



THERMALLY CONDUCTIVE MATERIALS FOR POWER ELECTRONICS OVERVIEW

James Walker
Senior R&D Leader

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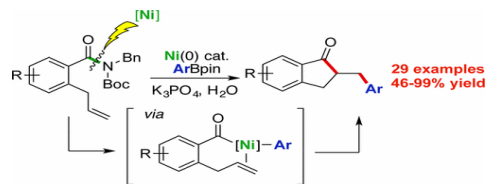
ACKNOWLEDGEMENT

R&D labs around the globe



- Critical Contributors: Joe Sootsman, Stephanie Valenzuela, Emma Gonzalez, Andrés Becerra, Brad Tuft, Praveen Agarwal, Alvin Gwon and many others!

JAMES WALKER BACKGROUND



J. Am. Chem. Soc., 2017, 139, 30, 10228-10231

2017

PhD, Iowa State University
Organic Chemistry

2012

University of Cincinnati
BS, Chemistry

Core R&D

2018

Senior Chemist
Catalyst Discovery

2020

Associate Research Scientist
Catalyst Discovery

Dow Consumer Solutions

2021

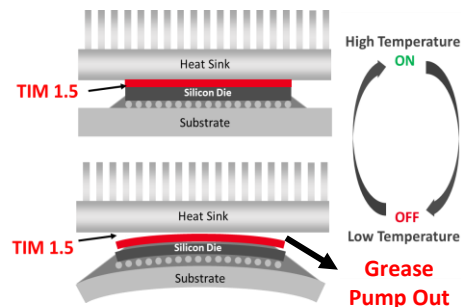
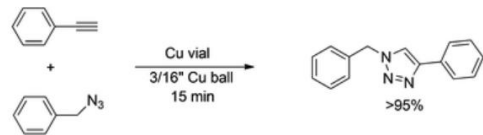
Associate Research Scientist
Engineered Materials PD

2023

R&D Leader/Associate Research Scientist
Engineered Materials PD

2025

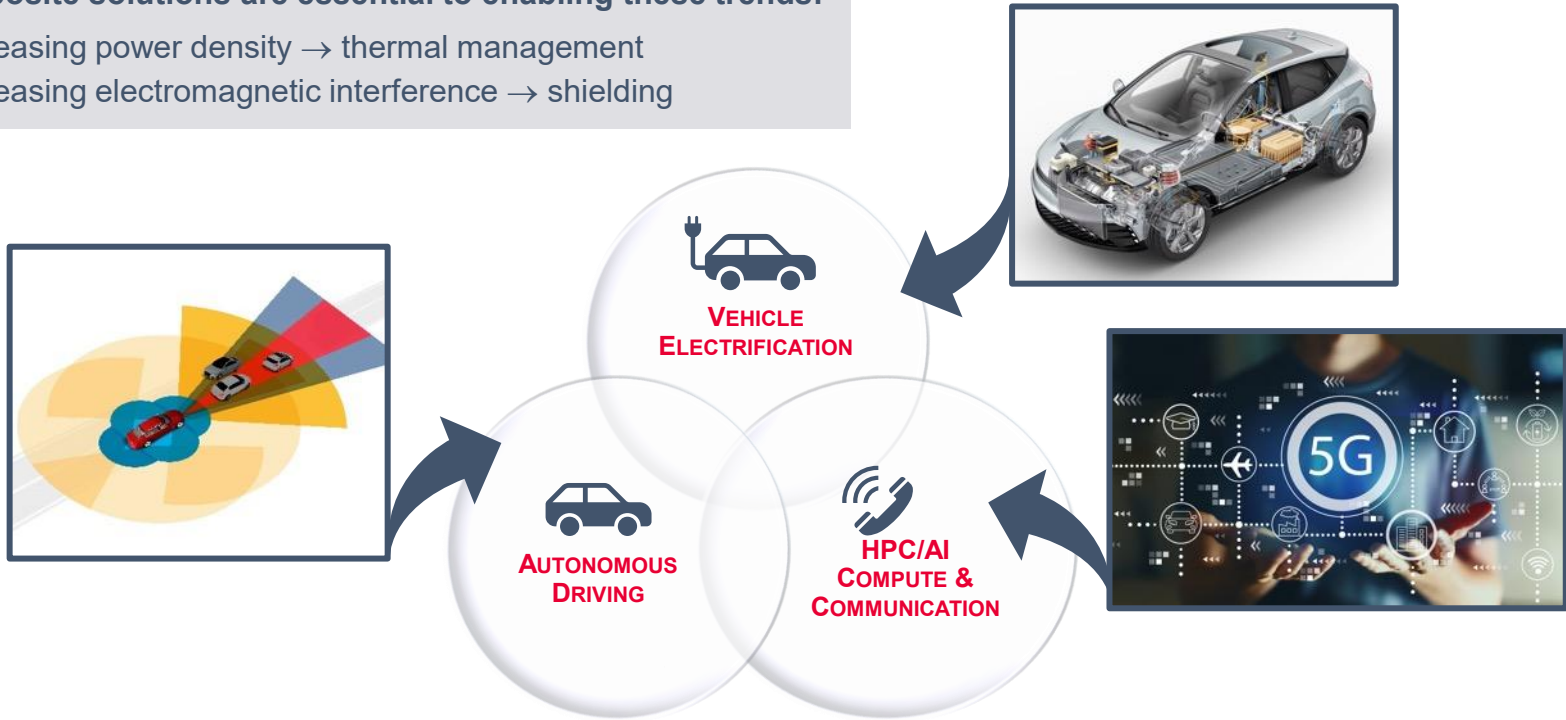
Senior R&D Leader
Engineered Materials PD



