DOWSIL™ Thermal Gap Fillers for Battery Applications

Presented by Erica Everett & Ken Weidner

The Battery Show Webinar Series
September 2020

Presenters

Erica Everett

Marketing Manager, Transportation & E-Mobility

Erica has been with Dow for ten years, and is responsible for driving the business strategy and growth for silicones and hybrid technologies for electric vehicles and transportation electronics. Erica holds a bachelor's degree in Marketing and Business Management from Northwood University, and MBA from Wayne State University.

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Ken Weidner

Technical Service & Development Scientist, Transportation & E-Mobility

Ken is a technical service and development scientist supporting the adoption and use of silicone materials into automotive electronics. Ken has been involved with the development of materials for electronic applications for over 30 years, with an emphasis on protection and interconnectivity. Ken holds a Bachelor and Masters of Science in Electrical Engineering from Auburn University.

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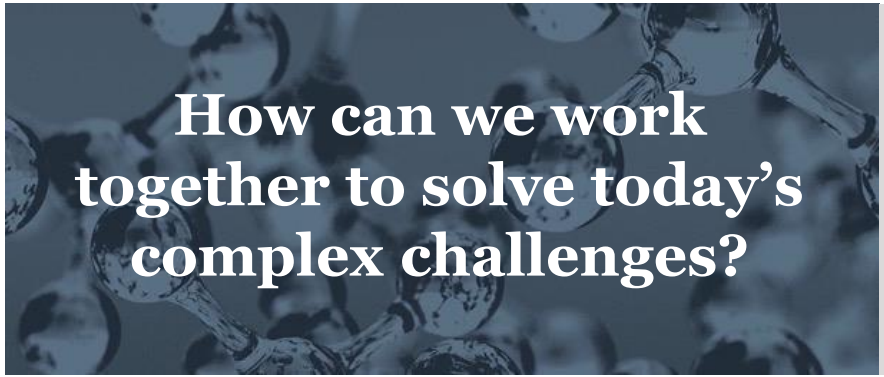
AGENDA

- ✓ *MobilityScience™ introduction*
- ❑ *Introduction to portfolio of thermally conductive silicones*
- ❑ *New DOWSIL™ TC-5515LT Low Density Thermal Conductive Gap Filler*
- ❑ *Question & Answer Session*

This Is Dow



It starts with passion and purpose. At Dow, our people use science and collaboration to create what matters most to our customers, society and the planet. Our ambition to be the world's most innovative, customer-centric, inclusive and sustainable materials science company drives best-in-class performance and a culture where new ideas thrive.

2019 NET SALES	EMPLOYEES	MANUFACTURING SITES	GLOBAL REACH
$43B	**~36,500**	**109 sites**	**31 countries** in which Dow manufactures products

Note: All data as of December 31, 2019

MobilityScience™

How we're driving change in the transportation industry together

DOW®

September 2020

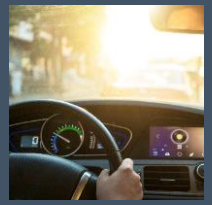
Seek Together

MobilityScience™

Definitions

Seek Together™

Mobility








- Construction & optimization
- Power
- Utilization
- Control

Science

- Silicones
- Polyolefin Elastomers
- Polyurethanes
- Acrylics
- Specialty chemicals

MobilityScience™

How can we collaborate?

Seek Together™

One Dow

Cross-business team providing easy access to the breadth and depth of Dow

Leading technology

World leading integrated material science portfolio

Customized development

Mobility specific innovation

Global reach

Reliable global supplier at scale

Expertise & support

Decades of industry experience and expertise

Sustainability

Holistic approach to material and vehicle life cycle

MobilityScience™

What trends can we explore as partners?

DOW®

Seek Together™

MobilityScience™

Our global transportation capability

Seek Together™

Building blocks

Advanced back-integration

- Acrylics
- Propylene oxide
- Ethylene oxide
- Polyolefin elastomers
- Silicones

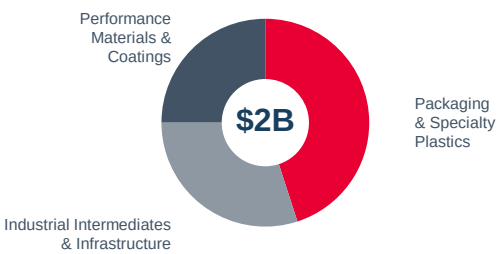
Capabilities

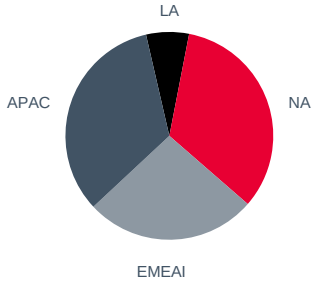
World-class science and engineering capabilities

- High-throughput research
- Catalyst discovery and ligand synthesis
- Polymer science
- Materials science
- Formulation expertise
- Process engineering
- High-performance computer modeling
- Application development
- Product safety

Scale

Global reach





BATTERY PACK ASSEMBLY

CLICK HOT SPOTS FOR DETAILS

Carbon or glass fiber reinforced polymer housing (CFRP or GFRP)
Lightweight, durable, fast-processing composite replaces conventional aluminium battery case.

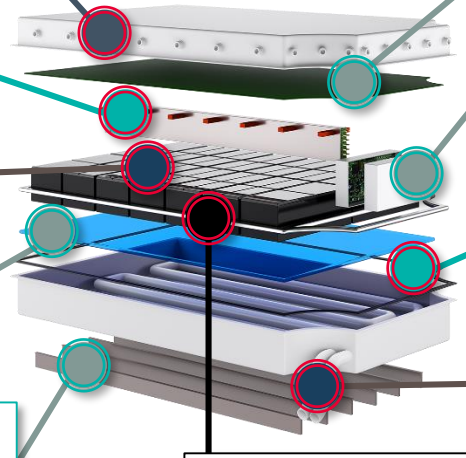
Encapsulants
Lightweight cable protection, dielectric encapsulation, and vibration absorption.

Dispersant & rheology modifier
For electrode material synthesis or ceramic coating on separator.

Thermally conductive gap filler
Polyurethane- or silicone-based filler replaces traditional thermal pad for effective heat dissipation.

Thermally conductive adhesives
Polyurethane- or silicone-based adhesives form excellent bonds with traditional aluminium (PU) or CFRP composite (Si) battery housings.

Thermal insulation foam
Polyurethane- or silicone-based foam for good, lightweight insulation performance; reduced internal/external temperature differential; good flame retardant properties.



Conformal coating
Thin polyurethane- or silicone-based film/membrane offers protection against moisture, dust, static, etc.

Foam gasket
Efficient sealing/EMI shielding with formed-in-place, cured-in-place, or dispensed foam gaskets.

Coolant fluid
Acrylate/polyethylene glycol (PEG) coolant for improved heat dissipation.

Cell cushion gasket
EPDM material offers space release and vibration dampening between cells.

