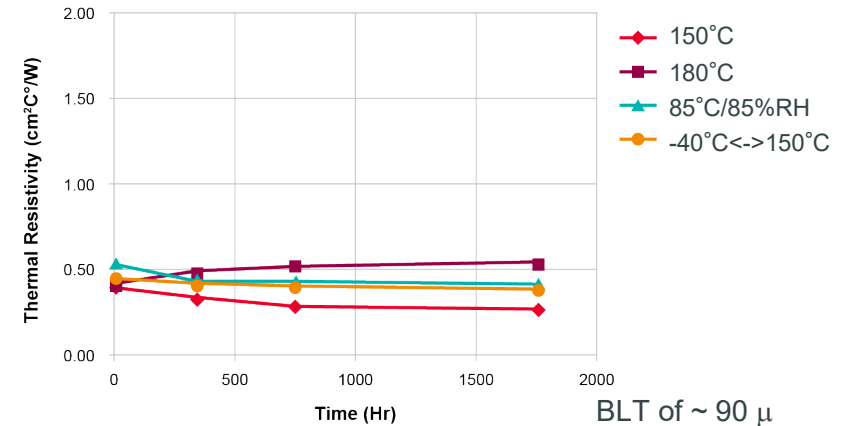
Thermal Resistivity

Based on ASTM D5470
Steady state method
Substrates: Si

Thermal Resistivity at Initial



Thermal Resistivity After Aging of DOWSIL™ TC-4525 Gap Filler A/B

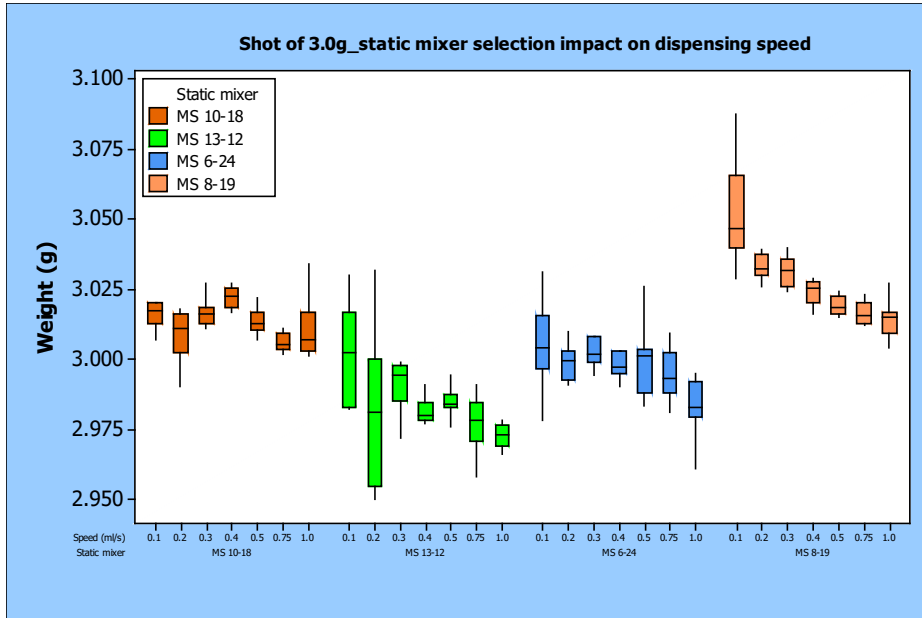


Good thermal stability behavior independently of the environmental aging tested.

| | DOWSIL™ TC-4525 Gap Filler | Competition 1 | Competition 2 |
|---|----------------------------|---------------|---------------|
| Minimum BLT @ 50N (mm) | 82 | 104 | 106 |
| Thermal Conductivity (W/m.K) – Measured | 2.75 | 1.71 | 1.95 |
| Thermal Conductivity (W/m.K) – Data Sheet | 2.60 | 1.80 | 2.00 |

— Product Processing at Equipment Vendors

Ideally Suited for Automated Dispensing Metered Mixing Equipment Tested by Scheugenpflug Equipment Vendor

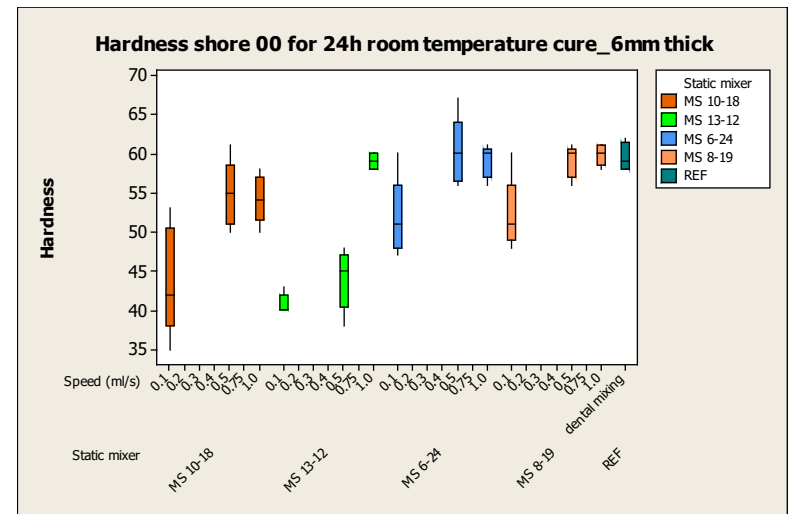


Various static mixers are evaluated in order to identify the best selection for an efficient dispensing speed, proper Cmk and suitable hardness of material.

