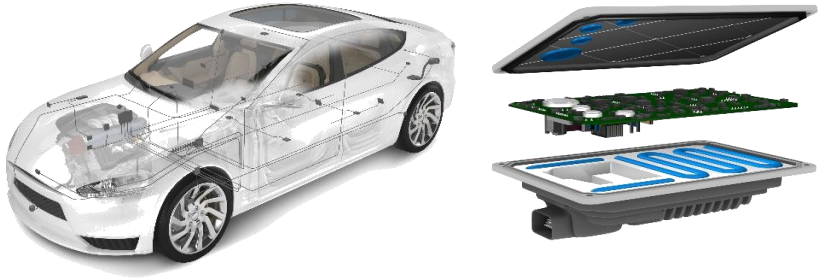
Silicone adhesives for lifetime performance in vehicle electrification and autonomy

DOWSIL™ Mobility and Transportation Electronic Adhesives

Seek Together™



MobilityScience™

How we're driving change in the transportation industry together

DOW®

October 2020

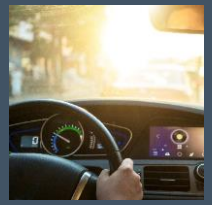
SeekTogether®

MobilityScience™

Definitions

Seek Together™

Mobility








- Construction & optimization
- Power
- Utilization
- Control

Science

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

MobilityScience™

Our global transportation capability

Seek Together™

Building blocks

Advanced back-integration

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

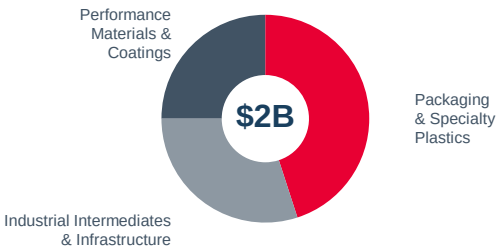
Capabilities

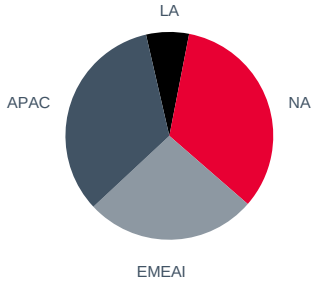
World-class science and engineering capabilities

- 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





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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

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What trends can we explore as partners?

DOW®

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Dow solutions for transportation electronics

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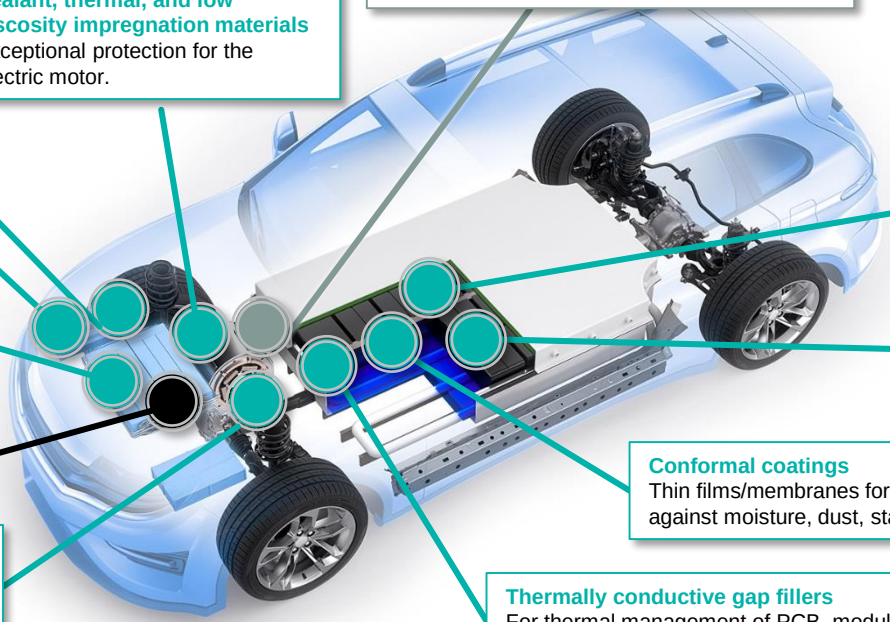

Polyurethane

Silicone

EPDM

Hood-liner, engine cover and engine encapsulation
Polyurethane materials offer acoustic powertrain efficiency, thermal management and improved sound insulation.

Silicone gel
High temperature-resistant pottant solution for IGBT and control units.

Sealant, thermal, and low viscosity impregnation materials
Exceptional protection for the electric motor.

Foam gasket & sealant
Efficient sealing for power units and control units.

EMI shielding materials
Help increase safety and reliability of battery pack.

Adhesives & thermal materials
Strong bonding and heat management in the on-board charger.

Adhesives & foam sealants
Excellent adhesion/sealing performance in battery pack, power and control units.

Under-the-hood components
EPDM for A/C hose, water hose, battery heating hose, molded parts, and NVH.

Conformal coatings
Thin films/membranes for protection against moisture, dust, static, etc.

Silicone elastomers
High performance materials for connector, damping, or protection parts for high voltage electric cable, valve caps, etc.

Thermally conductive gap fillers
For thermal management of PCB, modules, and battery pack (cells and cooling plate). Also used in power and control units.

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Use silicone for performance that lasts!

Seek Together™

Durable Performance

- Temperature extremes - -45-200 °C
- UV exposure
- High heat and humidity
- Water immersion
- Stress relaxing

Protect electronics

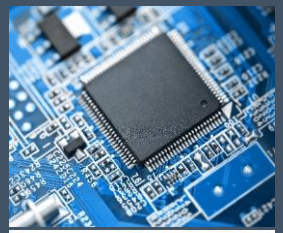
- Water impermeable
- Prevent metal corrosion

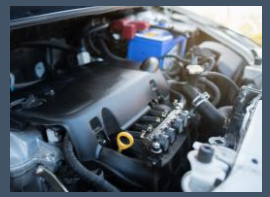
Stress relief & Light weighting

- Long term elasticity and flexibility
- Vibration damping
- Eliminate mechanical fasteners

Ease of Processing

- Tunable hardness, cure chemistries, cure speed
- Low toxicity and low abrasion fillers
- Simple mix ratios





Lifetime performance in challenging conditions

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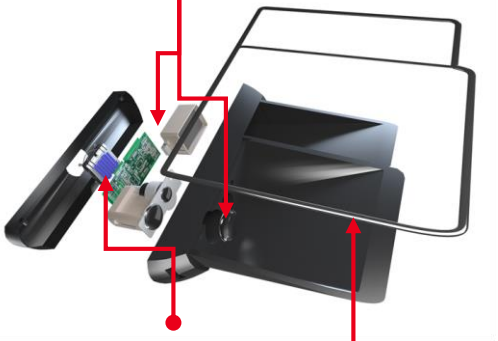
Use DOWSIL™ silicone to durably protect electronics

Seek Together™

Cameras

Si Encapsulants or gels
To protect the electronics units and sensors

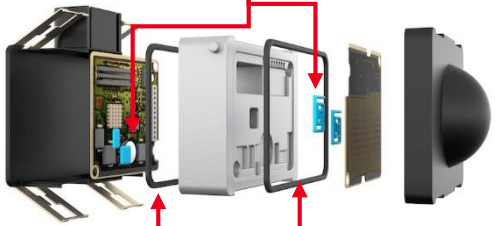


Si Thermally conductive silicones
To dissipate the heat generated by the PCB

Si Fast assembly adhesives or Si Foams
To seal and assemble modules

RADAR

Si Thermally conductive silicones
To dissipate the heat generated by the PCB

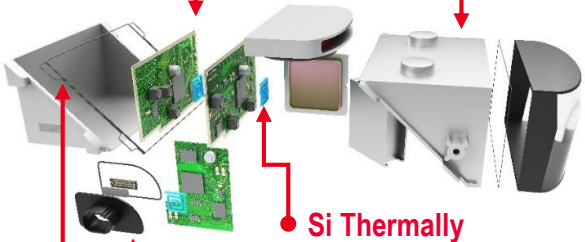


Si EMI Sealant
Electrically conductive material for grounding and shielding

LiDAR

Si Conformal Coatings
To protect PCB boards

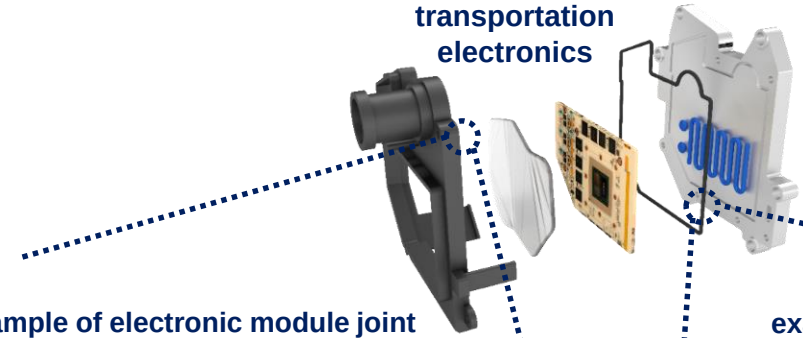
Si Fast assembly adhesives
To seal and assemble modules



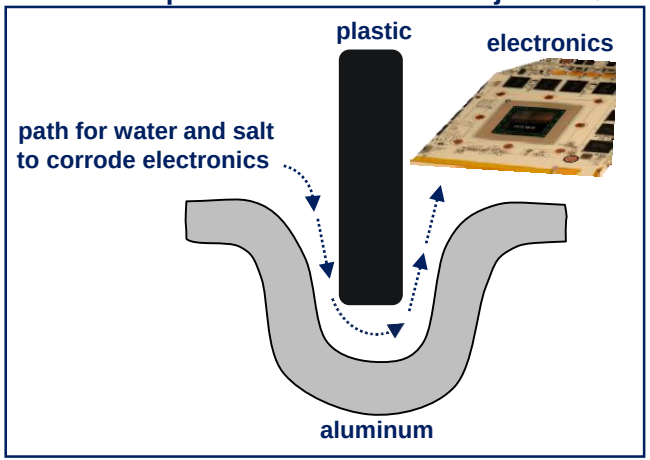
Si Thermally conductive silicones
To dissipate the heat generated by the PCB