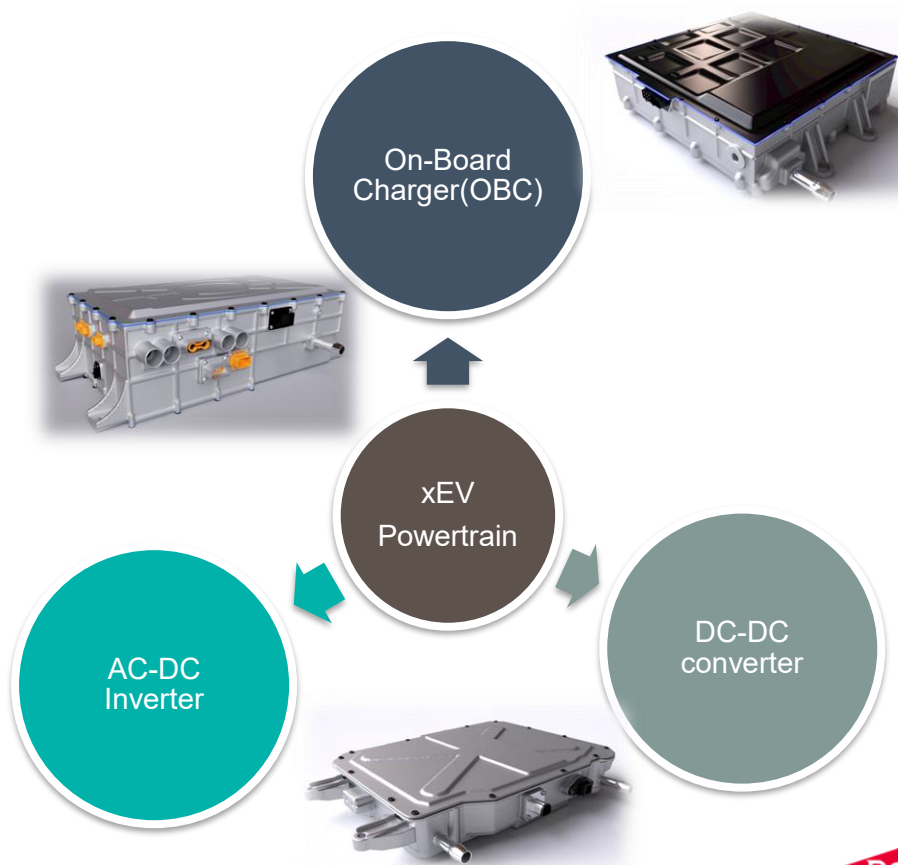
INTERSECTING TECHNOLOGY AND APPLICATIONS ARE DRIVING THE NEED FOR ADVANCED MATERIALS

