pcim
ASIA SHANGHAI

The High Performance Materials Developing for Power Module

Shihuan Lu, Sumitomo Bakelite (Suzhou) Co., Ltd.

Contents

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1. Overview : Next-gen Power Modules and Packaging Materials
2. Packaging Materials for Advanced Power Modules
    1. Epoxy Molding Compound (EMC)
    2. Thermal Interface Materials (TIM)
3. Conclusion

The Role of Power Module

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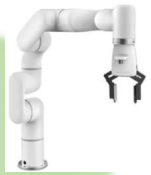
➢ **Power semiconductors control and convert the electrical power**

Power generation & conversion
- More efficient energy
- Clean energy
- Renewable energy



Consumption
- HEV, EV, Rail
- Environment-friendly appliances
- Smart house



➢ **WW target for clean and sustainable energy**

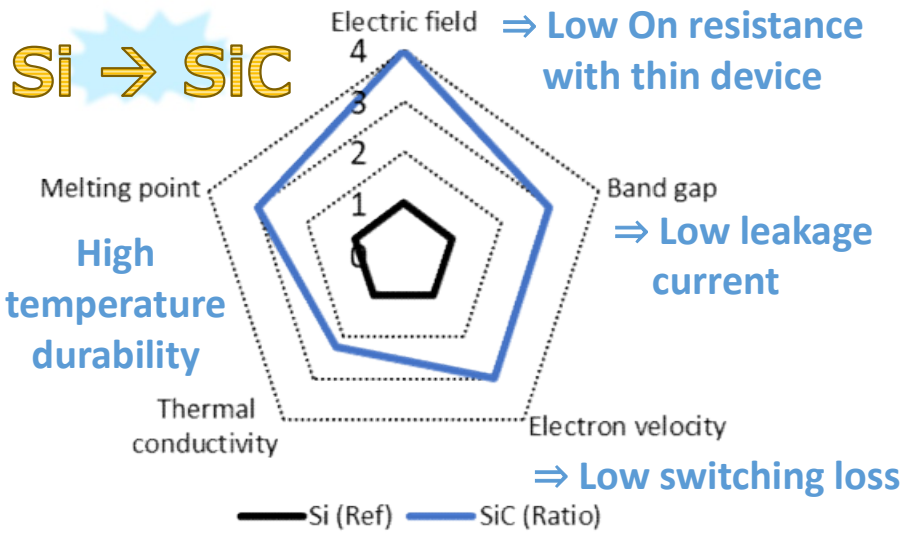
- Electric vehicle (EV)
- Renewable energy
- Carbon neutral

➡ **Increasing demand for high energy efficiency**

Demand is getting stronger for the devices with high energy efficiency

Wide-Bandgap Semiconductor & Its Requirement

➢ **Innovation through wide-bandgap semiconductors**

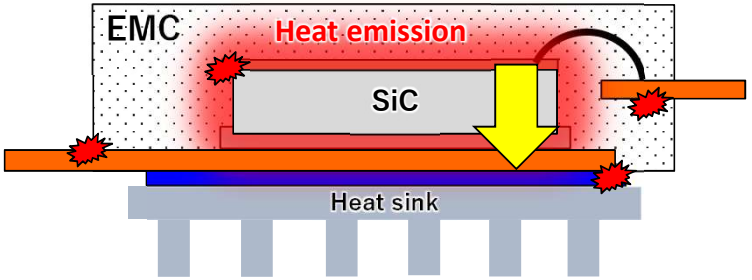


SiC chip enhances the performance and energy efficiency

➢ **The requirement from SiC to its package**

	Si	SiC
Apply voltage	≦ 650 V	**≧ 1200 V**
Junction temperature	≦ 175 ℃	**≧ 200 ℃**