Si Encapsulants or gels
For connector potting

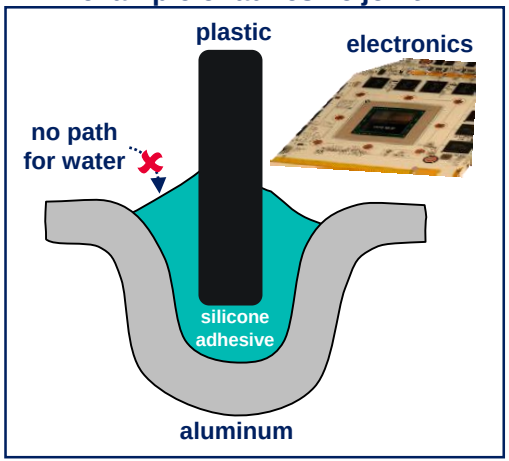
Use DOWSIL™ silicone to durably protect electronics



example of electronic module joint



example of adhesive joint



Advantages of silicone in joint

- Water proof
- Permanent flexibility
- Elastic
- Fast and simple assembly
- Consistent performance
- Vibration damping
- Eliminate physical fasteners

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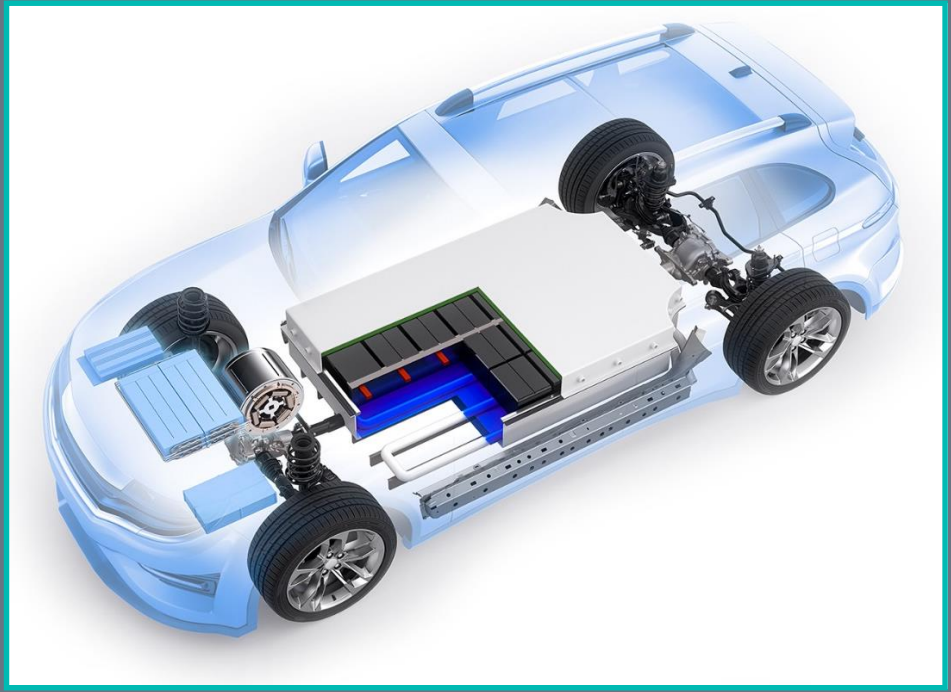
Use DOWSIL™ silicone to durably protect electronics

Seek Together™



E-mobility silicone applications

- Converter
- Inverter
- Autonomous steering controller
- RADAR/LiDAR
- Cameras
- Battery control units
- Thermal management
- Electromagnetic shielding

durable protection

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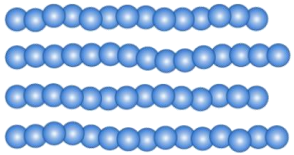
Specialty DOWSIL™ products for best in class performance in mobility solutions

Seek Together™



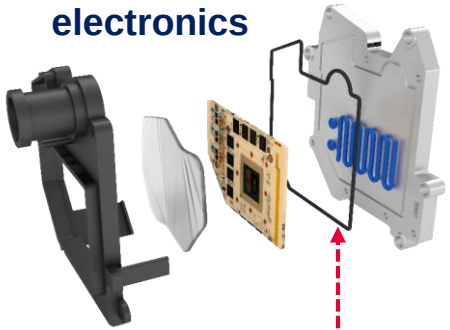
silicone polymers

formulate for performance

viscous fluid silicone product

cure

transportation electronics



high performance silicone elastomer

Leading technology

World leading integrated material science portfolio

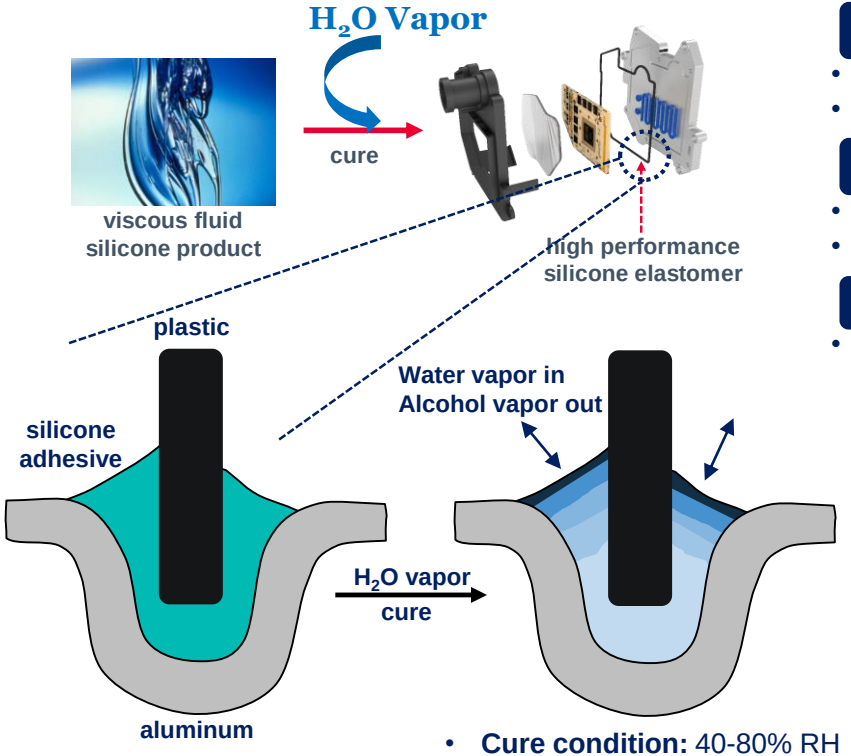
Expertise & support

Decades of industry experience and expertise

Customized development

Mobility specific innovation

Room temperature cure DOWSIL™ adhesives



Example of adhesive joint

Advantages

- Excellent adhesion to metals, glass, ceramics and some plastics
- No curing equipment such as ovens or lamps are required

Points to consider

- Environmental conditions such as dry winter air can affect cure
- Can limit throughput on part testing, handling, and shipping

Innovative Trend

- Shorter cure times – minutes/hours vs. days

DOWSIL™ EA-3838 that cures and builds bond strength in 5 min at room temperature

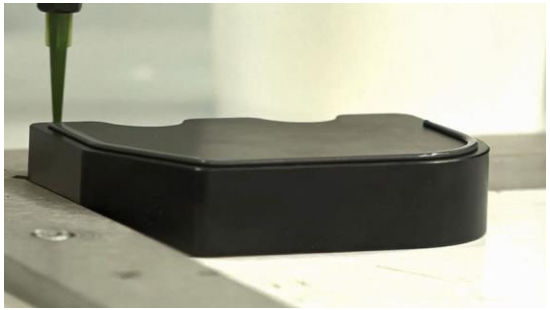
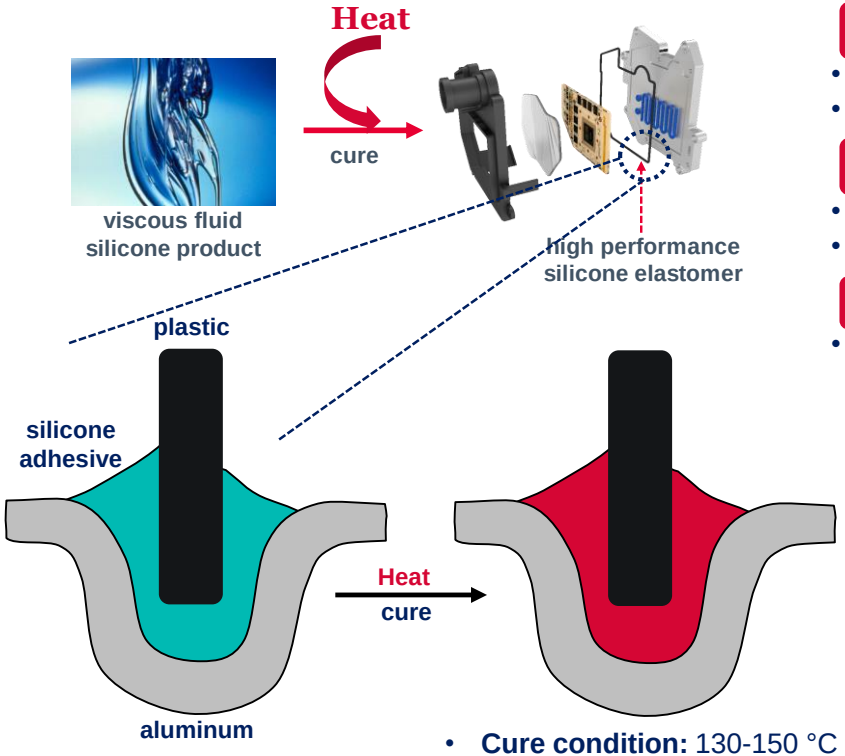


Photo: bdtronic

- **Cure condition:** 40-80% RH
- **Cure mode:** outside - in
- **Typical cure time:** hrs/days based on thickness

Heat cure DOWSIL™ adhesives



Example of adhesive joint

- **Cure condition:** 130-150 °C
- **Cure mode:** all at once
- **Typical cure time:** 30-60 minutes

Advantages

- Excellent adhesion to metals, glass, and broader range of plastics
- Parts can be tested, handled, and shipped immediately after cool down

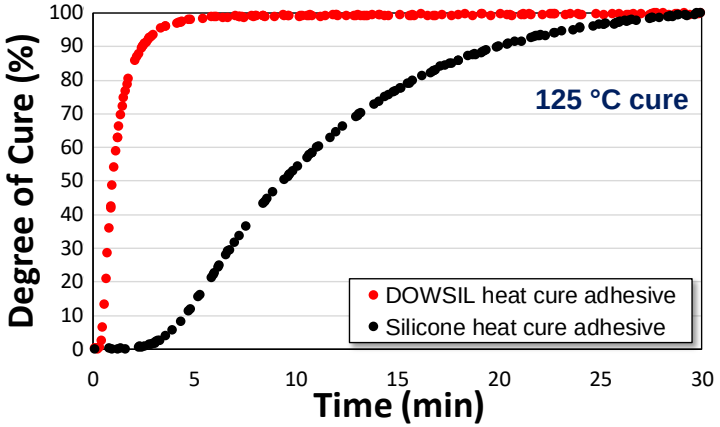
Points to consider

- Must reach required temperature at actual bondline
- Some electronics or substrates require lower temp or time at high temp