Composite solutions are essential to enabling these trends:

- Increasing power density → thermal management
- Increasing electromagnetic interference → shielding



APPLICATIONS



■ xEV

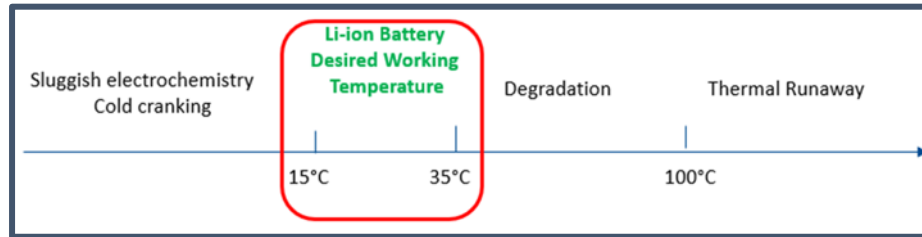
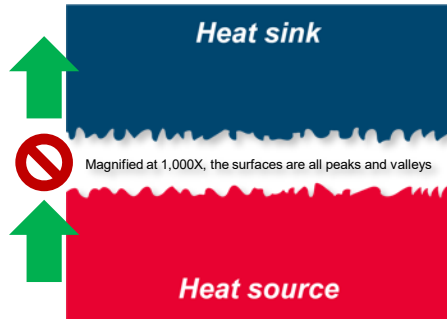
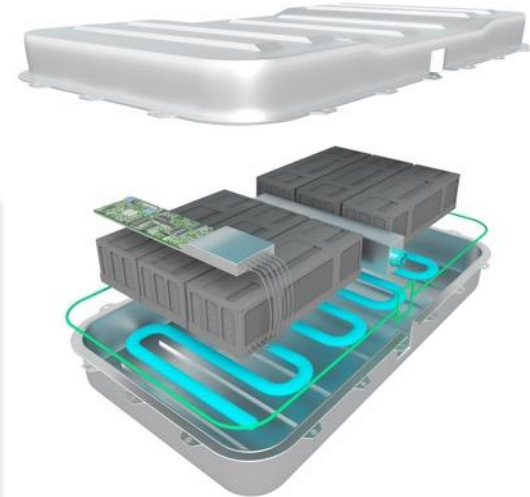
- On-board charger(OBC)
- DC-DC converter
- AC-DC inverter
- Other electric & electronic components

■ Industrial & electrical

- Inductor/transformer for solar power electronics
- SMPS(Switched Mode Power Supply) for LED