- Silicone
- Polyurethane
- EPDM
- Acrylate/PEG
- Polymer composite

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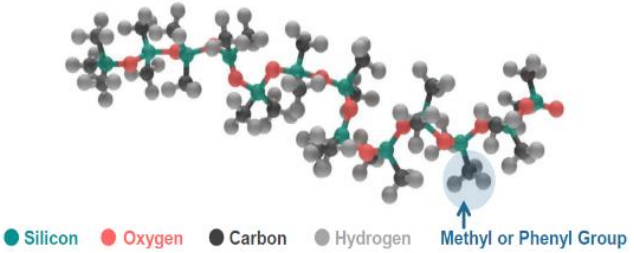
- ✓ *Introduction to portfolio of thermally conductive silicones*
- ❑ *New DOWSIL™ TC-5515LT Low Density Thermal Conductive Gap Filler*
- ❑ *Question & Answer Session*

Why Silicones for Thermally Conductive Applications ?

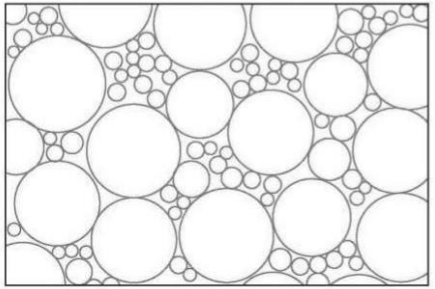
Typical features

- Low variability of properties with temperature and time
- Various curing chemistries available such as fast room-temperature reaction for easier part handling
- Excellent surface wetting ability
- Very high material purity



Silicone compounds loaded with thermally conductive fillers

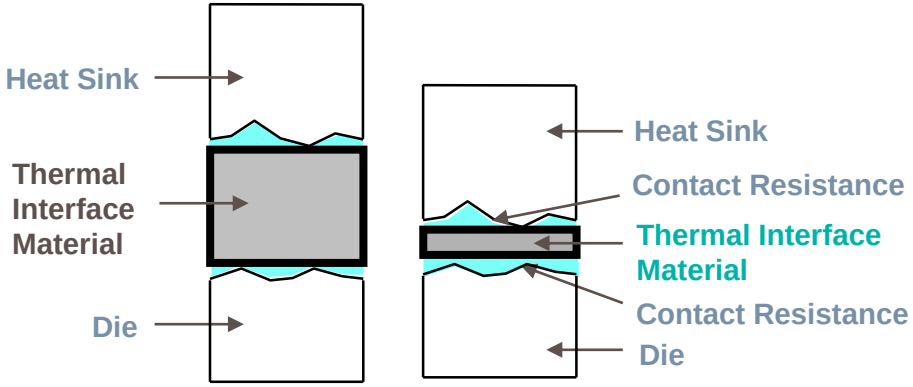
- Remain flexible even at very high filler content (> 80 vol.%)
- If desired, the material can still be made flowable
- Generally non-flammable (UL94 V-0)



Multimodal particle size distribution to achieve very high loading

Why Silicones for Thermally Conductive Applications ?

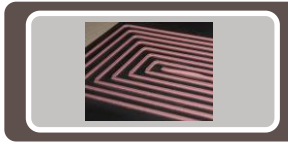
- **High thermal conductivity at lower viscosity**
  - Retains flowable viscosity at high filler content
- **Low energy surface**
  - Good wetting to minimize contact resistance
- **Electrical insulation**
- **Chemical stability**
- **Hydrophobicity**



Thick bondline: bulk properties are dominant

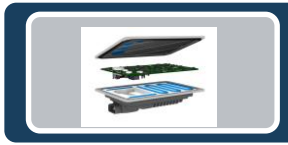
Thin bondline: wet ability and contact resistance are dominant

Range of thermally conductive materials



Adhesives

- Silicone adhesive with thermal conductivity
- Improved stability over time
- Can replace mechanical fixation
- Insulator or electrically conductive



Gap Fillers

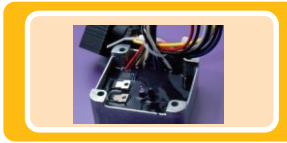
- Soft and compressible/stress relieving
- Ideal for applications with large gap tolerances
- Non-flowable
- Limited adhesion

Thermal Gels

- Alternative to thermal pads (performance/cost)
- Soft and compressible/stress relieving
- Flowable
- Limited adhesion

Thermal Compounds

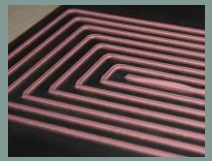
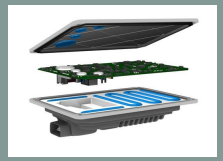
- Non-curing paste
- Low thermal resistance capabilities
- Limited stability
- Need mechanical fixation



Encapsulants

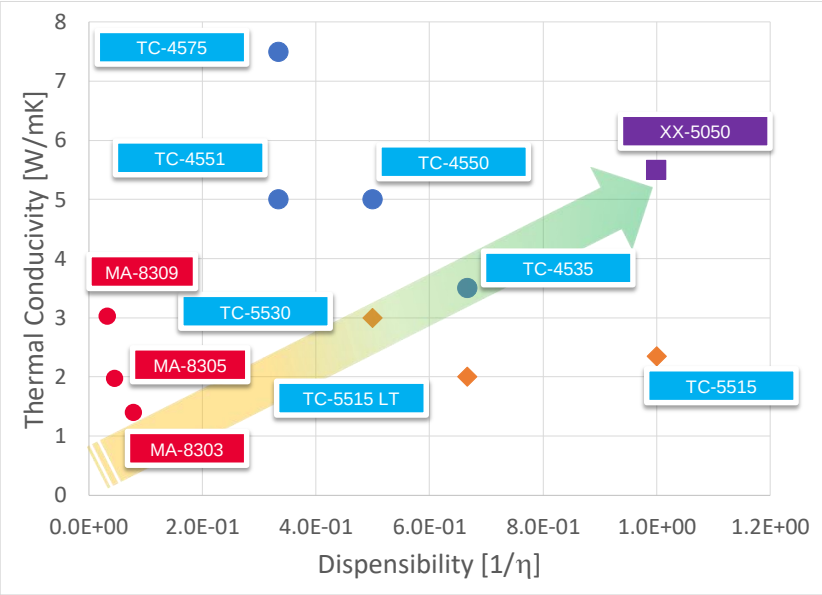
- Protection and heat dissipation
- Flowable
- Low modulus/stress relieving
- With or without adhesion