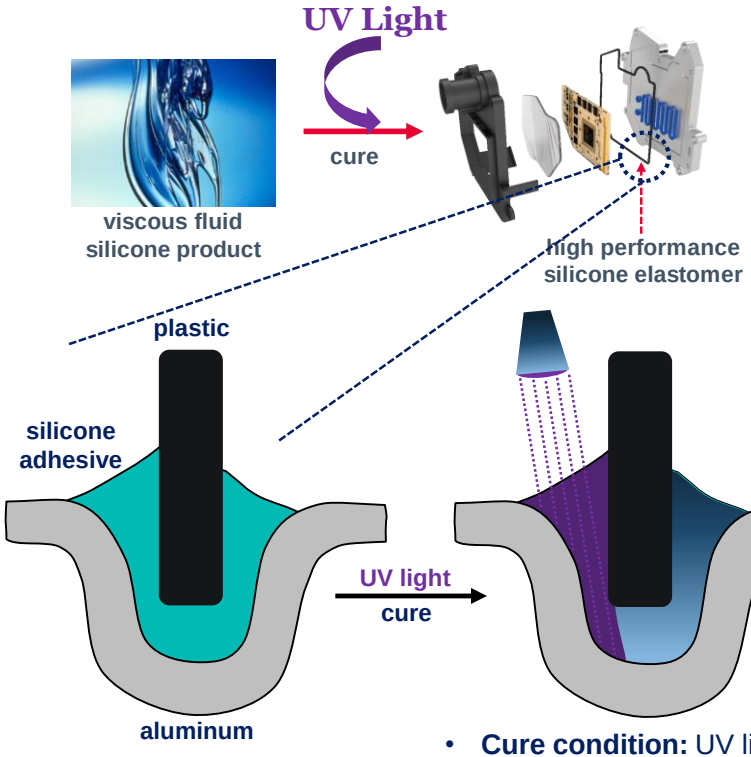
Innovative Trend

- Faster cure at high temp and cure at lower temp (80 vs 100 C)

DOWSIL™ EA-7100 5 min cure & adhesion
Compared to common 30-60 min cure & adhesion



UV cure DOWSIL™ products



Example of adhesive joint

- **Cure condition:** UV light exposure
- **Cure mode:** line of sight
- **Typical cure time:** seconds to minutes
- **Note**: secondary cure for shadow regions

Advantages

- Cure in seconds
- Minimal energy input - sustainable

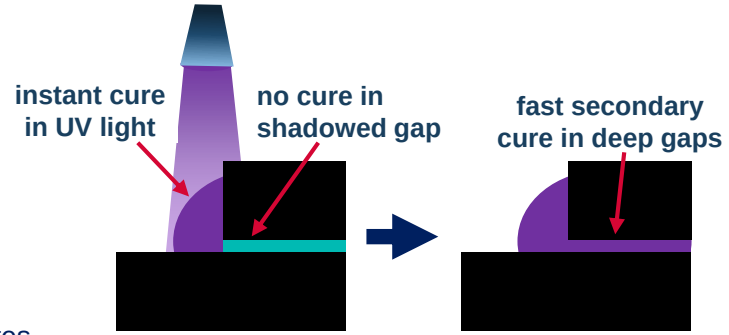
Points to consider

- Insufficient cure in deep sections or shadowed regions
- Low energy input can limit adhesion on some plastics

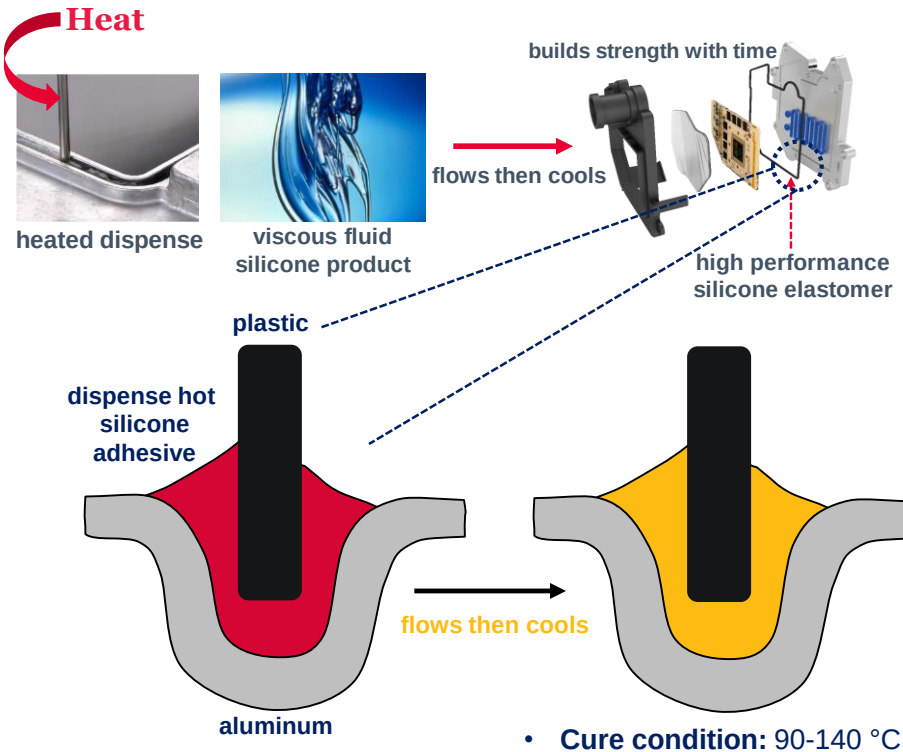
Innovative Trend

- Addition of secondary cure mechanisms to address shadow cure

DOWSIL™ CC-8030 that cures in seconds in UV exposure and cures in deep sections or shadowed area over time



Reactive hot melt DOWSIL™ adhesives



Example of adhesive joint

- **Cure condition:** 90-140 °C to dispense
- **Cure mode:** cools in place
- **Typical cure time:** instant green strength

Advantages

- Snap assembly – instant green strength upon cooling
- Minimal energy input - sustainable

Points to consider

- Requires automated hot dispensing capability
- Balance pot life at high temperature with working time

Innovative Trend

- Addition of secondary cure mechanisms to build strength

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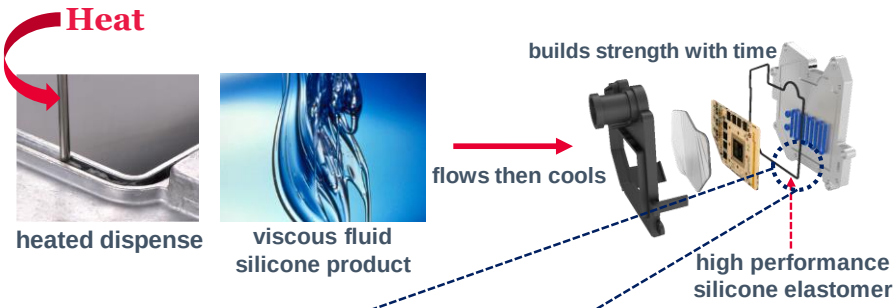
Reactive hot melt DOWSIL™ adhesives

Seek Together™



Example of adhesive joint

Advantages

- Snap assembly – instant green strength upon cooling
- Minimal energy input - sustainable

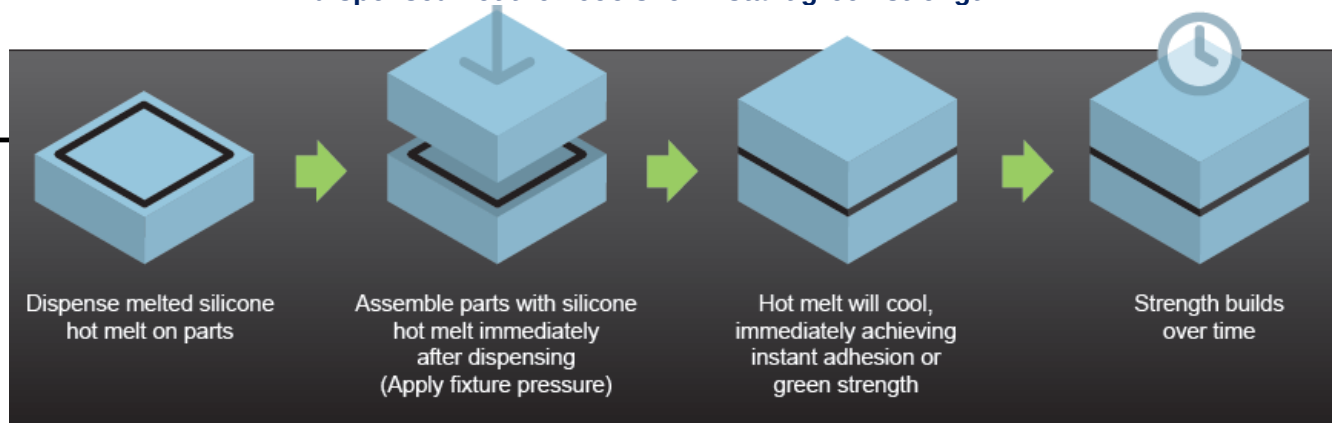
Points to consider

- Requires automated hot dispensing capability
- Balance pot life at high temperature with working time

Innovative Trend

- Addition of secondary cure mechanisms to build strength

DOWSIL™ EA- 5151 reactive silicone hot melt adhesive dispensed hot then cools for instant green strength



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Choosing the right material for your application

Seek Together™

- Identify cure type that meets performance and supply chain needs
- Collaborate with Dow early to go beyond the technical data sheet
- Focus on application-specific testing