ELECTRONIC PERFORMANCE IS ENABLED BY THERMAL MANAGEMENT

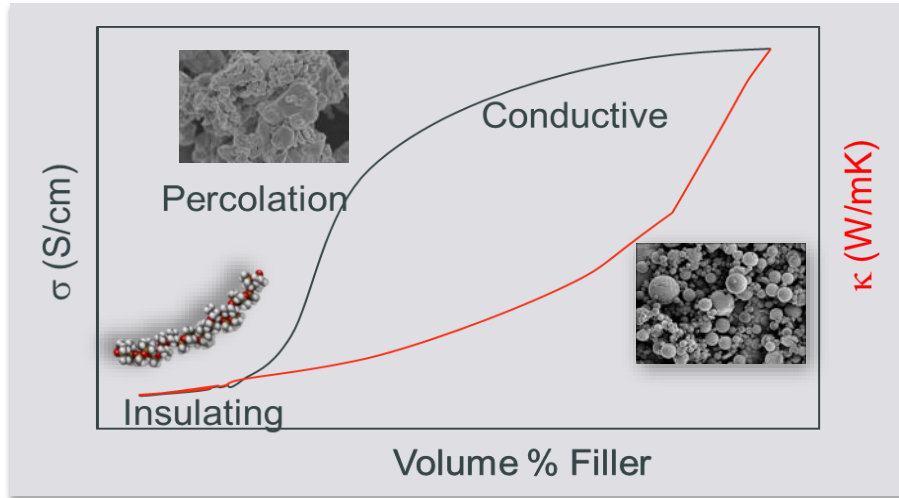
- Electronic devices generate waste heat
- Heat must be dissipated to avoid efficiency reduction, device failure and catastrophic results
- Thermal interface materials mitigate roughness that causes poor heat transfer



ENGINEERED PARTICLE ASSEMBLY TO PROVIDE TRANSPORT

- 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

- 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

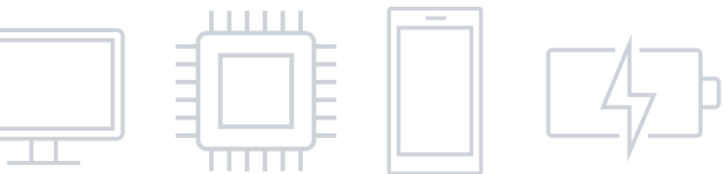
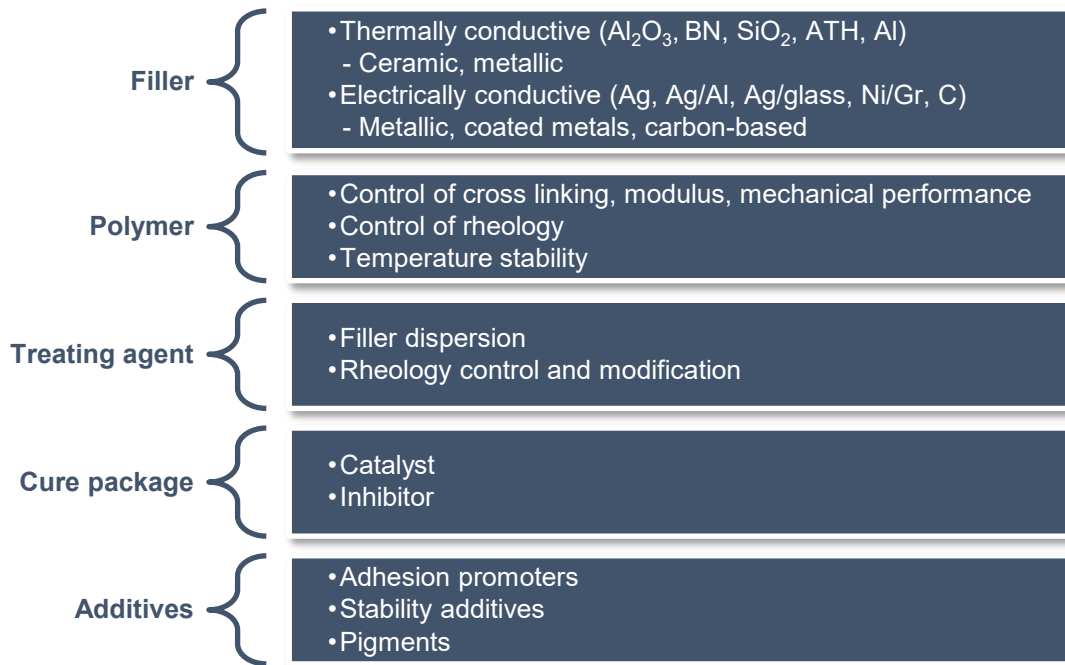