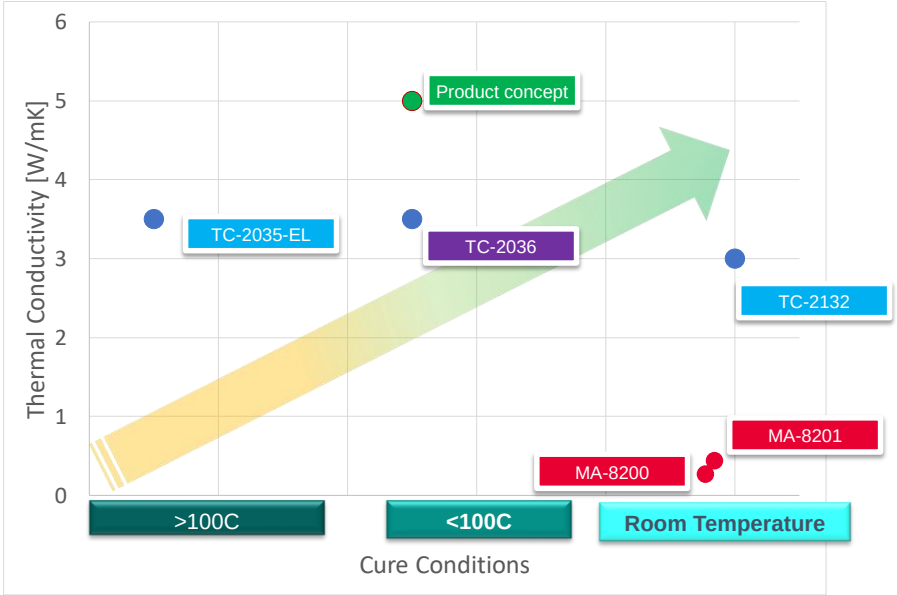
Commercial portfolio of thermal silicones at Dow – Summary

	Adhesives	Gap Fillers	Thermal Gels	Compounds	Encapsulants
					
Thermal conductivity	0.8 – 3.3 W/ m.K	1.5 – 5.0 W/m.K	1.5 – 2.5 W/m.K	0.9 – 5.2 W/m.K	0.3 – 2.7 W/m.K
Viscosity	Semi-flowable to non-flowable	Non-flowable	Semi-flowable	Semi-flowable to non-flowable	Flowable
Curing type	Addition / Condensation	Addition	Addition	Non-cure	Addition
Bond line thickness	40 µm – 150 µm	150 µm – 5 mm	150 µm – 5 mm	< 40 µm	from mm to cm
Primerless adhesion	Yes	No	No	No	Possible
Dispensing	Static mixer (2K) Needle (1K)	Static mixer (2K)	Screen printing (2K) Static mixer (2K)	Screen printing (1K) Squeegee (1K) Needle (1K)	Static mixer (2K)

Trends with Thermal Materials for Better EV Battery Packs

- Increased filler loading required for higher thermal conductivities





- Product development efforts with highly filled systems to
  - Improve dispensability rate and repeatability
  - Reduce cure temperature requirements

GAP FILLERS

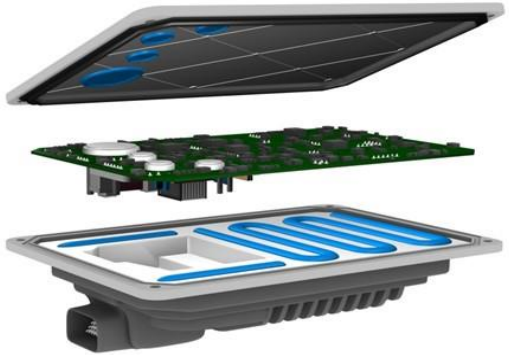
- **Soft and compressible to relieve stress**
- **Ideal for applications with large gap tolerances, typically from 150 µm to 5 mm**

Benefits

- Excellent mechanical ageing
- Maintain low stress interfacial contact
- Non-flowable for thicker bondline, highly thixotropic for fast processing
- Fast heat cure or room-temperature cure

Limitations

- Not for thin bondlines
- No chemical bonding, tack adhesion only
- Mixing: 2-part only



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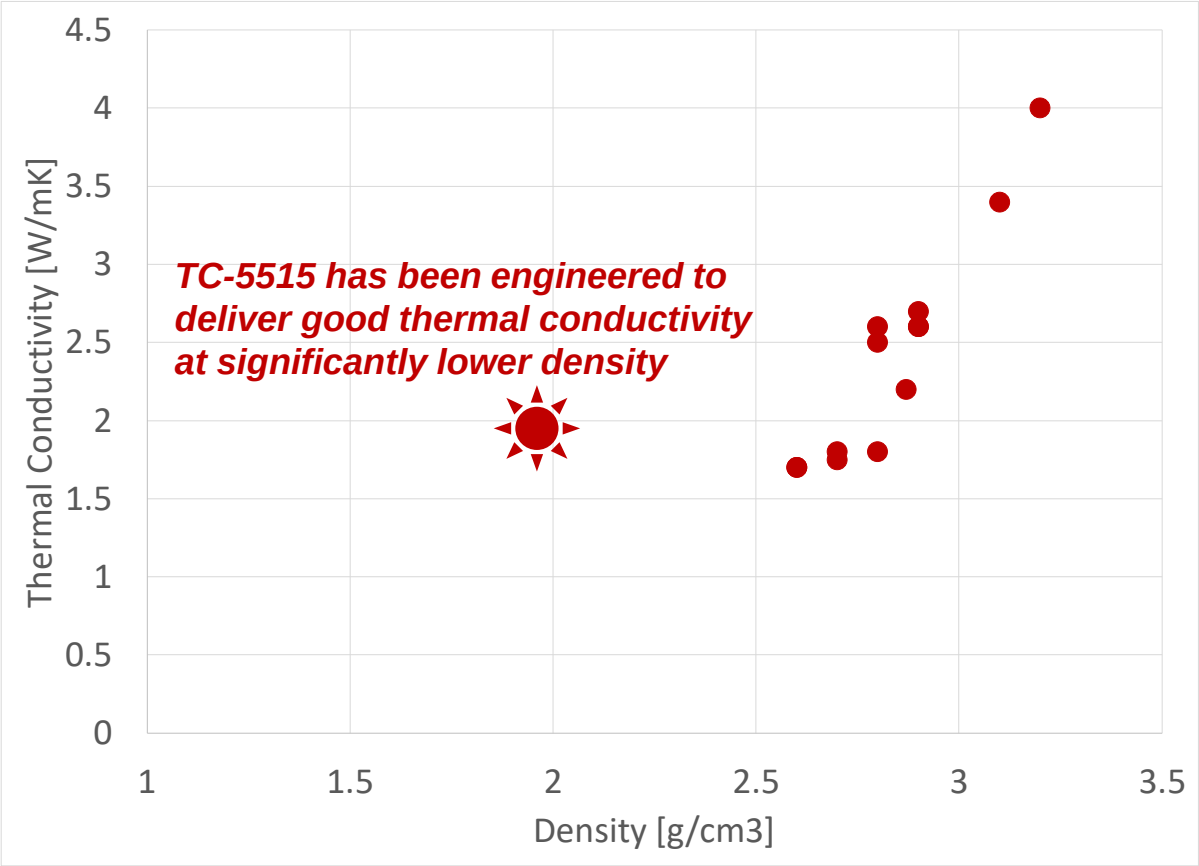
TC-5515 LT: Enabling Innovation in Gap Fillers and Thermal Gels

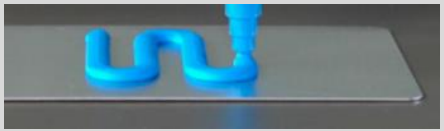


DOWSIL™ THERMAL GAP FILLER FAMILY

Material	Part	Thermal Conductivity* (W/m·K)	Specific Gravity** (cured)
DOWSIL™ TC-4535 CV	2 Part	3.5	3.1
DOWSIL™ TC-4525	2 Part	2.6	2.9
DOWSIL™ TC-5515 LT	**2 Part**	**2.0**	**1.95**

Thermal conductivity*: by hot disk, CTM 1163, ISO 22007-2
Specific gravity**: cured sample, CTM 0022, ASTM D792

- Dow Thermal Gap Filler Definition: A non-slump dispensable and curable system which resulting a soft and thermal conductive material able to dissipate the heat from the heat source to the cold source.
- Typical thickness: above 150μm up to 5mm.



