



Pioneering Nanotube Interfaces Together

Thermal Management Expo, Novi 2025

Joe Sootsman, PhD, Prinicipal Application Scientist, Dow
Craig Green, PhD, CTO, Carbice

Who is Dow



2023
NET SALES

\$45B



EMPLOYEES

~35,900



MANUFACTURING
SITES

98



GLOBAL REACH
Countries in which Dow
manufactures products

31 countries

Our ambition

Be the most **innovative**, **customer-centric**, **inclusive** and **sustainable** materials science company in the world.

Global, fully back-integrated supplier

Silicones

Polyolefin
elastomers

Polyurethanes

Acrylics

Specialty
chemicals





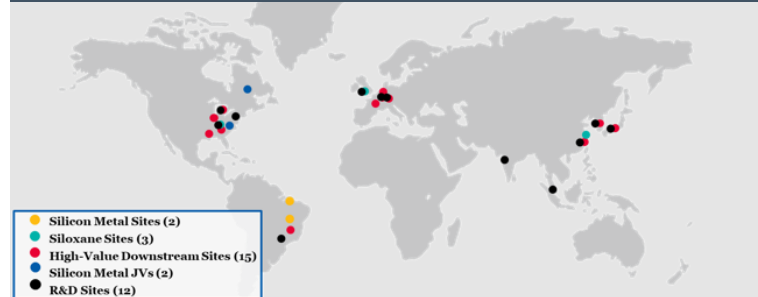
Demonstrated performance



>500 million vehicles use Dow conductive composites



Global reach



Global R&D, manufacturing and customer support



Customer support



Support throughout adoption, production and use



Offers innovation



Formulation knowledge and backward integration



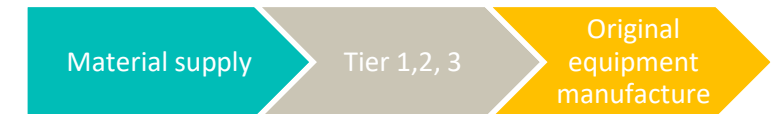
Recognized products



Award-winning materials



Industry leadership

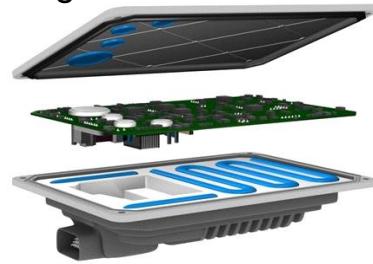


Broad customer and industry participation

Dow's thermally conductive commercial product family

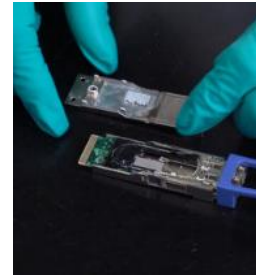
Gap fillers

- Soft; stress-relieving
- Designed for large gaps
- Low assembly force
- Rework and field repair



Gels

- Soft and stress-relieving
- Designed for variable gaps
- Dispensing or printing; low assembly force
- Rework and field repair



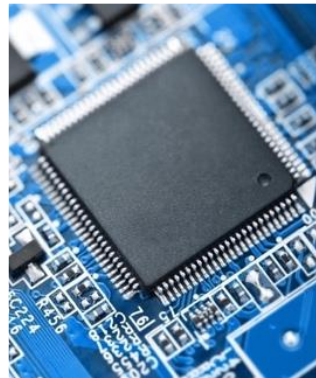
Adhesives

- Silicone adhesives with thermal conductivity
- Improved stability over time
- Replace mechanical fixation
- Insulating or electrically conductive



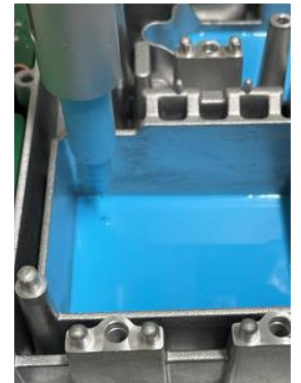
Compounds (greases)

- Thin bond line
- Lowest thermal resistance
- Non-curing paste
- Pump-out resistance