Example adhesive Technical data sheet

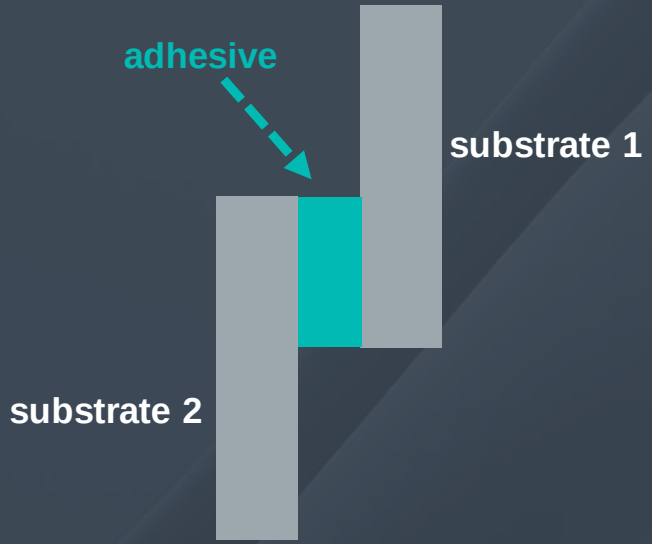
Durometer, Shore A	30
Elongation, %	550
Tensile Strength, psi	675
Tear Strength, lb./in. Die B	80
Adhesion, psi (al to al)	300
Dielectric Strength, volts/mil	500
Dielectric Constant	2.9

Example adhesive Technical data sheet

Specific Gravity (Cured)		1.09
Tensile Strength	psi	490
	MPa	3.4
	kg/cm^2	34
Elongation	%	260
Durometer Shore A		43
Tensile Modulus	psi	160
	MPa	1.1
	kg/cm^2	11
Adhesion – Lap Shear to Aluminum	psi	350
	MPa	2.4
	N/cm^2	240

Adhesives often compared based on “adhesion” or “lap shear” strength

A common method to evaluate adhesives

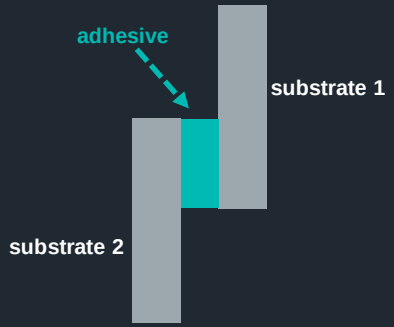


Basic description of lap shear test

- Select adhesive
- Glue two surfaces together
- Pull apart and measure force

example single lap joint test

Align material selection to application specific testing



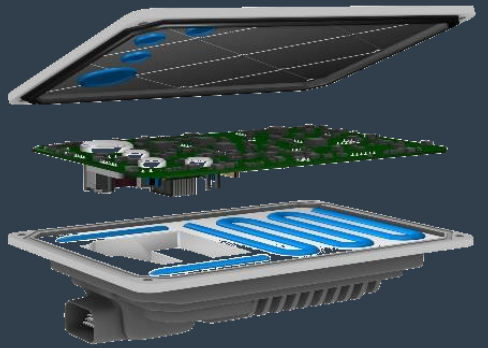
Common reasons for lap joint use

- Simple
- Inexpensive
- Gives some information on adhesion

To consider

- High force over seconds to minutes
- Provides no information on durability

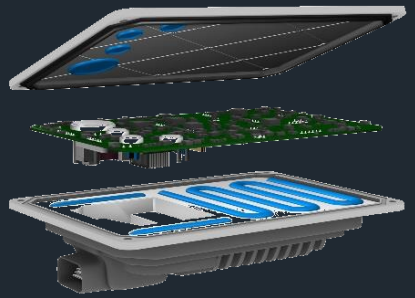
electronic module



Requirements for actual module in the field

- Years to decades of life
- Constant low or repeated forces
- Changing conditions
    - Thermal cycling
    - Humidity differences
    - Vibrations

Align material selection to application specific testing

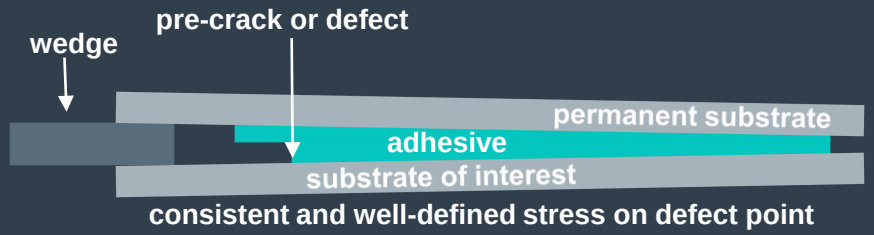


Testing modules

- Required for validation and final steps

To consider

- Costly
- Small sample sets
- Screening challenge
  - Many adhesives
  - Multiple substrates
  - Surface treatments

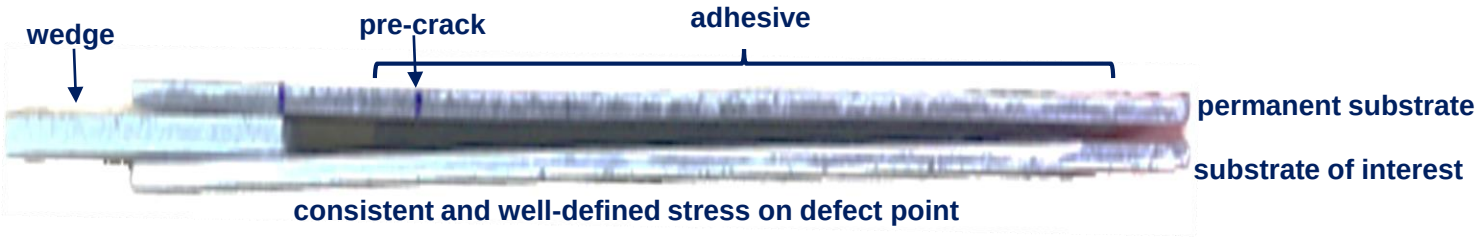


Dow durability testing

- Test samples that match the application
- Expose to environmental stresses
- Correlate to lifetime performance
- Maximize performance for “in field” conditions
- Modified wedge specimen (ASTM D3762)

Build “actual” adhesive joint and run through durability testing

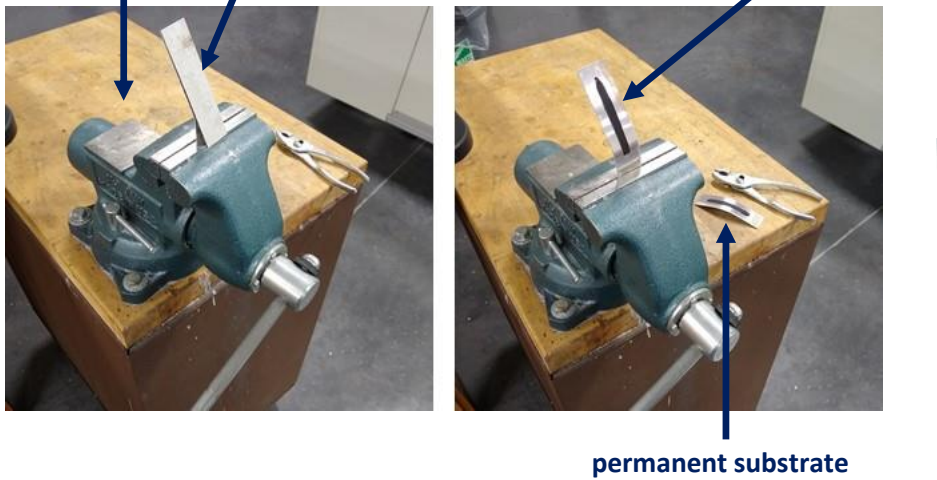
Dow durability sample leveraged from aerospace industry

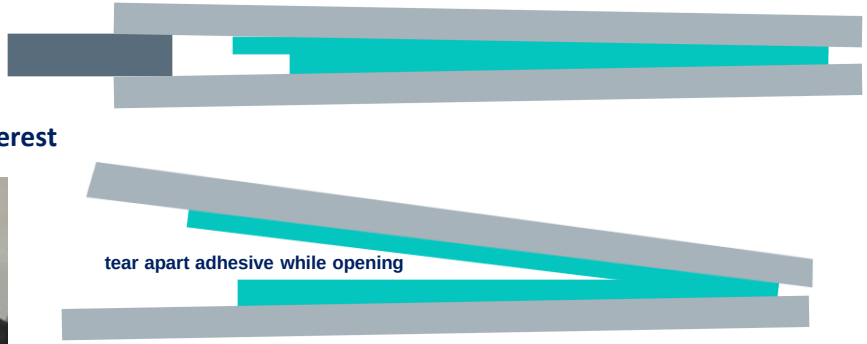


Key Points

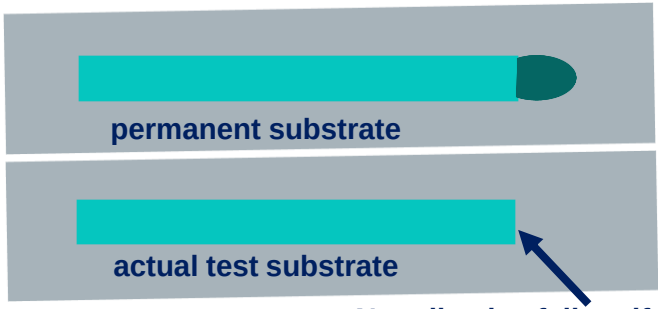
- **Mimic joint** - better representation of adhesion in the application than the lap shear test
- **Consistent defined stress** - maintain mechanical stress on joint
- **Exposure** - combine mechanical stress (strain) and environmental exposure (e.g. water, salt)
- **Inexpensive** - low cost compared to testing many electronic modules
- **Statistical power** - build large sample sets

Evaluating durability samples after environmental exposure





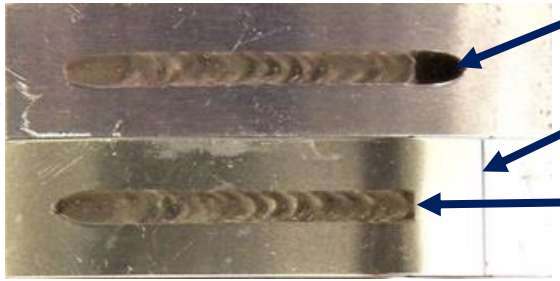
Pull open joint and inspect for adhesive failure