- Addition of fillers to matrix increases thermal conductivity by 3-40X polymer
- Common Tc fillers:
 - Al_2O_3
 - ZnO
 - BN
 - Aluminum trihydrate (ATH)
 - Aluminum

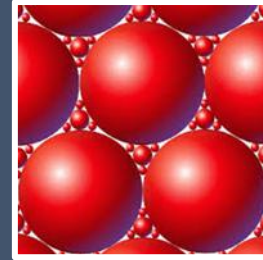
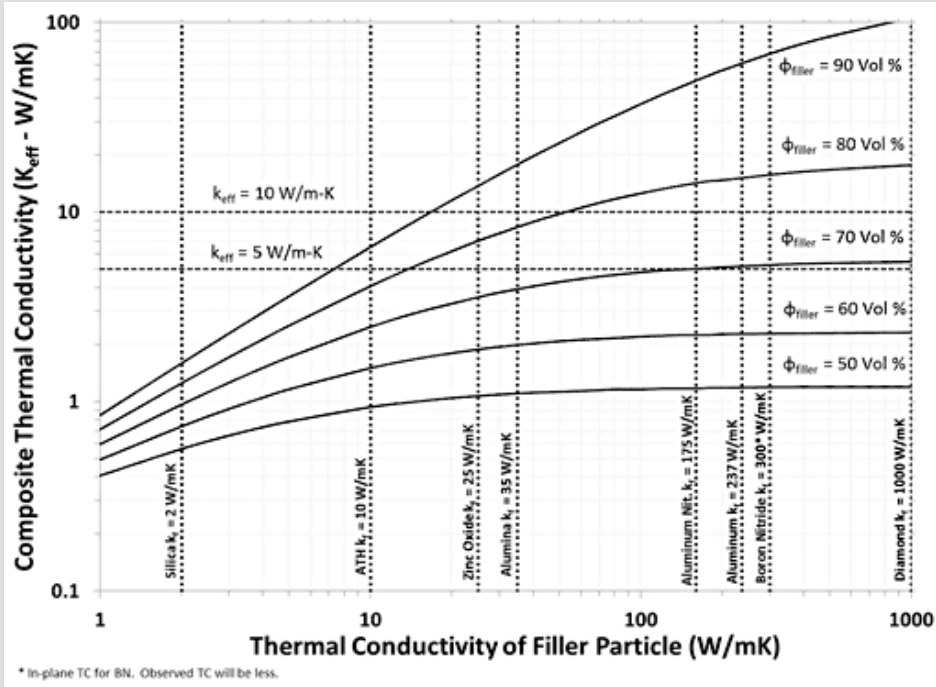
HIGHLY ENGINEERED PARTICLE COMPOSITES

Optimized to provide
unique balance of properties:

- Rheology
- Thermal/electrical conductivity
- Cure behavior
- Mechanical properties
 - Modulus
 - Adhesion
 - Strength/elongation



IMPACT OF FILLING VOLUME AND FILLER CONDUCTIVITY



$$k = D\rho C_p$$

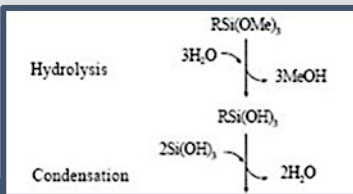
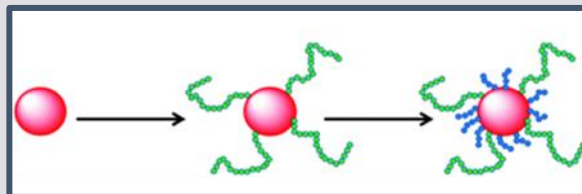
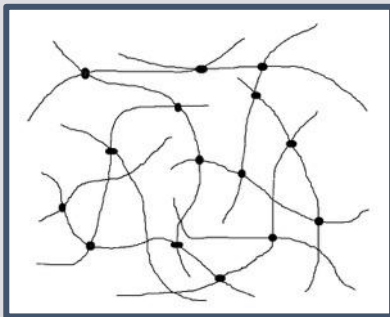
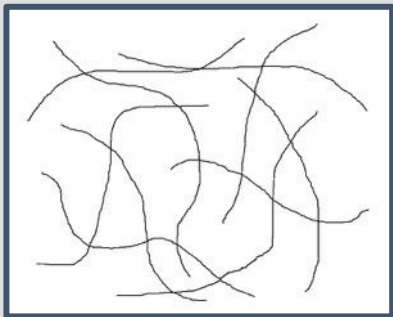
k = Thermal conductivity