➢ **Severe environment of SiC package**

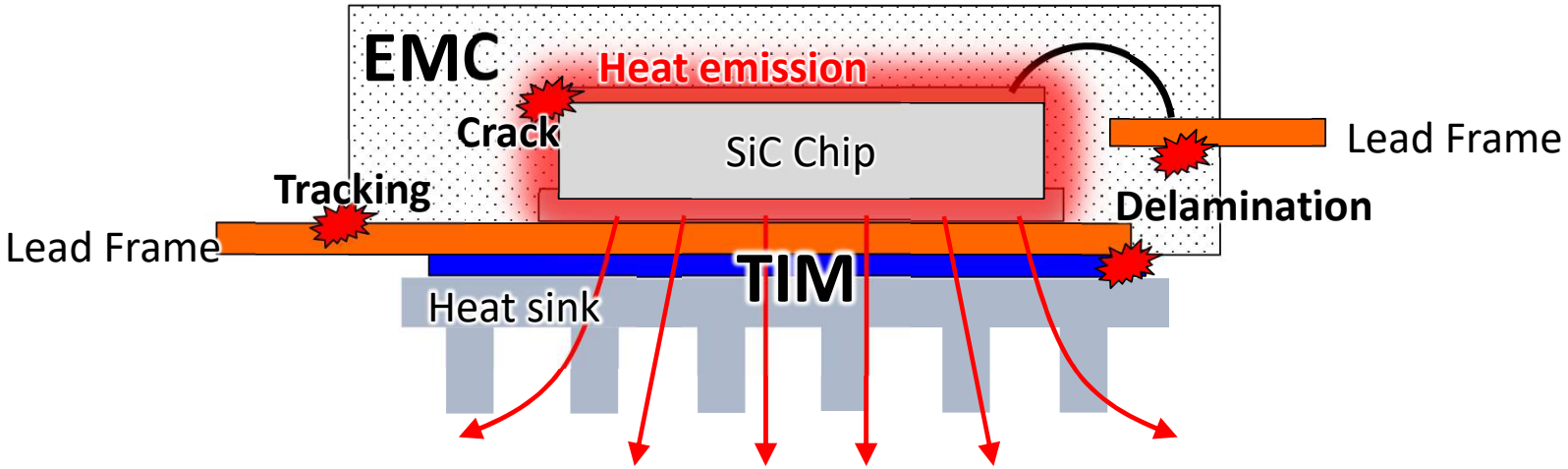


High voltage and current generate more heat, causing the damage to the package

SiC delivers high performance but imposes significant stress on its package

Requirement for Packaging Material for High Reliability

➢ **Major failure mode in SiC package**

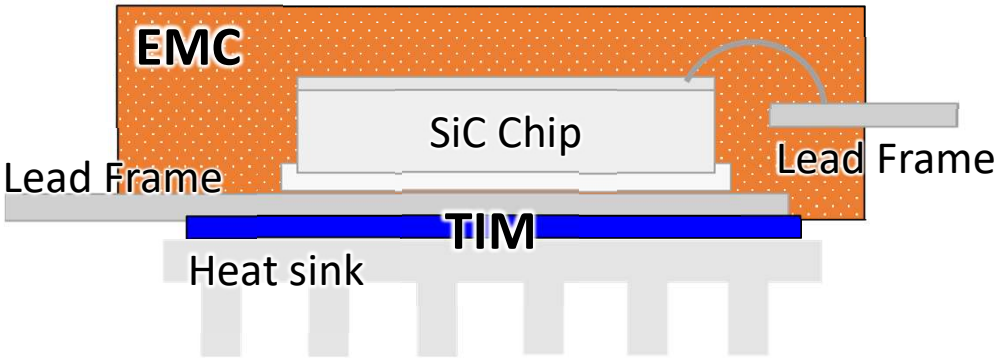


➢ **Requirement for packaging material**

PKG Requirement	High Tj : ≧ 200degC					High voltage : ≧1200V
Failure Mode	General		Delamination		Crack	Electrical tracking
Requirement for Packaging material	**High Tg**	**High thermal conductivity**	**Strong adhesion**	**Low modulus**	**High toughness**	**High insulation**