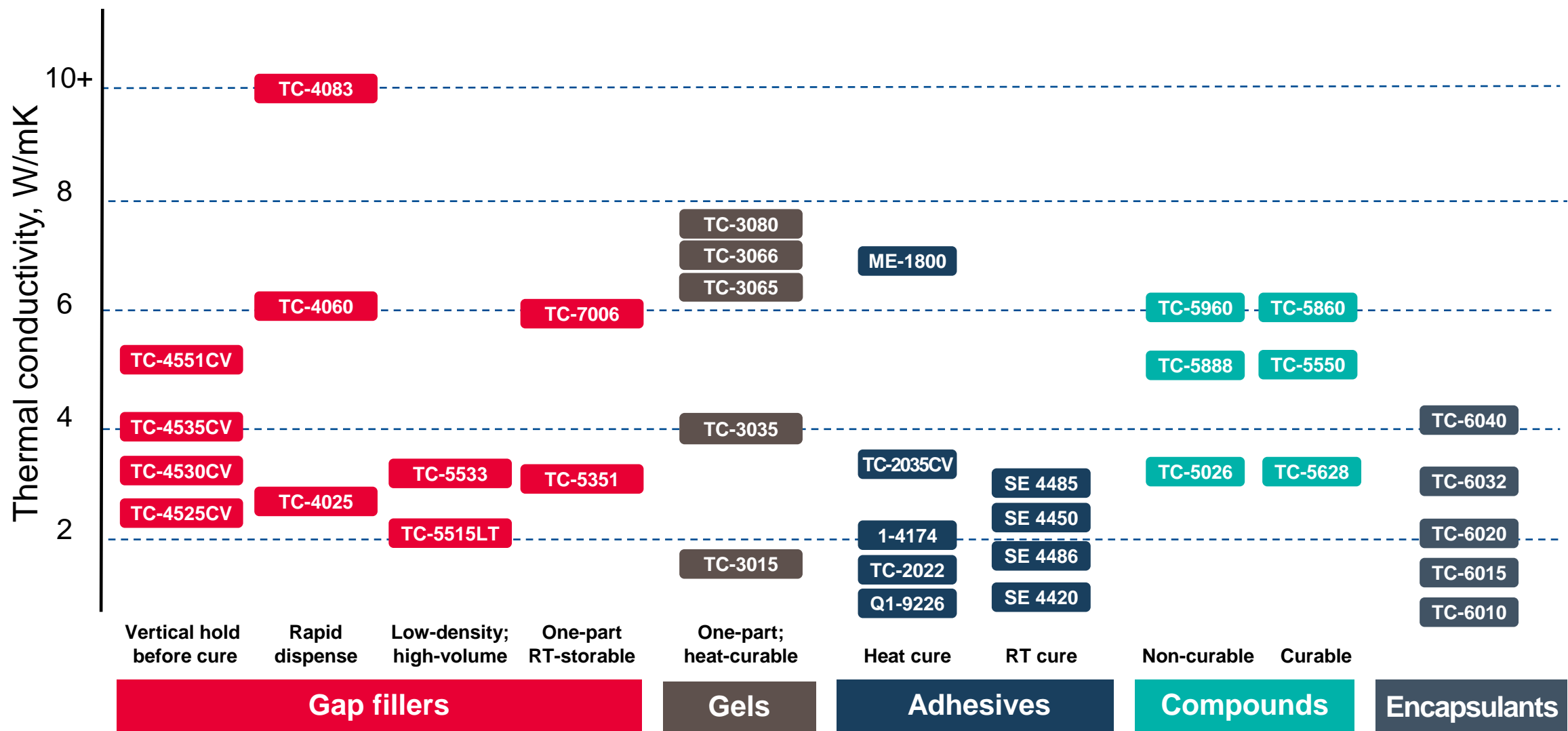


Encapsulants (pottants)

- Environmental protection
- Volumetric heat dissipation
- Flowable; self-leveling
- Soft; stress-relieving