No adhesive failure if adhesive is in same place as imposed defect

Evaluating durability samples after environmental exposure

Good – no adhesive failure
Durable to stress + exposure

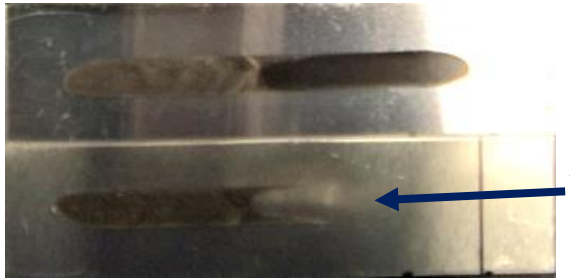


Surface that cured on top of Teflon tape

Wedge insertion line

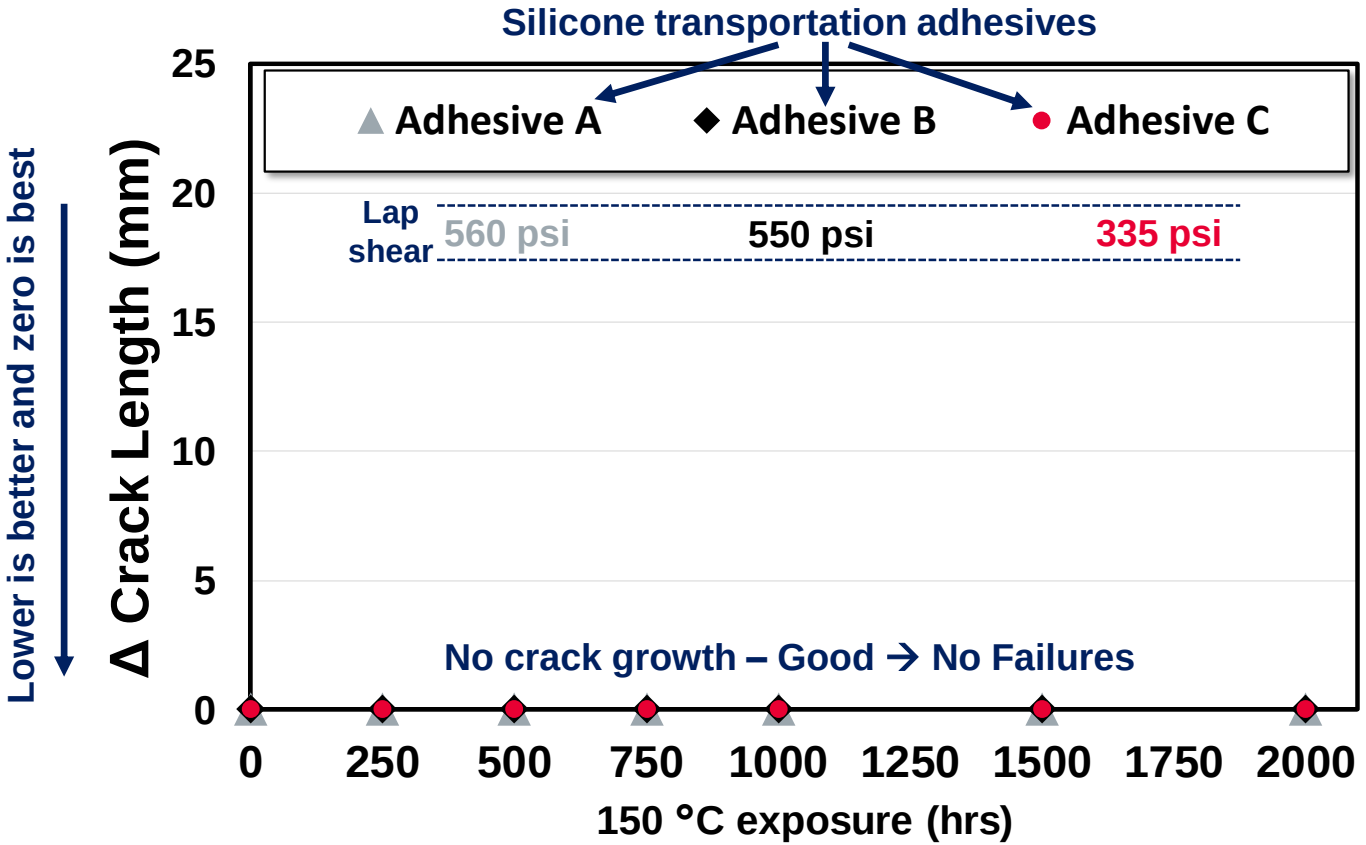
Defined edge at pre-crack. No change in crack length. No adhesive failure

Bad – adhesive failure
Not durable to stress + exposure



Adhesive failure

Adhesion durability – 150 °C accelerated aging



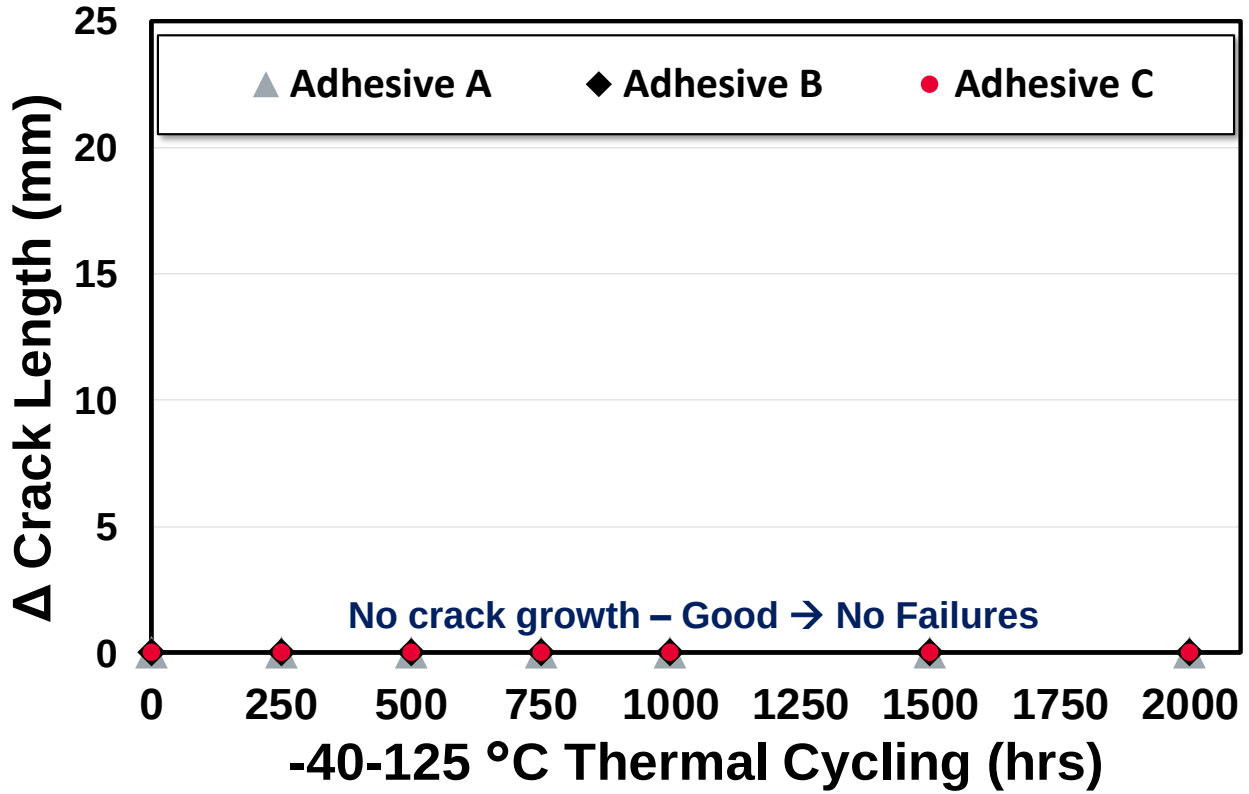
Replicates - 3 replicates each adhesive, ea substrate, ea time point – 210 total; **Substrates –** 30% GF PBT and Aluminum alloy; **Data shown –** Aluminum substrate

Measure adhesion durability to correlate to lifetime performance

Aging 2000 hr

Lap Shear	150 °C	-40-125°C	85 °C 85% RH
560 psi	Adhesive A  ✓		
550 psi	Adhesive B  ✓		
335 psi	Adhesive C  ✓		