D = Thermal diffusivity

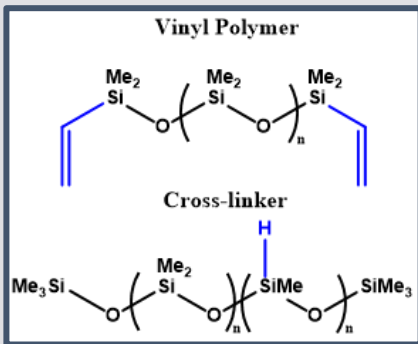
ρ = Density

C_p = Heat capacity

POLYMER MATRIX OPTIMIZATION – LEVERAGE KEY INTERMEDIATES

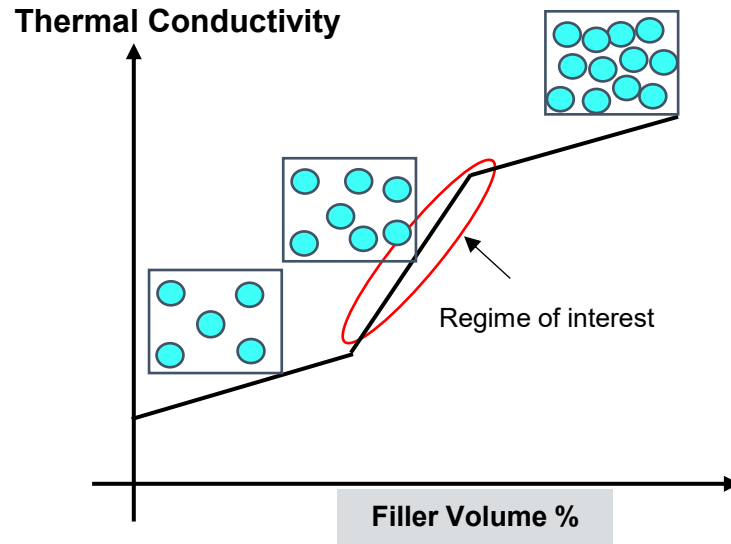
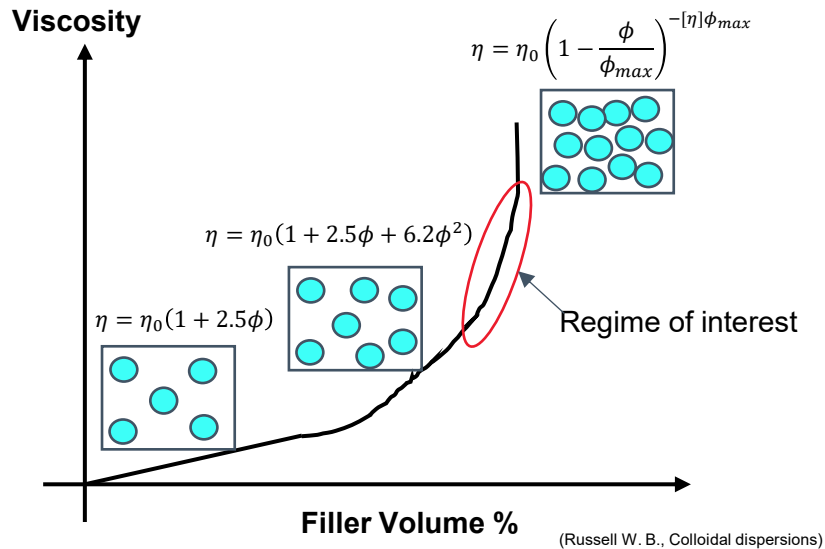