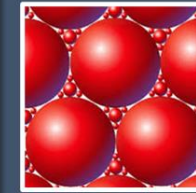
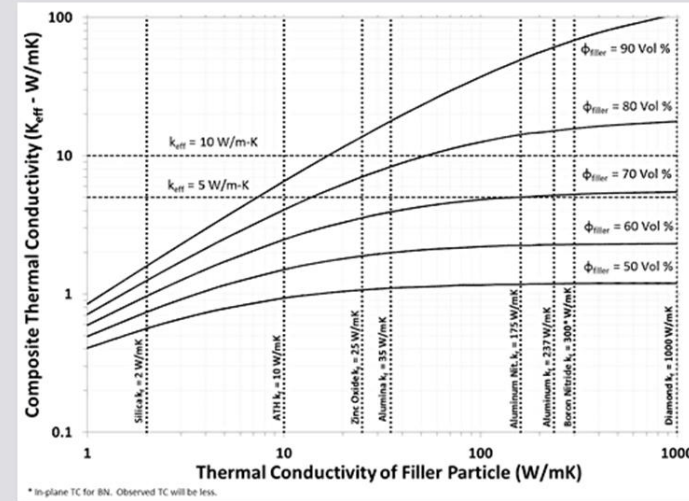
SELECT DOWSIL™ THERMALLY CONDUCTIVE PRODUCTS



*These are typical properties, not to be construed as specifications.

COMPOSITE MATERIALS – FORMULATION OF FILLER AND POLYMER

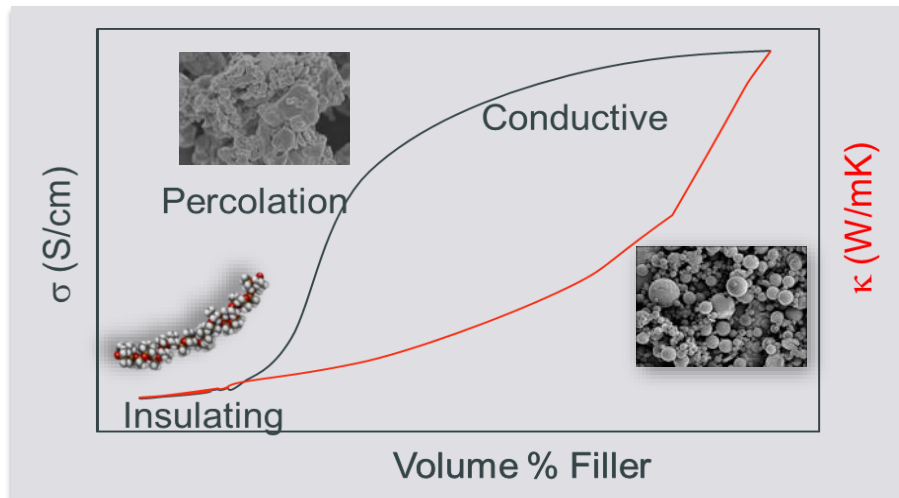
- Conductive composites deliver solutions where thermal and/or electrical conduction are needed.
- Typical conductive composites are:
 - Formulations consisting of solid filler and siloxane polymers
 - Liquid materials engineered for dispensability



$$k = D\rho C_p$$

k = Thermal conductivity
 D = Thermal diffusivity
 ρ = Density
 C_p = Heat capacity

- Addition of filler to polymeric matrix provides up to 19 orders of magnitude change in volume resistivity
- Common EC fillers:
 - Ag
 - Ag/Ni
 - Ag/glass
 - Carbon



- Addition of fillers to matrix increases thermal conductivity by 3-40X polymer
- Common Tc fillers:
 - Al_2O_3
 - ZnO
 - BN
 - Aluminum trihydrate (ATH)
 - Aluminum

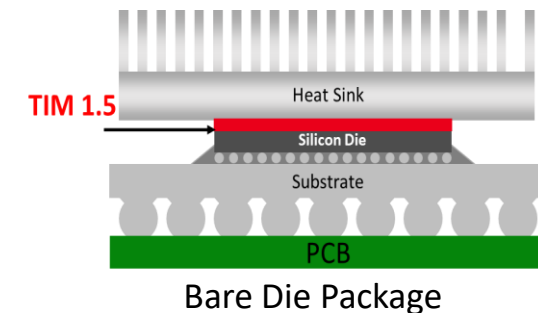
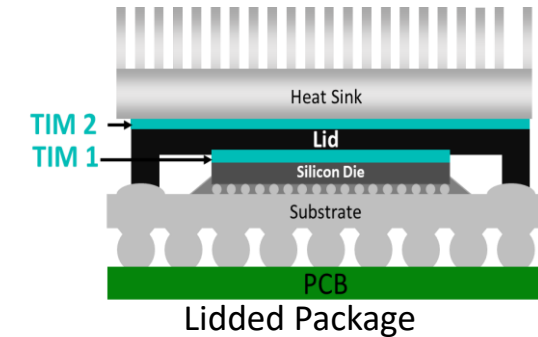