DOWSIL™ TC-5515 LT KEY PROPERTIES OUTLOOK

DOWSIL™ TC-5515 LT is a 2.0 W/m·K, two parts, RT cure low density thermal conductive gap filler.

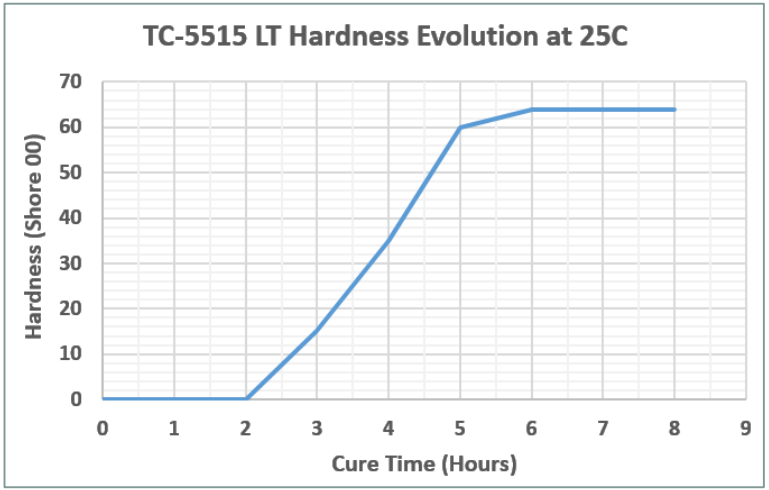
Key Property	Test Method*	Result
Mixed Viscosity	CTM 1094, ASTM D4287	140 Pas (10 S^{-1})
Specific Gravity (cured)	CTM 0022, ASTM D792	**1.95 g/cm^3**
Thermal Conductivity (Hot disk)	CTM 1163, ISO 22007-2	**2.0 W/m·K**
Thermal Conductivity (ASTM D5470)	CTM 0069, ASTM D5470	1.7 W/m·K
Working Time (by viscosity)	CTM 1094, ASTM D4287	90 mins
Cure time	CTM 0099, ASTM D 2240	6 h @25 °C, 30 mins @ 80 °C
Hardness	CTM 0099, ASTM D 2240	Shore 00 65
DMA Shear Modulus**	CTM 1098, ASTM D4065	0.27 MPa
Flame retardant	UL 94 V0	UL 94 V0 at 1mm

*CTM: Corporate Test Method.
*ASTM: American Society for Testing and Materials.
*ISO: International Organization for Standardization
*UL: Underwriters Laboratories
DMA Shear Modulus**: 25mm parallel plates with10 N press, 0.05 strain, 1 HZ frequency.

PDF
TC-5515 LT TDS

DOWSIL™ TC-5515 LT Curing

- Room temperature fast cure help to save energy and boost production efficiency.
- 5% off-ratio do not have obvious impact hardness, working time and curing time.



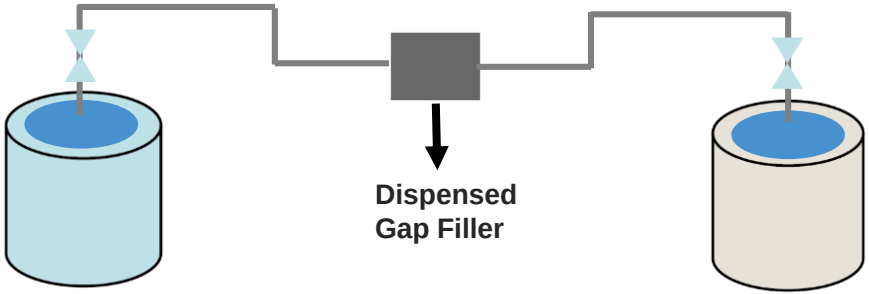
Cure time at 25 ºC: 6 hours (by hardness)

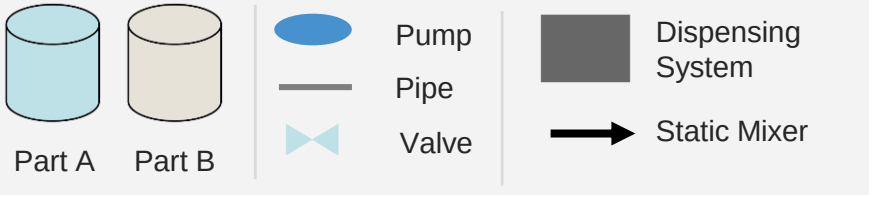
Cure time test method by Hardness: CTM 0099, ASTM D2240.

A : B	Hardness (Shore 00)	Working Time (Mins)	Curing Time at 25 ºC (mins)
95 : 100	68	95	400
100 : 100	65	90	360
105 : 100	62	85	340

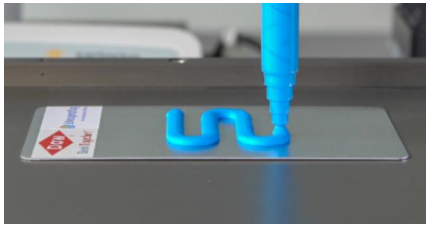
Hardness: CTM 0099, ASTM D2240.
Working time: mixed viscosity double time, CTM 1094, ASTM D2196
Curing time: test method by Hardness CTM 0099, ASTM D2240.