- Surface chemistry
- Matrix compatibility



- Chain lengths
- Cross-link density
- Viscosity
- Mechanical properties

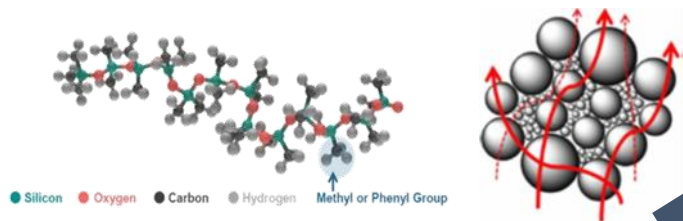
BALANCE OF RHEOLOGY AND TC IS KEY



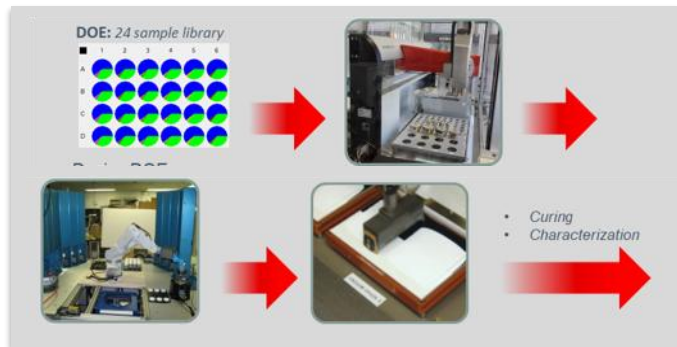
- Managing viscosity/processability at high filler loading is a key challenge
- Strong dependence of viscosity on filler loading makes formulating TCC highly challenging
- Filler selection and matrix filler interaction is key to achieve low viscosity/processability along with high TC

ELECTRONIC PERFORMANCE IS ENABLED BY THERMAL MANAGEMENT

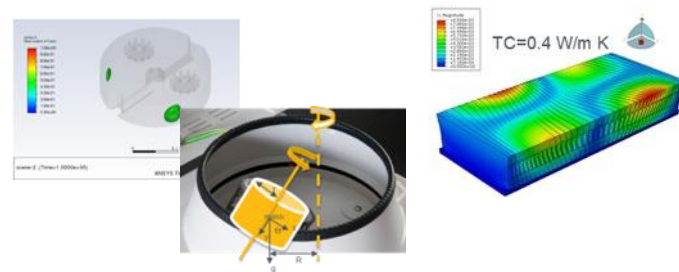
- **Foundational research** – Building and leveraging competency and understanding in conductive composite formulation science



- **High-throughput screening** – Accelerate and improve workflow for formulation and process