Adhesion durability – -40-125 °C cycling accelerated aging



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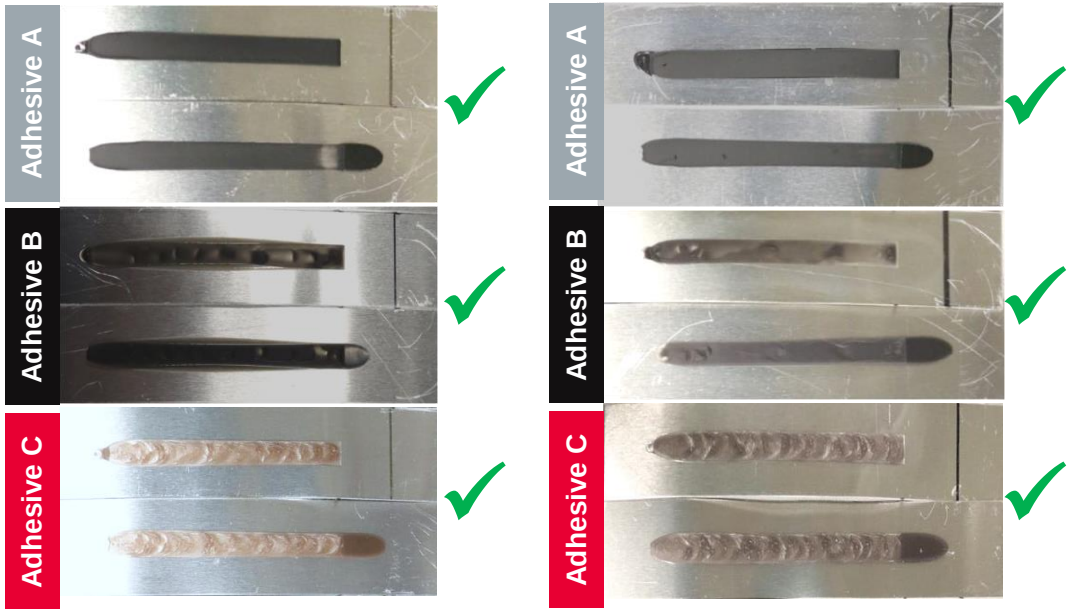
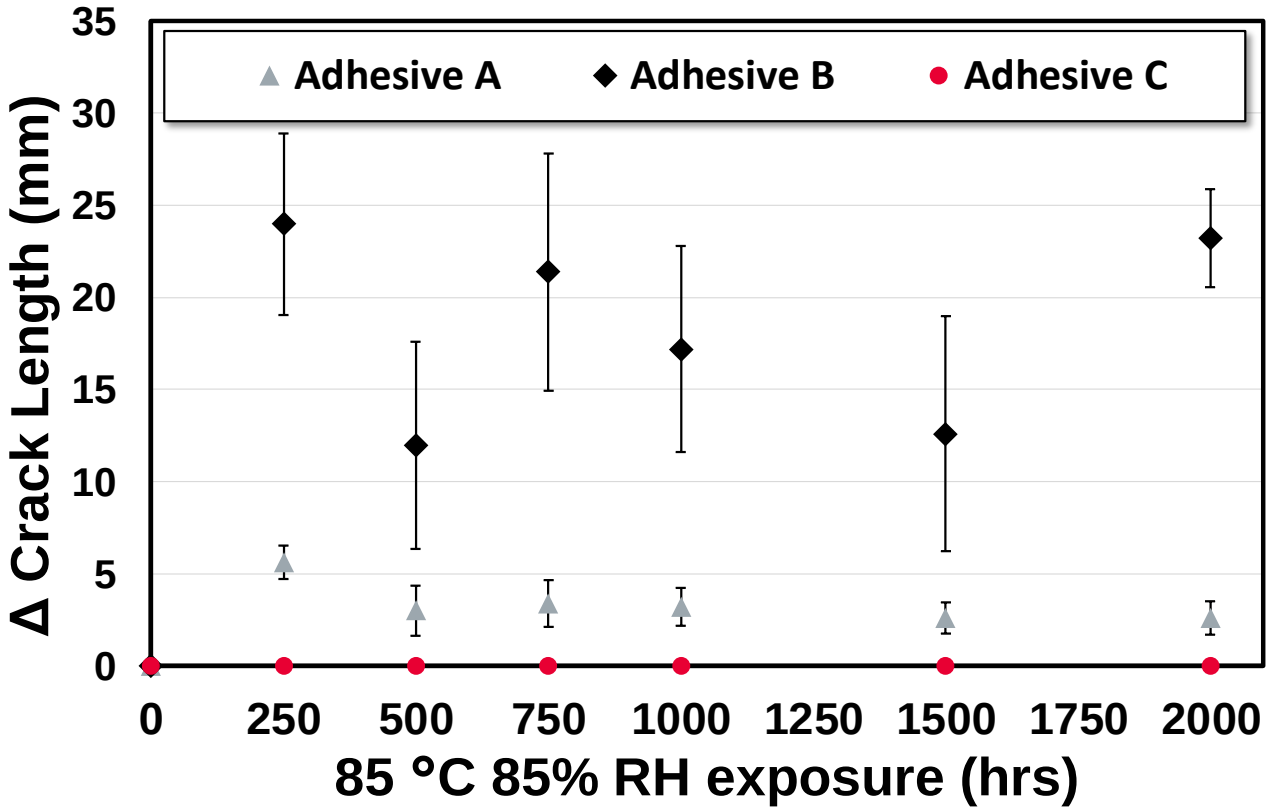
Measure adhesion durability to correlate to lifetime performance

Aging 2000 hr

Lap Shear	150 °C	-40-125°C	85 °C 85% RH
560 psi	Adhesive A ✓	Adhesive A ✓	
550 psi	Adhesive B ✓	Adhesive B ✓	
335 psi	Adhesive C ✓	Adhesive C ✓	

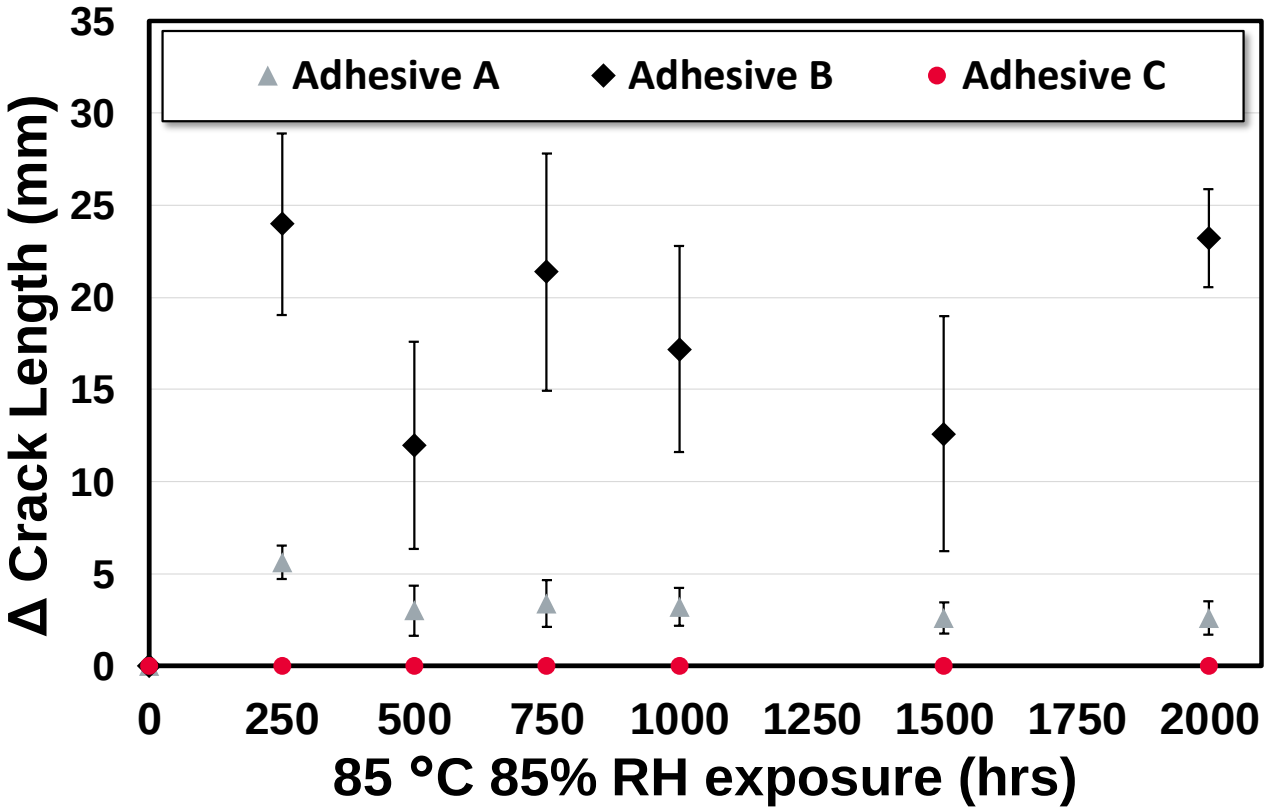


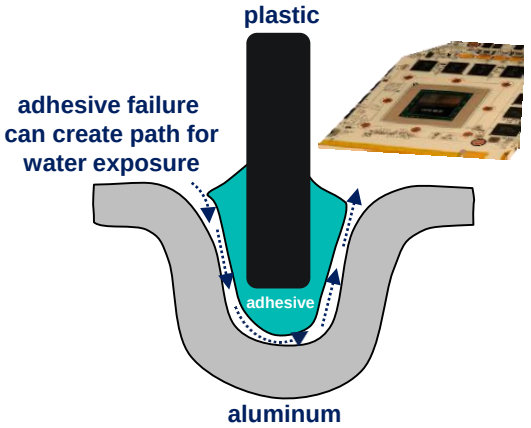
Adhesion durability – 85 °C 85% relative humidity aging



Replicates - 3 replicates each adhesive, ea substrate, ea time point – 210 total; **Substrates –** 30% GF PBT and Aluminum alloy; **Data shown –** Aluminum substrate

Adhesion durability – 85 °C 85% relative humidity aging





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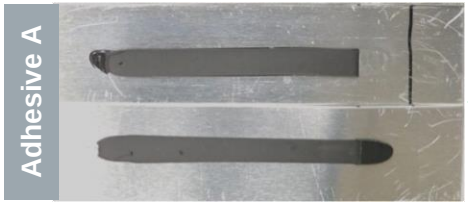
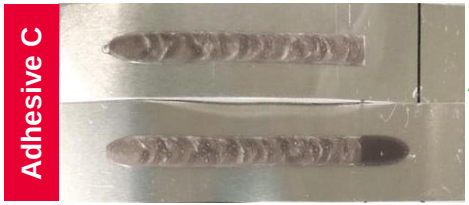
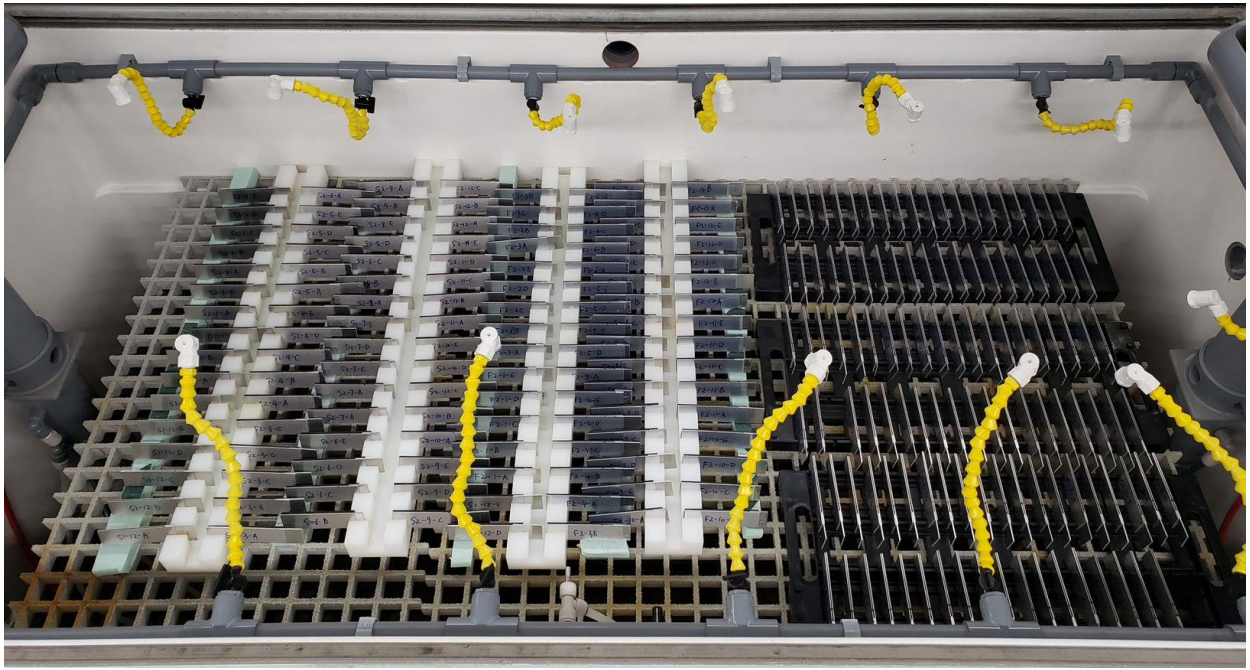
560 psi	Adhesive A  ✓	Adhesive A  ✓	Adhesive A  ✗
550 psi	Adhesive B  ✓	Adhesive B  ✓	Adhesive B  ✗
335 psi	Adhesive C  ✓	Adhesive C  ✓	Adhesive C  ✓