Pioneering Nanotube Interfaces Together

Introduction to Dow + Carbice Partnership and Technologies

CHALLENGES FOR ELECTRONICS RELIABILITY

- **Thermal Interface Materials (TIM)** play a critical role in the thermal management of electronic devices that are increasingly **compact** and **powerful**, and which **generate high level of heat**.
- **High Power Devices** → SiC power electronics driving higher temperatures and need for better thermal management
- **Consolidation of Modules** → Multi-functional power modules are increasing in size and power density
- **Fast assembly and sustainability needs growing** → fast assembly needs to improve productivity and sustainability solutions along life cycle



WHO IS CARBICE, PIONEERS OF CARBON NANOTUBE TIMs

Carbice

- Founded in 2011, Carbice is an Atlanta, Georgia-based company with industry experienced leadership team.
- Growing ongoing business in space applications.

What they do

- Carbice design, manufactures, and sells CNT TIMs for high performance electronics applications like satellites, automotive power electronics, ADAS, data centers, semiconductor, and energy systems.

Why it matters

- The growth of TIMs in Electronics markets, increased power demands from electronics and data is creating a need for high-performance thermal management.

How it works

- Billions of vertically aligned CNTs are grown in situ from a gaseous precursor onto a recycled aluminum backing sheet to create a TIM product with both liquid-like and solid properties.
- Current products sold Space Pad™



Baratunde Cola, PhD
CEO and Founder

20 years of deep tech and material company advisement. Nation's top scientist award winner.



Craig Green, PhD
Chief Technology Officer

Leading thermal engineering expert in the field. Expertise from transistor to system level.



Hal Lasky
Chief Operating Officer

40 years of experience and expertise in the global semiconductor industry. Former VP at IBM.



Harold Covert
Chief Financial Officer

>30 years of experience as CFO in the global semiconductor and electronics industry



Rafael Spears
GM of Aerospace & Defense

25 years of Aerospace and Defense experience. Former Director at the Aerospace Corporation.



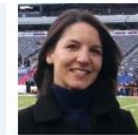
Matthew Smith, PhD
Director, AI, Compute and Power

Fellow in Oak Ridge National Labs' Innovation Crossroads Program. Technical advisor at DOE, DoD & NSF



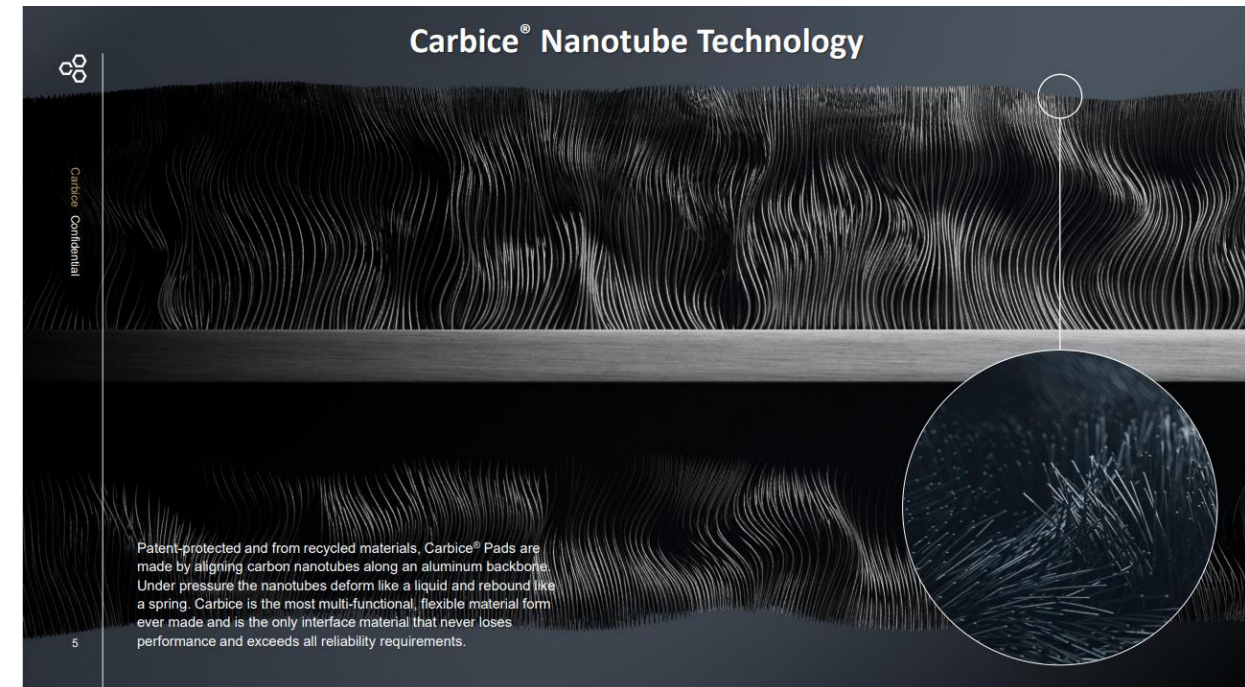
Marcus Walker, MBA
Vice President of Business Operations and Finance