Static mixer MS 6-24 is identified as providing the best trade-off between dispensing speed, accuracy and material performance.

Equipment Scheugenpflug A280: Material feeding for highly abrasive materials directly from the original delivery container.

| | |
|---------------------------|-----------------|
| Metering machine: | CNCELL |
| Metering head: | Dos P016 |
| Cylinder barrel diameter: | 8 mm |
| Maximum speed: | 1.0 ml/s |
| Piston sealing: | Turcon-Variseal |
| Material feeding: | A280 – 2°C |
| Vacuum: | Yes |
| Pressure: | 2.5 bar |



Ideally Suited for Automated Dispensing Metered Mixing Equipment Tested by Bdtronic Equipment Vendor

Result of the measurements with the different static mixers:

| Static mixer | Pressure cp.A | Pressure cp.B | Cm | Cmk | Dispensing rate |
|------------------------|---------------|---------------|--------|--------|-----------------|
| 12.7x12 | 3.1 | 2.7 | 0.79 | 0.789 | LDR |
| 12.7x12 | 8.3 | 8 | 3.685 | 3.684 | HDR |
| 12.7x18 | 11.6 | 11 | 5.967 | 5.963 | HDR |
| 10x18 | 6.4 | 6 | 0.842 | 0.839 | LDR |
| 10x18 | 18.3 | 18 | 4.788 | 4.786 | HDR |
| 12.7x18 (Multi String) | Not measured | Not measured | 0.766 | 0.762 | LDR |
| 12.7x18 (Multi String) | 11.9 | 10.4 | 10.084 | 10.077 | HDR |

The 12.7x18 show an adequate mixing of the components and the pressure over the static mixer is ok. Also the Cm and Cmk is good.

Furthermore, it can be seen that the Cm-/Cmk increases by using the Multi-string mixing head.

- Cmk describes exactly how a system maintains a preset value.
(Depending on what is the target to dispense)
- LDR: Low Dispensing Rate / High Dispensing Rate

- Static mixer MS 12.7-18 is identified as providing the best trade-off between dispensing speed, accuracy and material performance.
- It is possible to realize high dispensing rates (3,665 g/s, maximum tested).



Dispense dots with the high dispensing rate



Pile material up

Summary

DOWSIL™ TC-4525 2.5 W/m.K Gap Filler – 2 Part

Technology

- Platinum cure system for a fast controlled cure
- Silicone gel matrix for long term reliability
- Low modulus to prevent delamination during mechanical/thermal stress
- Treated Alumina filler to enhance thermal conductivity while managing stability of bulk properties

Features

- Excellent performance reliability showing stability during temperature cycling: Mechanical, Thermal, Hold Vertical Position
- Maintain a good interface contact during module life to assure a stable thermal management
- Fast room temperature cure while offering a workable assembly time
- Stability during temperature cycling

Design for a Smooth Assembly Process Line Integration

- Low filler settlement – reduce the need of homogenization
- Reduce abrasion of pump system due to a selected filler type
- Good dispensing ability validate at key equipment vendors
- Ability to hold vertical position when uncured to allow to flip the board during the assembly process (slump test)
- Excellent spreadability at low pressure, improves the fatigue life of a PCB

DOWSIL™ TC-4525 Thermally Conductive Gap Filler – Properties

| Properties | DOWSIL™ TC-4525 Gap Filler |
|--|---|
| Thermal conductivity (W/m.K) (Transient Method) | 2.6 |
| Cure profile | 2 h @ 25°C / 10 min @ 80°C |
| BLT (10 s @ 0.13 MPa) Minimum BLT (10 s @ 0.64 MPa) | 277 μ 139 μ |
| System | OK |
| Working Time at 25°C | 40 min |
| Viscosity (Pa.s) | 207 (A); 193 (B) |
| Density (g/cm ³) | 2.9 |
| Hardness (Shore 00) | 55 |
| Reliability Temperature storage: 150°C/3000 h, 175°C/500 h Thermal shock: -40°C to 150°C, 3000 cyc. Humidity = 85% RH at 85°C | 3000 h reached with good behavior records |
| Shelf life | 10 months @ 25°C |
| Ease of dispensing | Successful evaluation conducted at Bdtronic and Scheugenpflug equipment vendors |

For more information, please visit our website:

consumer.dow.com

You can also download the
DOWSIL™ TC-4525 Gap Filler sell sheet.



— Thank You

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