- All 3 adhesives pass 150 °C aging and -40-125 °C aging without failures
- Only one adhesive passes combined exposure of heat + water + mechanical stress
- Lap shear did not predict performance durability

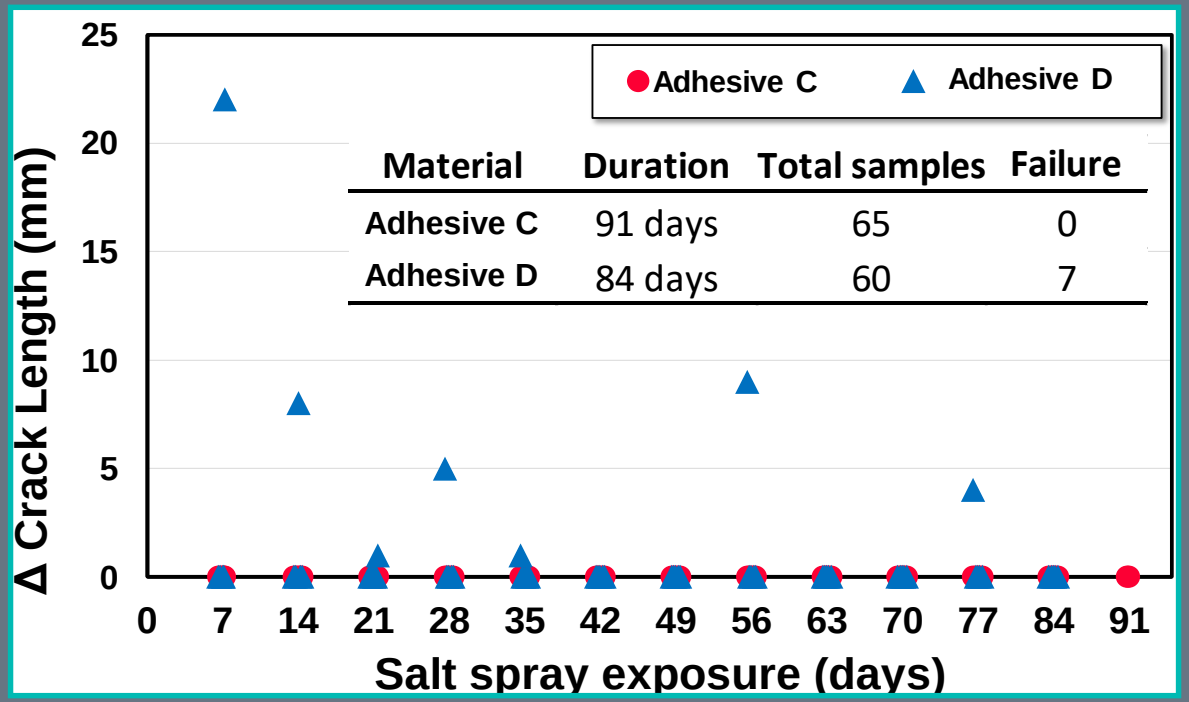
Exposing durability samples to salt spray conditions

Dow durability samples in salt spray chamber



Statistical power – Large sample sets for statistical strength
Automotive tests - Run same environmental exposure cycles as required by automotive industry
Predictive screening - Test many adhesives, substrates, and surface treatments

Match durability testing to standard validation tests



Material	Duration	Total samples	Failure
Adhesive C	91 days	65	0
Adhesive D	84 days	60	7

Automotive salt spray cycle steps

1. Mist atomized 1% mixed salt solution over samples
2. Ambient stage: 25 ± 3 °C 45% RH – 8 hrs
3. Humid stage: 49 ± 2 °C 100% RH – 8 hrs
4. Dry stage: 60 ± 2 °C < 30% RH – 8 hrs
5. Repeat daily for desired number of cycles

Run durability samples through E-module validation type tests

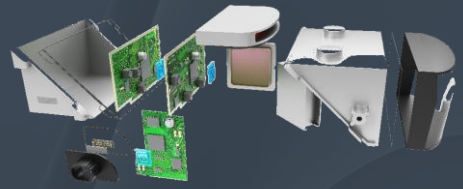
MobilityScience™

Match durability testing to standard validation tests

Seek Together™

	Salt Spray Exposure (days)		
	40	60	Pass Leak Test?
Adhesive A	X		N
	X		N
	X		N
		X	N
		X	N
Adhesive C	X		Y
	X		Y
	X		Y
	X		Y
		X	Y
		X	Y

- All modules passed initial leak tests before exposure
- Placed into salt spray cycle
- Durability testing predicted performance in actual E-module testing



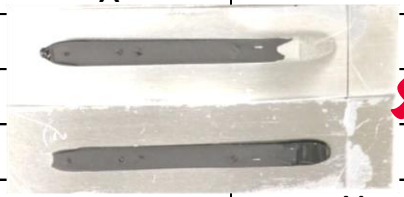
Automotive salt spray cycle steps

1. Mount e-module at intended final orientation
2. Soak in chamber at 70 °C for 1 hr. Then adjust to 35 °C.
3. Spray with 5 wt% salt solution for 1 hr. Turn off spray
4. Allow chamber to cool to RT for 1 hr
5. Repeat steps 2-4 three times for a total of 9 hr
6. 15 hr at RT. Humidity uncontrolled. No salt spray.
7. 24 hr sequence repeated for desired cycles

Match durability testing to standard validation tests

Seek Together™

	Salt Spray Exposure (days)		
	40	60	Pass Leak Test?
Adhesive A	X		N
			N
			N
			N
		X	N
Adhesive C	X		Y
			Y
			Y
			Y
			Y
		X	Y



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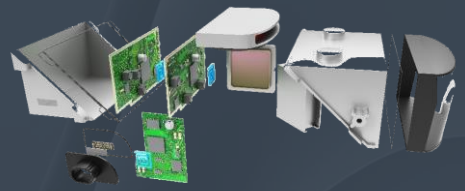
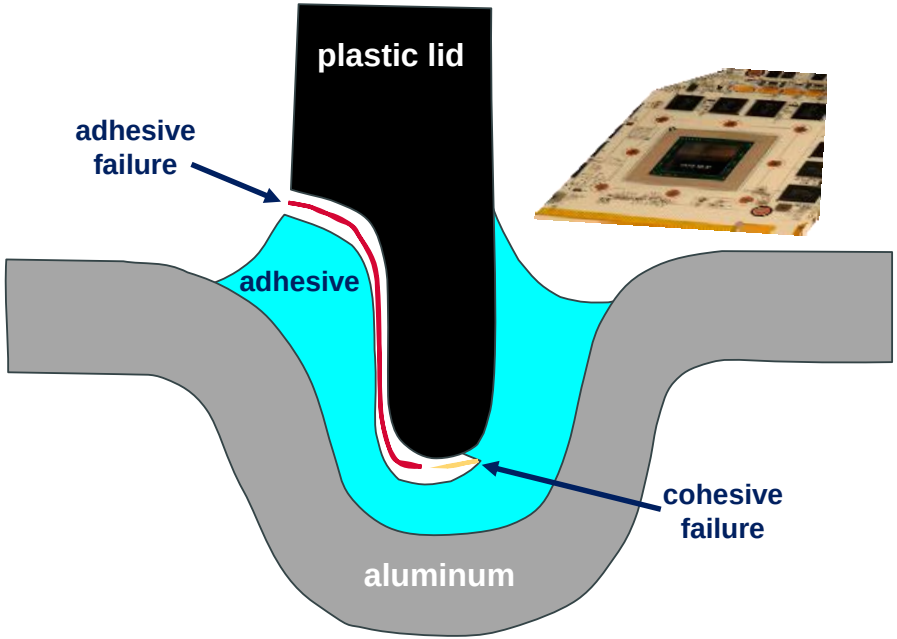
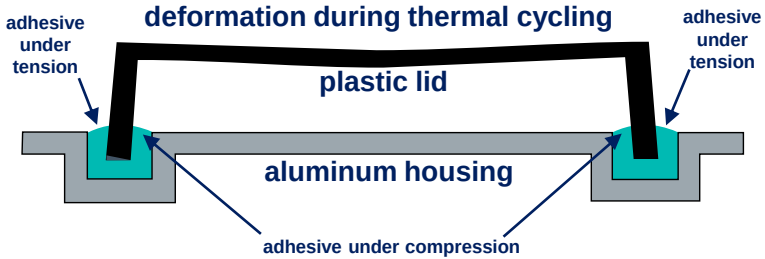


- Winner? → Adhesive C!
- No failures in all durability tests
- Lowest “adhesion” value on TDS