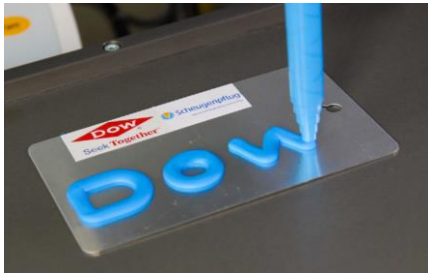
DOWSIL™ TC-5515 LT Dispensing Process



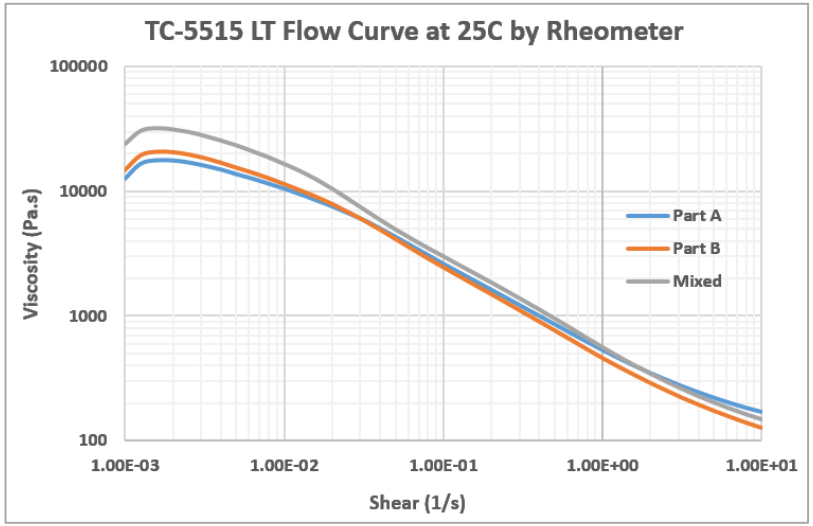


TC-5515 LT have low abrasion (low Mohs hardness filler) to dispensing valve, thus low equipment maintenance cost.
Other dispensing configurations are appropriate. Dow equipment partner and TS&D representatives can help you design the right process for your application.



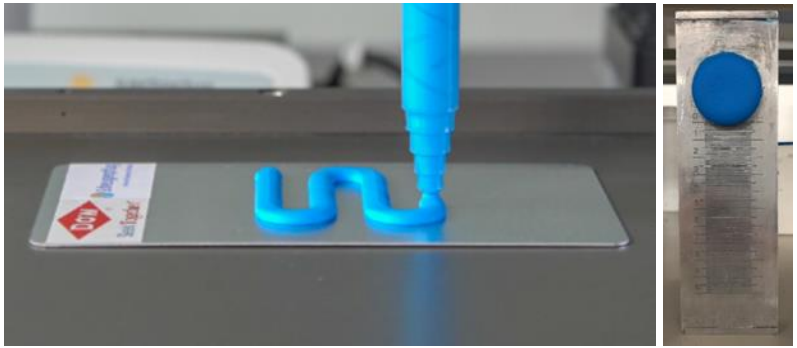


DOWSIL™ TC-5515 LT – RHEOLOGY



Thixotropic index (1 s^{-1}/10 s^{-1}): 3.5

Test Method:
TA ARES G2 Rheometer. 25mm parallel plates, 0.6mm gap. Flow sweep from 0.001s^{-1} to 10s^{-1}.

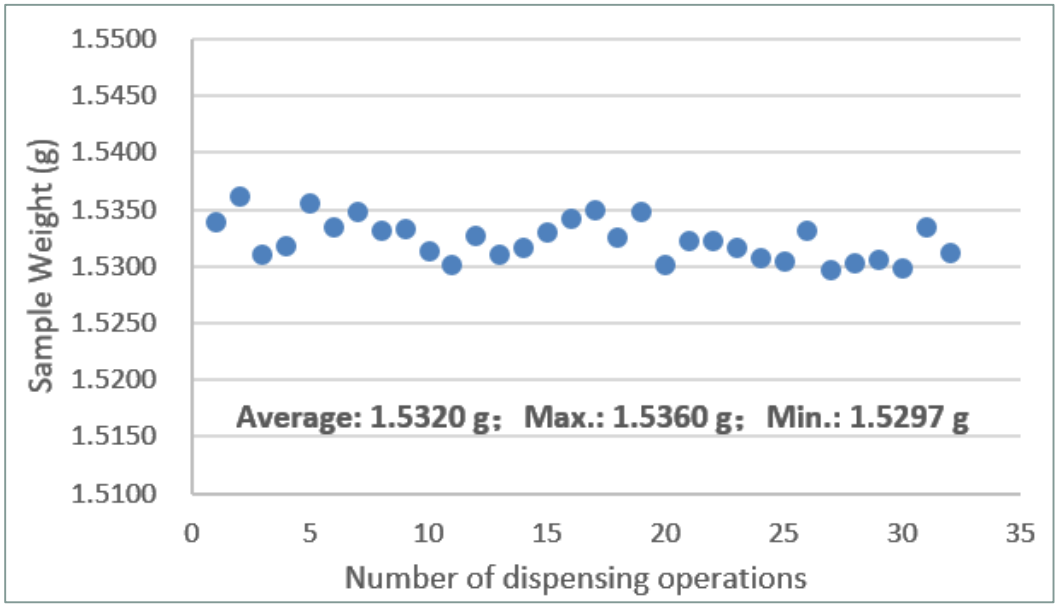


Thixotropic nature of the material allows:

- Easily dispense by meter mix system with a high throughput.
- Stay in place (no flow) once dispensed for a good accuracy of the pattern.
- Hold vertical position on the substrates in an uncured form up to completed cure.

DOWSIL™ TC-5515 LT Dispensing Performance

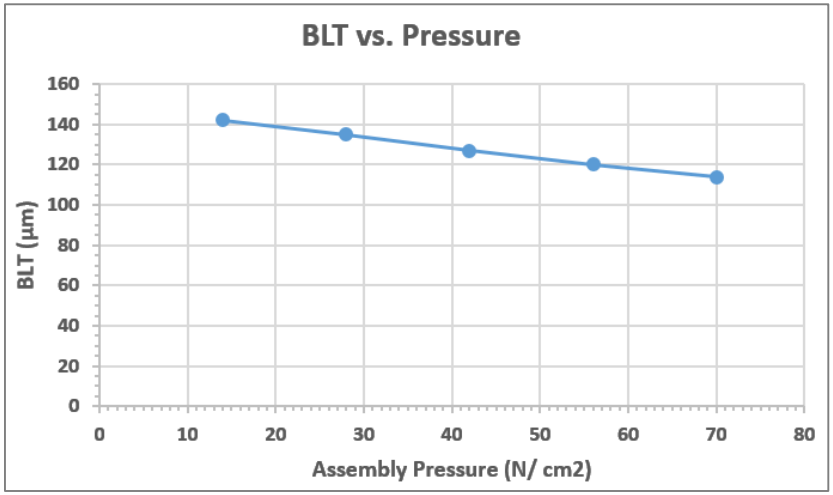
- TC-5515 LT is capable of accurate dispensing for automatic production.