Expert in strategy and finance. Former Accenture Technology consultant.



Theresa Pantazopoulos
Vice President of Marketing and Communications

25 years of brand and communications experience. Former VP at Edelman.



DOW AND CARBICE PARTNER TO ADVANCE THERMAL INTERFACE MATERIALS

Partnership combines Dow's silicone thermal management expertise and Carbice's carbon nanotube (CNT) technology to offer a full TIM solution portfolio, addressing various thermal management challenges.



Pioneering Nanotube Interfaces Together

- #1 Silicone Global Leader
- Industry recognized technical team with an 80-year history in silicone science
- Silicone leader liquid TIM portfolio
- Customer intimacy globally
- Leading brand reputation and quality



- CNT industry leader
- CNT world's only high volume aligned CNT manufacturing facility
- Carbice lab: simulation, innovation capabilities
- Proven solutions Space Pad
- Industry experienced leadership team

Dow is your partner and point of contact



COMBINED CAPABILITIES THROUGH PARTNERSHIP

Demonstrated Performance



Extensive industry recognition of award-winning technology at Dow

Global Reach



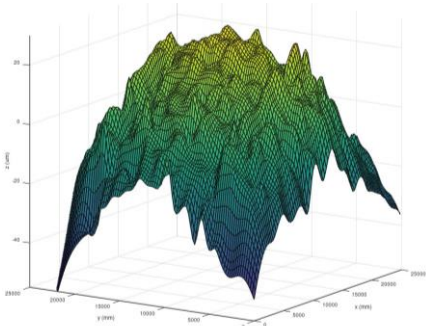
Global R&D, manufacturing and customer support

Customer Support



Support throughout adoption, production and use

Offers Innovation



Custom capabilities in the simulation of interfaces predicting material performance