Partner with Dow for application expertise in addition to materials science know-how

adhesive joint in actual module

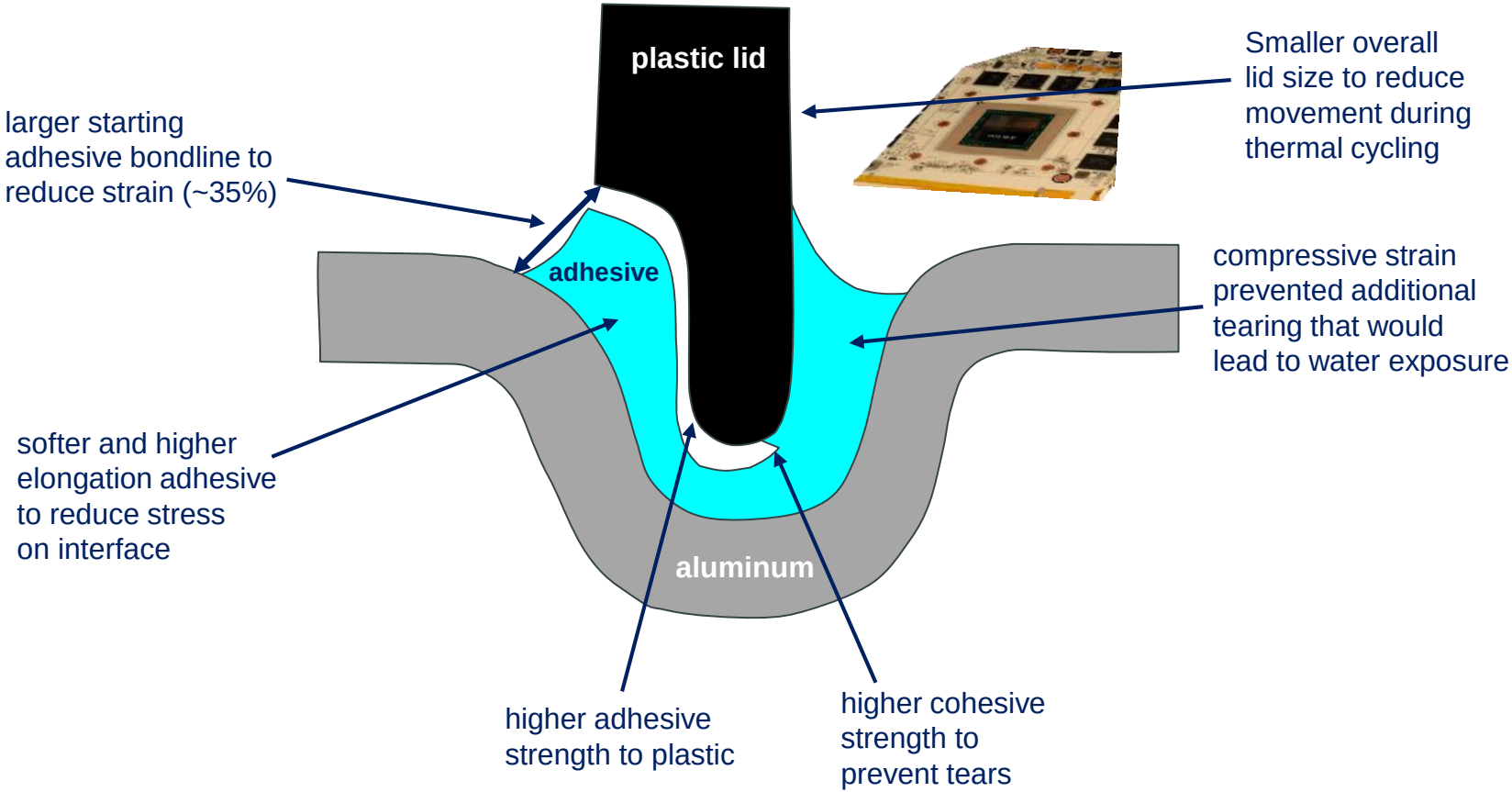




Key Points

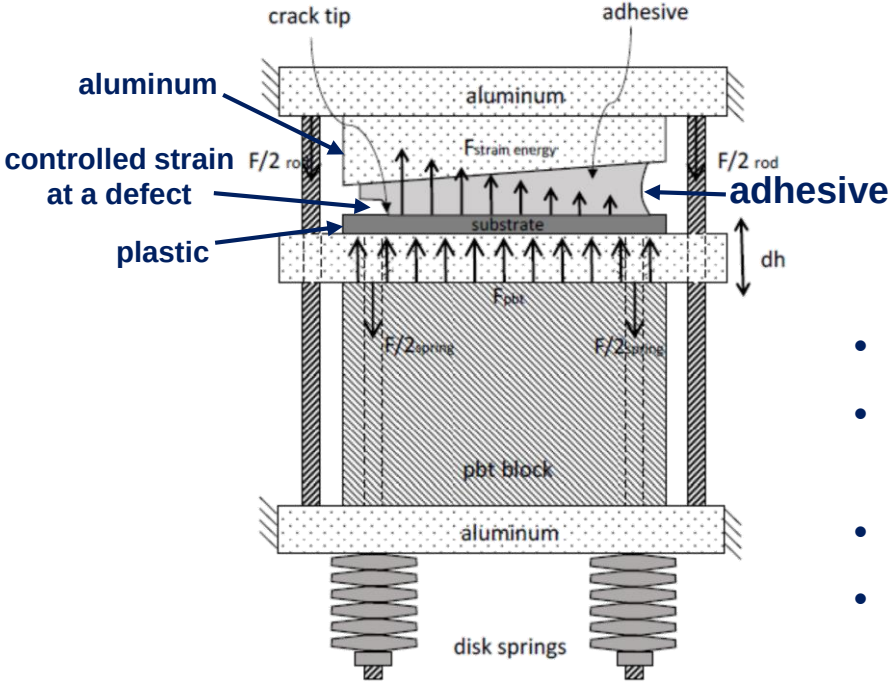
- Customer worked with Dow to address a failure
- Separation during thermal cycle testing -40-125 °C
- Dow provided application analysis
- Leverage Dow technology and application expertise to design solutions and innovate

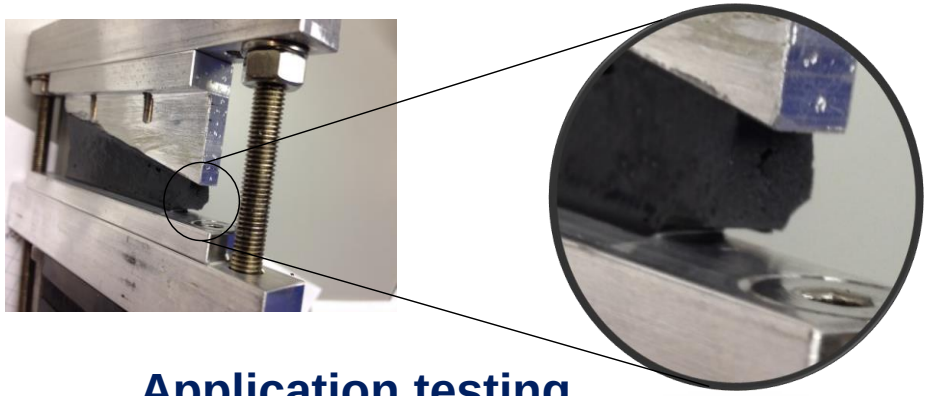
Dow recommendations to resolve customer issue



Go beyond the technical data sheet for application specific performance

Dow application frame to precisely control strain at a defect



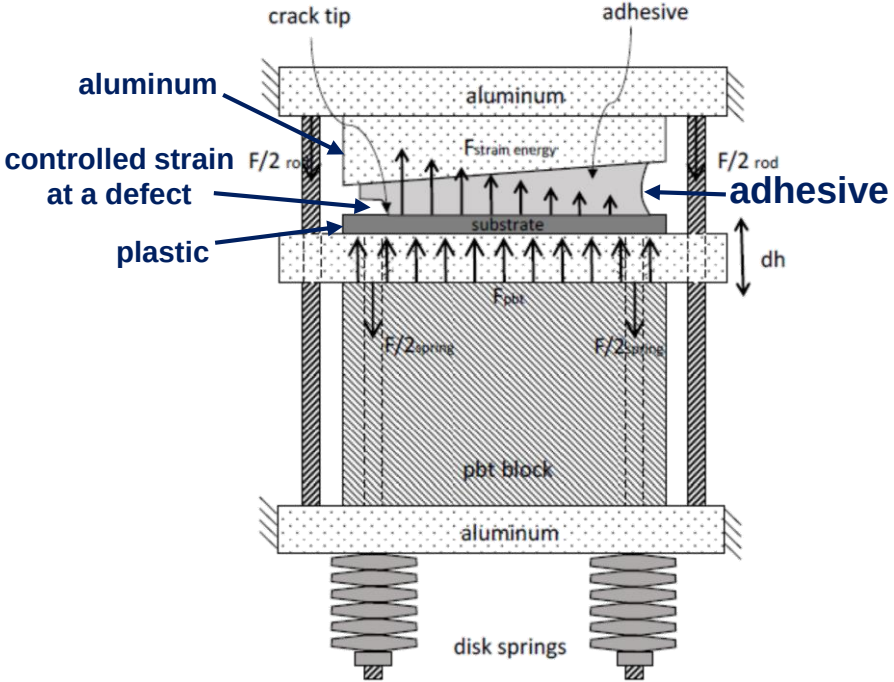


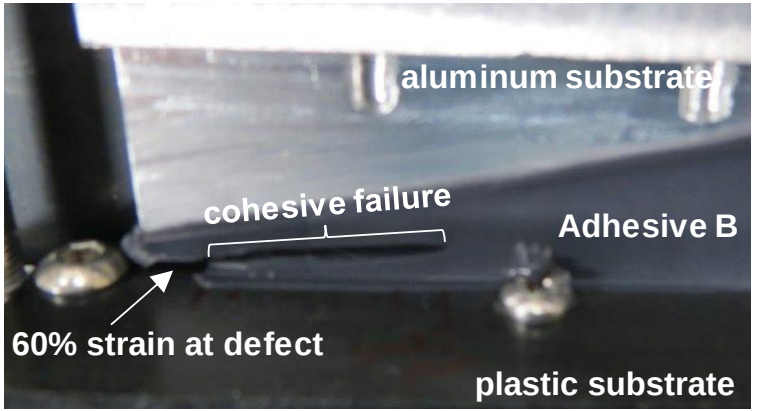
Application testing

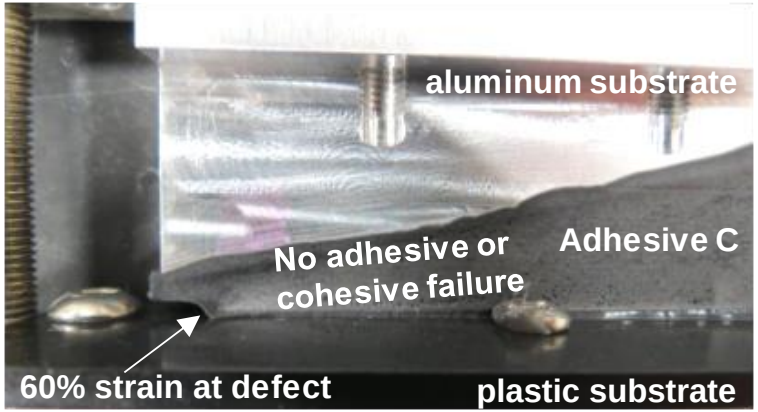
- Test at expected strains in module
- Determine if cure cycle effects performance (such as shrinkage stress)
- Cycling and fatigue testing
- Goes beyond lap shear or peel testing to predict performance in application

Go beyond the technical data sheet for application specific performance

Dow application frame to precisely control strain at a defect







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Partner with Dow to define material requirements and produce technical solutions that meet emerging market needs

Let's collaborate!

Partner with Dow to get access to:

- A world-leading R&D organization and deep chemistry toolbox
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  - Excellent technical and application expertise
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THANK YOU

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