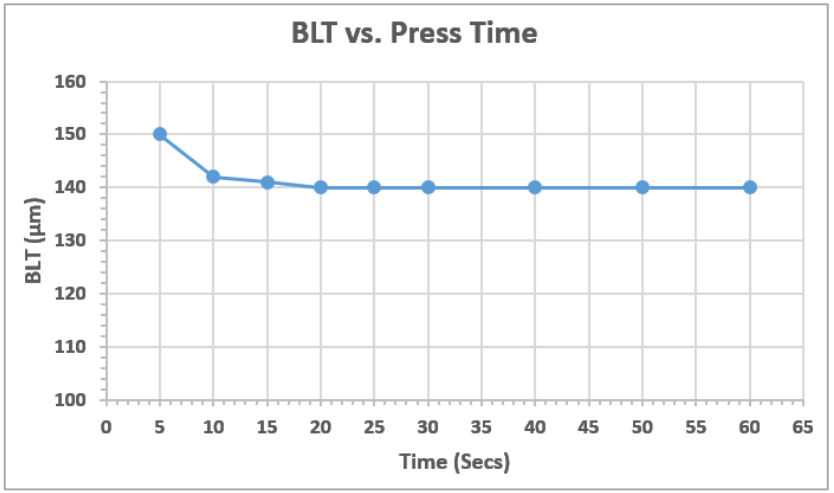


Scheugenpflug Piston Dispenser Dos P016 Ø16

- Min. Quantity per Shot: 1.56g (±2.5%)
- Max. Quantity per Shot: 27.44 (±1%)
- Max Metering Rate: 1.2 ml/s
- Mixing tube: Ø12 mm, 19 coils
- Accuracy: ± 0.04g
- Cpk: 2.12 (LSL 1.521, USL 1.638)

DOWSIL™ TC-5515 LT Bond Line Thickness (BLT)





Test Method:

- Texture Analyzer
- Temperature 25 ^{o}C
- Holding time: 10 secs

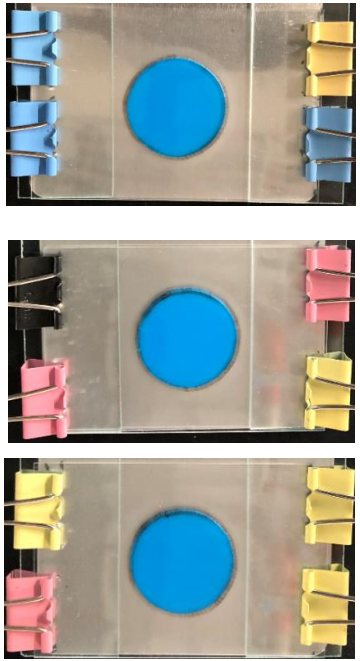
Test Method:

- Texture Analyzer
- Temperature 25 ^{o}C
- Pressure: 14 N/ cm^{2}

DOWSIL™ TC-5515 LT – VERTICAL HOLDING

- TC-5515 LT hold vertical position during aging on mounted surface.

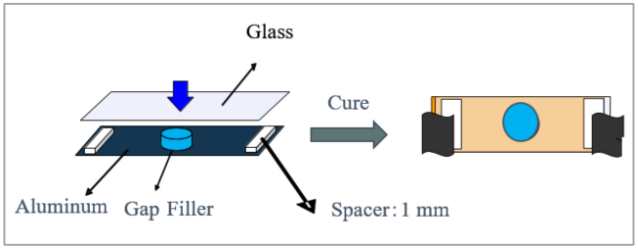
Thermal Shock (-40 to125 °C) 3000h



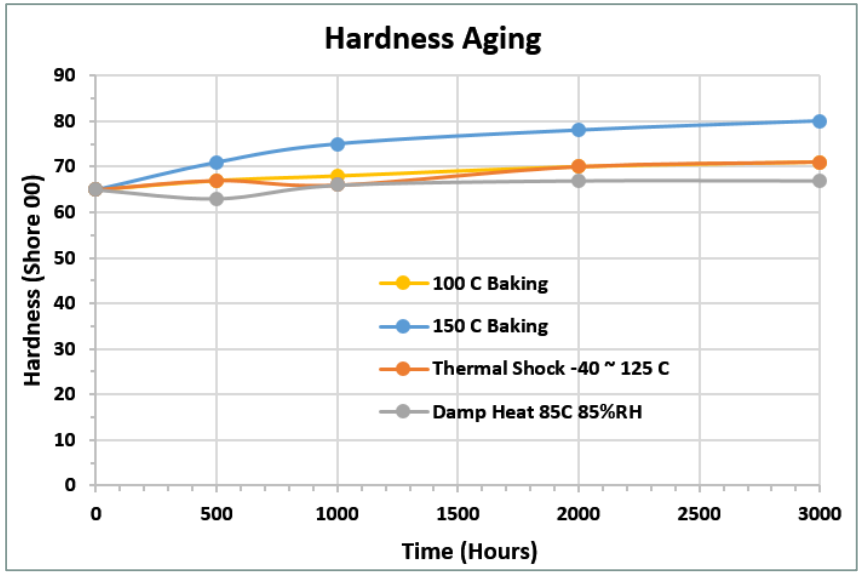
Condition	Observation (3000h)
150 °C baking	No drop
85 °C 85% RH	No drop
-40 ~125 °C thermal shock	No drop

Test Method:

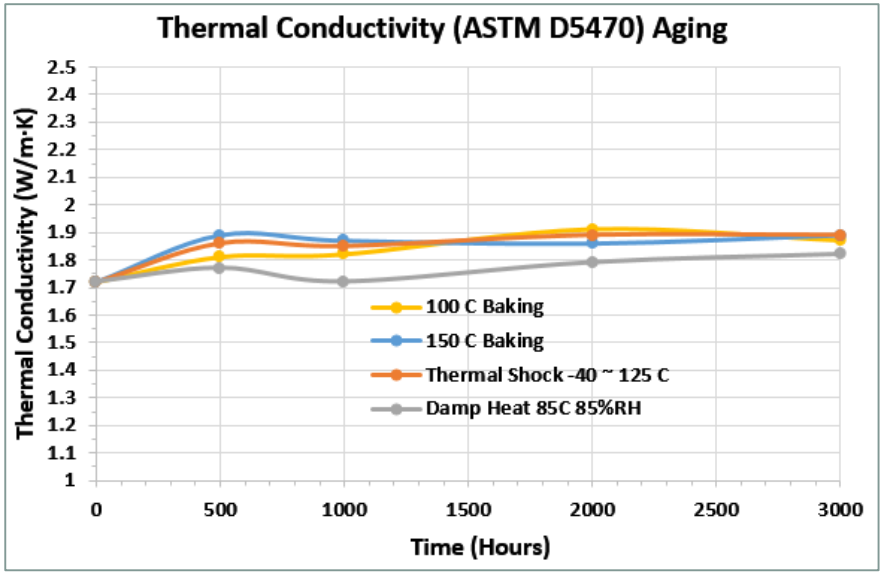
- Gap 1mm between AL and Glass
- 25 °C cure 24h → Vertical aging
- Aging condition: 150 °C baking, 85 °C 85%RH, -40°C /30min to 125°C /30min thermal shock.