Technical Expertise



Dedicated application testing laboratories

Leading Material Development



Enhance
*product
performance*



Improve
*reliability and
efficiency*

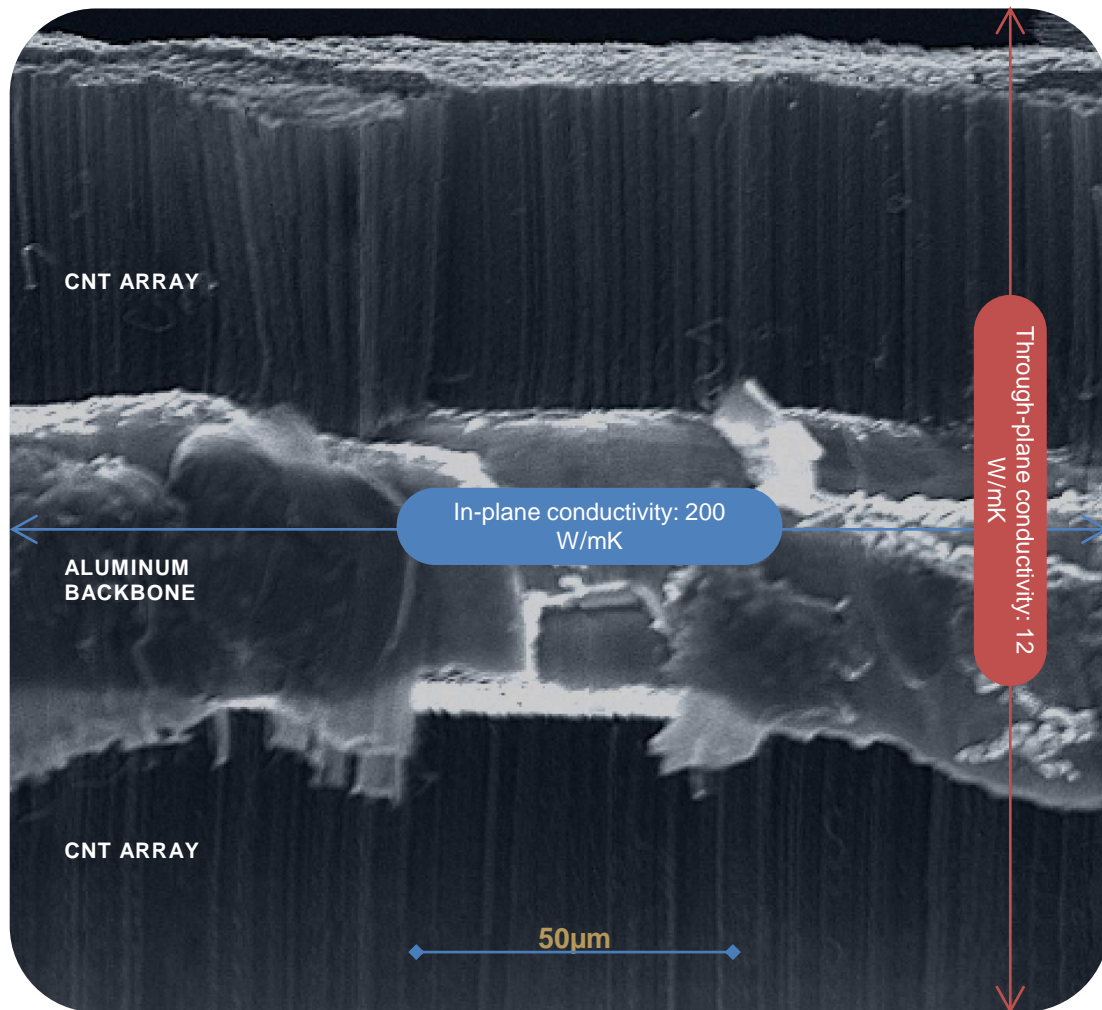


Deliver
*sustainable
solutions*

Continuous development of new thermal management technology

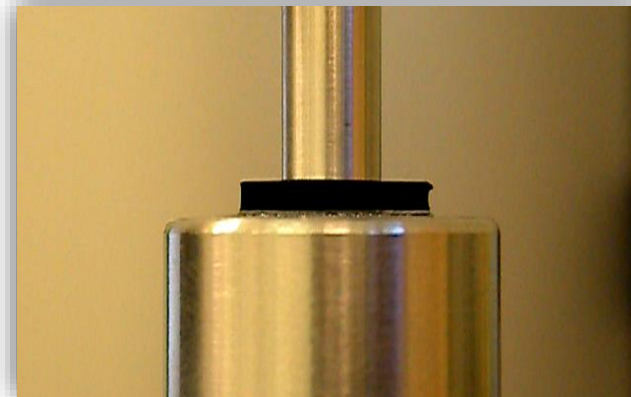


CARBICE TECHNOLOGY – VERTICALLY ALIGNED CARBON NANOTUBES (CNTs)



Fast Facts

- Vertically aligned carbon nanotubes grown from aluminum foil substrate
- Through plane conductivity – 12 W/mK
- Aluminum x-y plane – 200 W/mK
- CNT infiltrated with polymeric binder to stabilize the structure and provide wetting



Aligned CNTs enhance compressibility compared to other carbon-based solutions

Learn more at Carbice.com



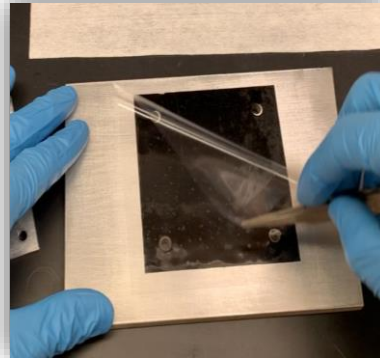
CARBICE PAD PROVIDES A UNIQUE THERMAL SOLUTION

RELIABLE



- Thermal resistance at end of product life same as at time zero (does not degrade)
- Compressive and shear stress does not break material in application (no impact from CTE mismatch)
- Absorbs shock loads