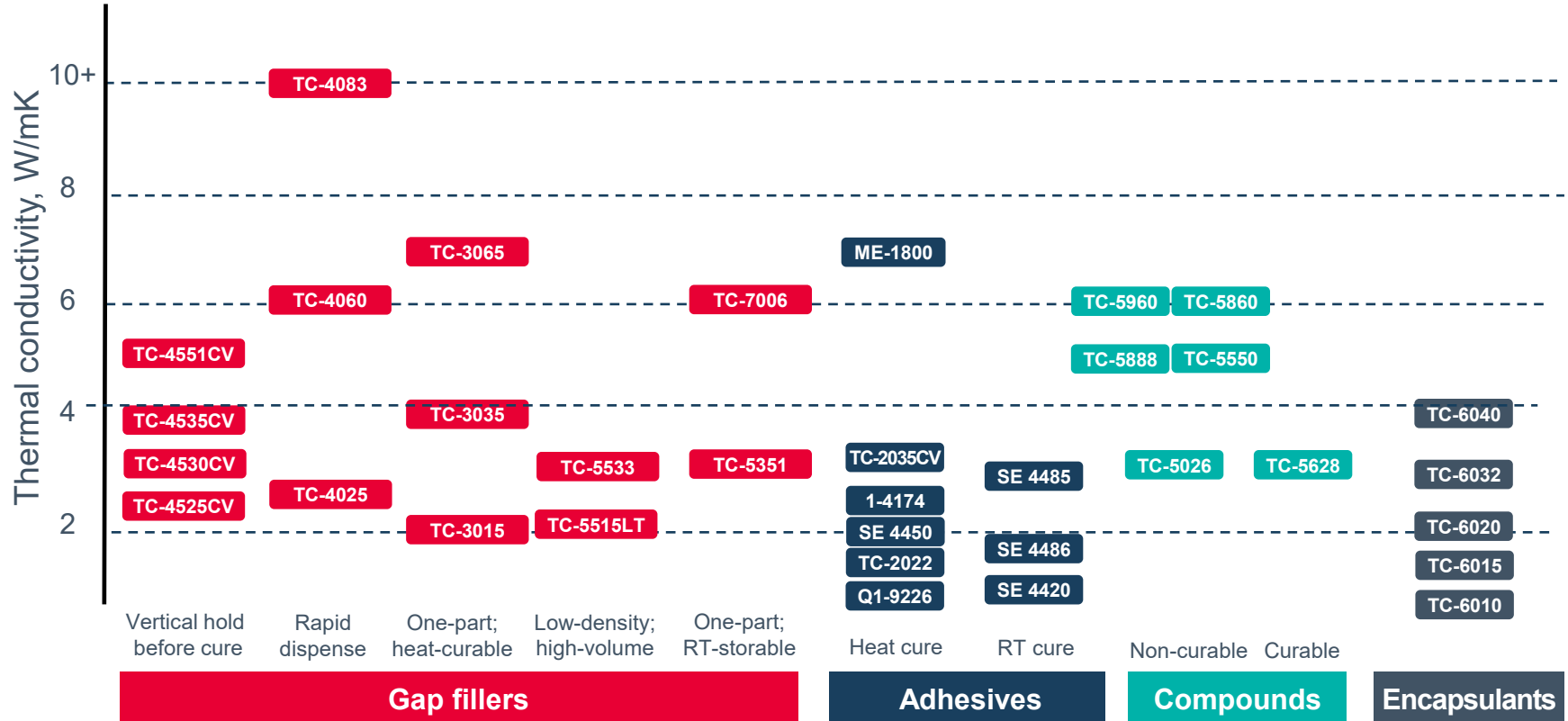
- **Modeling** – Enable faster scale up and understanding of filler dispersion in products and thermal performance in application



- **Application Science** – Enable easy adoption of materials and fundamental test capability to support customers



SELECT DOWSIL™ THERMALLY CONDUCTIVE PRODUCTS



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



DOWSIL™ TC-6032

Thermally Conductive Encapsulant







DOWSIL™ TC-6032

Thermally Conductive Encapsulant

DOWSIL™ TC-6032 is a new thermal conductive encapsulant with high thermal conductivity that delivers controlled volatility, and reliable performances in automotive power and electronics application.

Applications:

- On-board charger(OBC) for EV
- DC/DC converter for EV and FCEV
- Inductor and Transformer for Solar Power Electronics
- Switched Mode Power Supply (SMPS) for LED
- Other electronic and electric parts for thermal management

Key benefits:

- Lower viscosity for impregnation and its flowability
- Less filler caking and easy re-homogenous
- Thermal Conductivity at **3.2 W/m·K**
- Excellent high temperature stability at **150°C**
- UL 94 V-0 Flammability
- Low volatile content (D4-D10) **<100ppm (0.01%)**

FOLLOW-UP



James Walker - LinkedIn Profile

Phone: 989-636-4102

Email: jawalker@dow.com



Dowsil™ TC-6032 Thermally Conductive Encapsulant





THANK YOU

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