DOWSIL™ TC-5515 LT – AGING PERFORMANCE

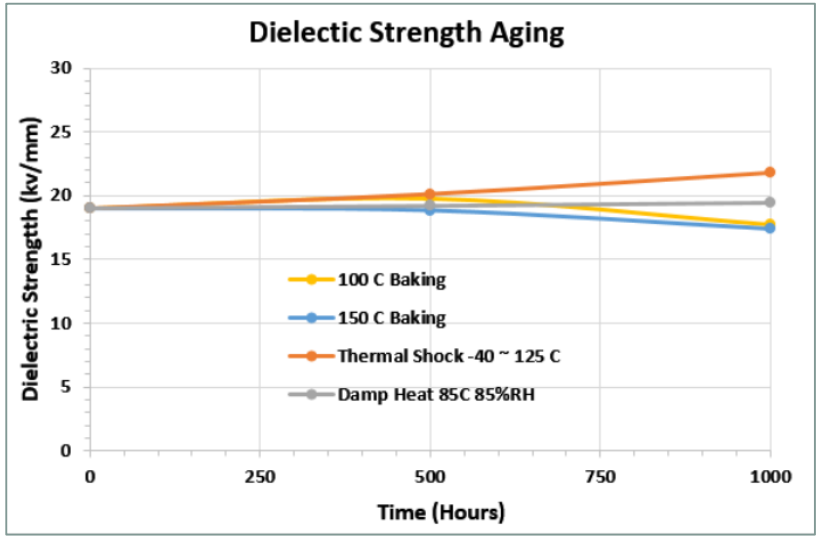


Cured at 25 °C for 24 h.
Hardness: CTM 0099, ASTM D2240
Thermal shock: -40 °C /30min to 125 °C /30min

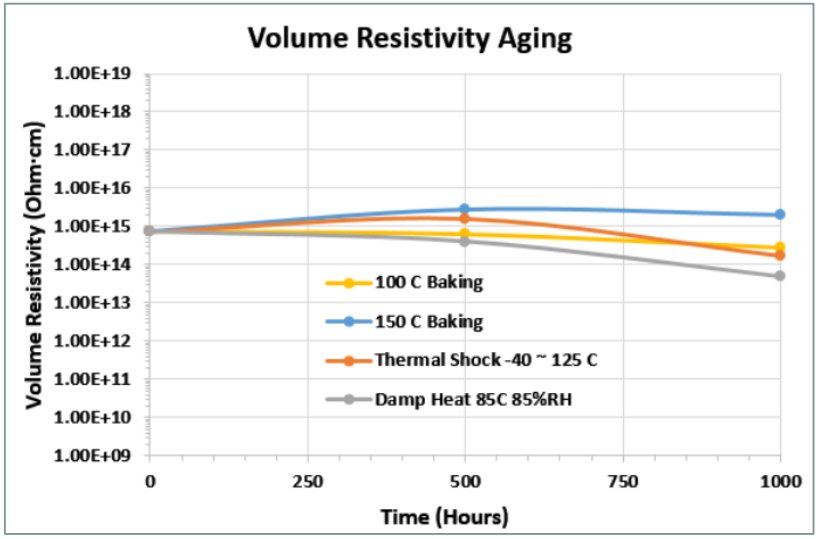


Cured at 25 °C for 24 h.
Thermal Conductivity: CTM 0069, ASTM D5470
Thermal shock: -40 °C /30min to 125 °C /30min

DOWSIL™ TC-5515 LT– ELECTRICAL AGING PERFORMANCE

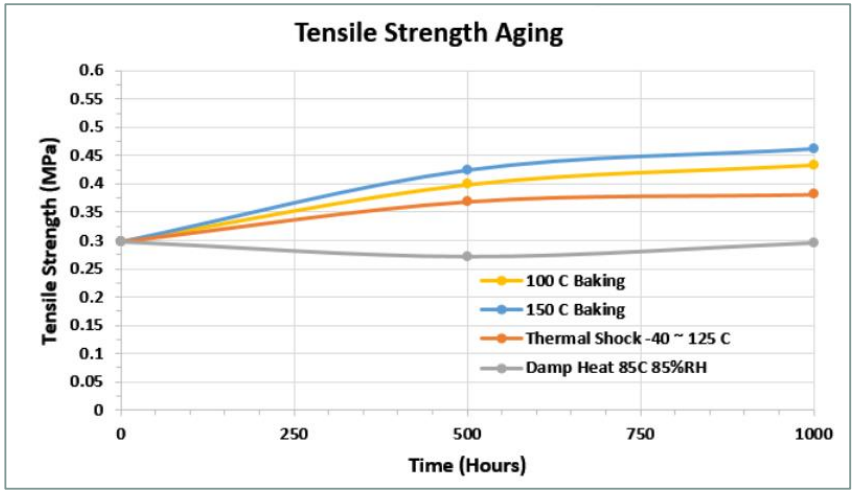


Cured at 25 °C for 24 h.
Dielectric Strength: CTM 0114, ASTM D149
Thermal shock: -40 °C /30min to 125 °C /30min

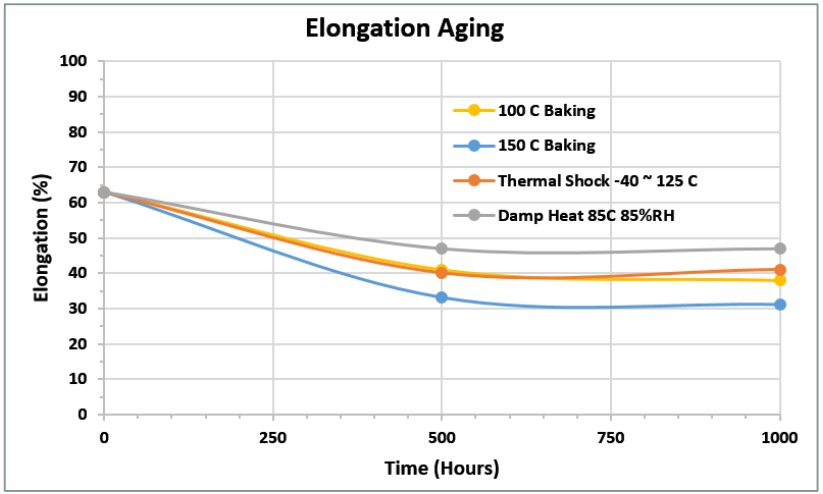


Cured at 25 °C for 24 h.
Volume Resistivity: CTM 0249, ASTM D257
Thermal shock: -40 °C /30min to 125 °C /30min