EASY TO USE



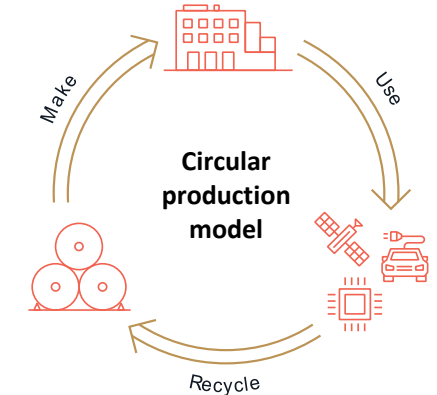
- Robust pad application that won't tear
- Peel-n-stick application
- Simple peel off re-work

AFFORDABLE



- Easy to use pad lends itself to high volume pick and place manufacturing
- Design pad for application
- Optimize assembly costs

SUSTAINABILITY



- Carbice Pads are manufactured using recycled aluminum and waste carbon gas in a low temperature circular production model
- The carbon and aluminum provide a stable chemistry that enhances shelf life and enables flexibility with inventory and efficient supply utilization.



CARBICE® SW-90 PRODUCT HIGHLIGHTS

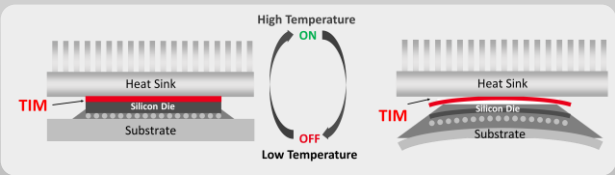


Performance like a *liquid*, user experience of a *pad*

Reliability

No concerns of pump-out behavior due to robust base pad by Carbice

Enhanced temperature range and stability provided Dow Silicones



Versatility

Near ambient seasoning temperature in contrast to PCMs and adhesives

Si wax tuned to temperature requirement for TIM



Re-workable

Tacky, but non-adhesive behavior allows for removal on demand

Enables rework of assembly components when necessary



- **Target applications:** ADAS module, Electronics, Communication, + more
- Available for sampling, commercialization **H2 2025**

	Carbice® SW-90
Thermal Resistance @30 psi [cm ² -K/W]	0.13
Initial Thickness [μm]	90
Lap Shear Adhesion [Mpa]	0.02
Operating Temperature [°C]	-55 to +150

Carbice SW-90



Made with
Dow Technology



CARBICE® SA-90 PRODUCT HIGHLIGHTS

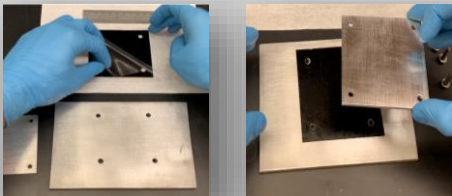


Exceptional *thermal* performance with the functionality of an adhesive

Assembly

Unique benefits in fabrication reducing the need for mechanical fastening

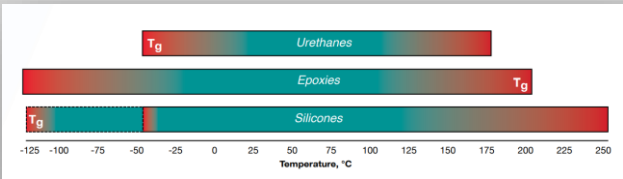
Easily adopted where pick and place is currently used



Thermal Stability

Reliable high temperature stability compared to organic adhesives enabled by Dow Silicone

Usable temperature range of Silicones vs. Organics



Re-workable

Stays in place due to adhesive nature, but retains ability to remove for rework of components



- **Target applications:** Inverter, IGBT, data centers, semiconductor, LED + more
- Available for sampling, commercialization **H2 2025**

	Carbice® SA-90
Thermal Resistance @30 psi [cm ² -K/W]	0.5
Initial Thickness [μm]	90
Lap Shear Adhesion [Mpa]	0.1
Operating Temperature [°C]	-55 to +200

Carbice SA-90



Made with
Dow Technology





Thank you

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Project #

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