DOWSIL™ TC-5515 LT– MECHANICAL AGING PERFORMANCE

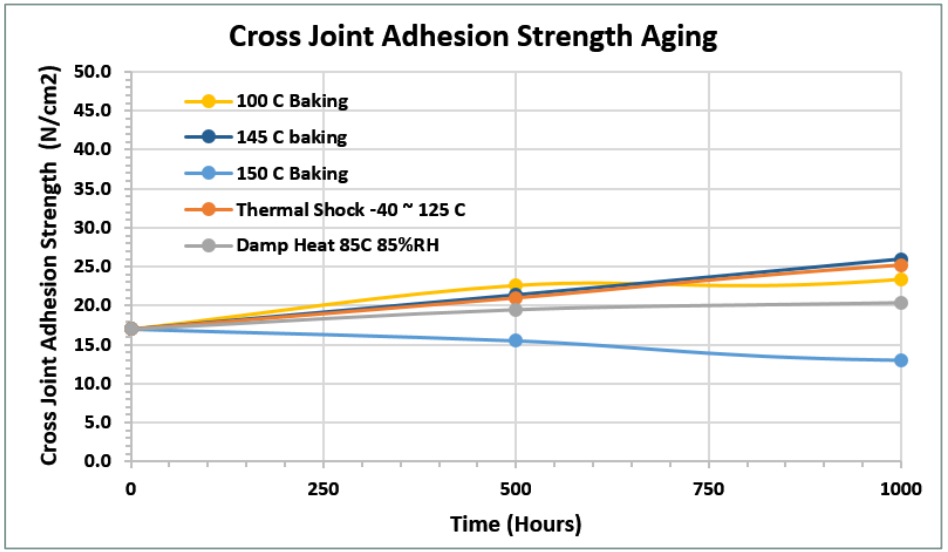


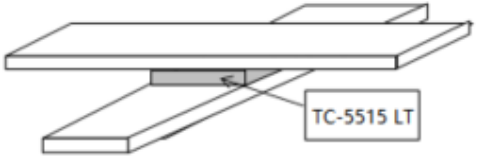
Cured at 25 °C for 24 h.
Tensile Strength: CTM 0137, ASTM D412
Thermal shock: -40 °C /30min to 125 °C /30min



Cured at 25 °C for 24 h.
Elongation: CTM 0137, ASTM D412
Thermal shock: -40 °C /30min to 125 °C /30min

DOWSIL™ TC-5515 LT – Interfacial Contact Aging Performance

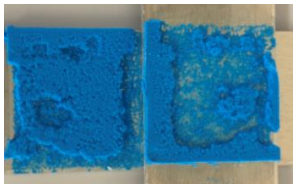




Test Method: Cross Joint Adhesion

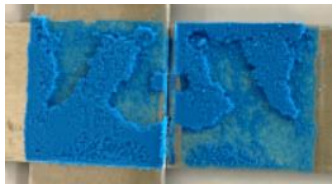
- Substrate: Al.
- TC-5515 LT thickness: 1.0 mm
- Cure Condition: 25 °C for 24h
- Aging condition: 100/ 145/ 150 °C baking, -40 °C /30min to 125 °C /30min thermal shock, 85 °C 85%RH.

Failure mode: 100% CF for all samples



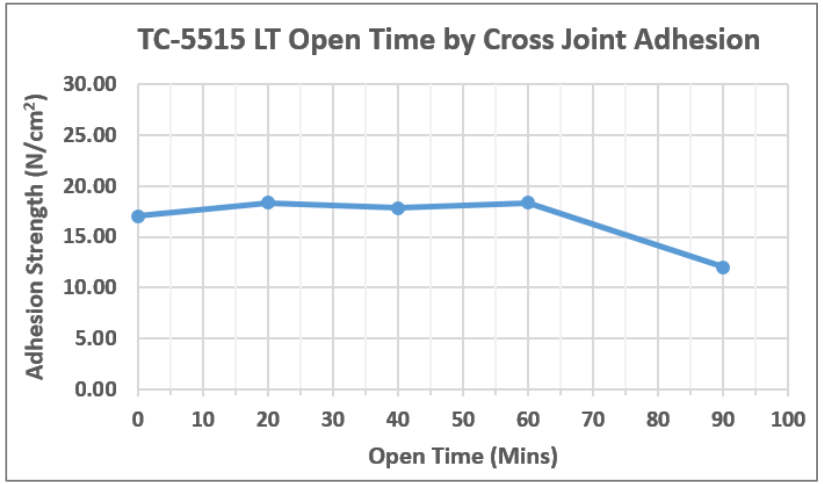
Initial

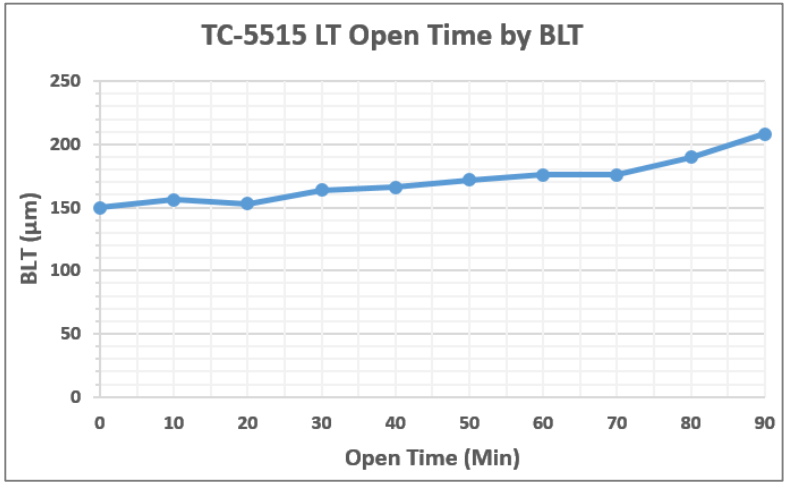
Thermal Shock
1000 h



DOWSIL™ TC-5515 LT Open Time For Assembly

- Suggest open time within 60 mins to achieve best interface contact strength.





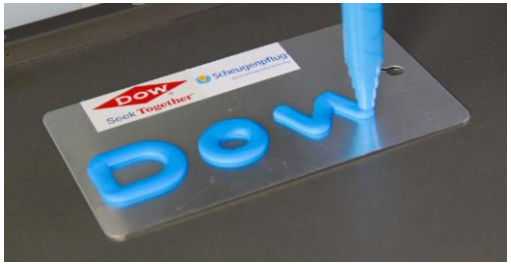
Test Method: Cross Joint Adhesion
- Substrate: Al
- Cure Condition: 25 °C for 24h

Test Method: BLT
- Texture Analyzer, 5 N/ cm² pressure
- Temperature 25 °C
- Holding time: 10 secs

DOWSIL™ TC-5515 LT SUMMARY

- DOWSIL™ TC-5515 LT is a two part, 2.0 W/m·K thermal conductive gap filler
- Target application is EV battery pack heat dissipation
- Key benefits are light weight and reliable performance for automotive
- Capable of accurate dispensing for automatic production

Low density gap filler with reliable thermal conductivity and performance for light weight EV battery pack assembly



AGENDA

- ❑ *MobilityScience™ introduction*
- ❑ *Introduction to portfolio of thermally conductive silicones*
- ❑ *New DOWSIL™ TC-5515LT Low Density Thermal Conductive Gap Filler*
- ✓ *Question & Answer Session*

Let's Collaborate!

MobilityScience™

Partnering with us can give you access to:

- A world-leading R&D organization and deep chemistry toolbox to develop innovative solutions
- Materials that enable cost-effective management of next-generation EV/HEV battery design challenges
- Global reach, with relationships across value chains to provide:
  - Excellent technical expertise
  - A strong regional manufacturing footprint
  - Local support and sourcing

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Seek

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THANK YOU

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