Proper selection of the packaging material is essential

The Innovation of Packaging Material



➢ **Thermal Interface Materials (TIM)**

Role :

- Joint between heat sink and lead frame
- Heat dissipation

Innovation :

- **High thermal dissipation**
- **With low Modulus**
- **Simple and moderate process**

➢ **Epoxy Molding Compound (EMC)**

Role :

- Mechanical protection of chip
- Electrical insulation

Innovation :

- **High Tg**
- **With low Modulus**
- **High insulation measured by CTI (Comparative Tracking Index)**
- **Strong Adhesion**

The innovation in packaging materials enhance the PKG reliability

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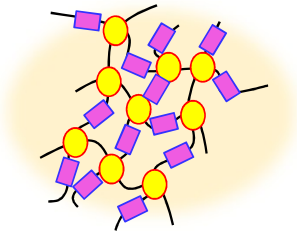
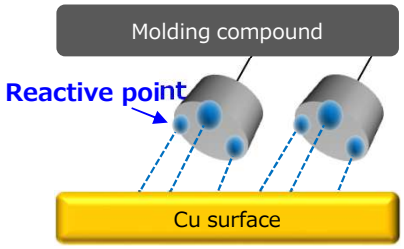
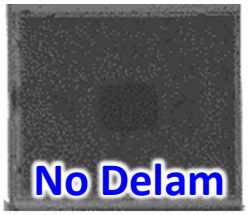
Overview of Epoxy Molding Compound (EMC)

➢ Outline of EMC development

High Temperature Operation	High Power	High Reliability
✓ Thermal Stability ▪ High Tg (≧240degC)	✓ High Insulation ▪ High CTI (≧ 600V)	✓ High Tg (≧240degC) ✓ High Toughness ✓ Strong Adhesion
	Electric carbonization 	
High cross linking & rigid structure resin	**Prevent from carbonized connection by additive**	**Multiple reactive point for stronger adhesion**

➢ High reliability under the severe environment

Replication study shows high reliability
- ✓ No delamination
- ✓ No crack



Test condition
at 230degC
with 15MPa/3min
(Full sintering)

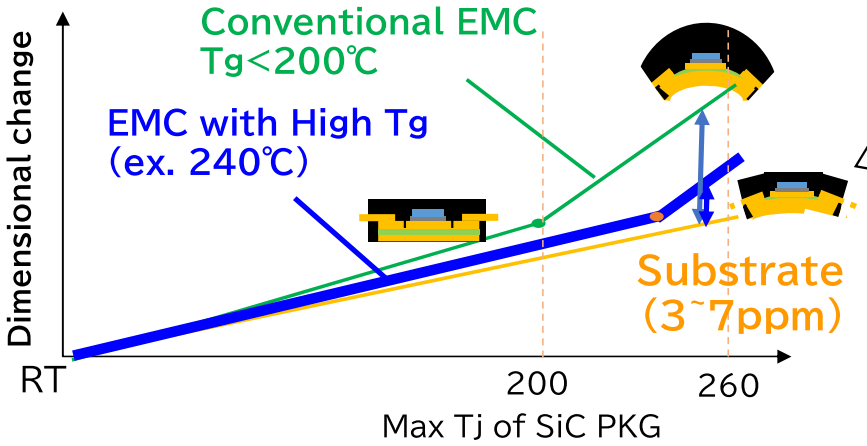
Several technologies are combined to achieve the high reliability

High Tg and Low Stress Design

➢ Importance of high Tg

Property	Temp > Tg
CTE	↑
Strength	↓
Modulus	↓
Adhesion	↓

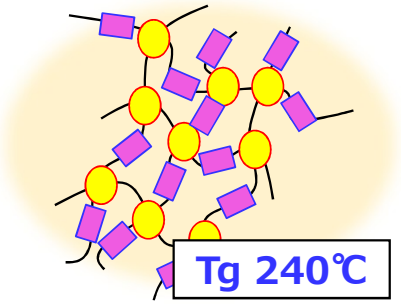
Resin property changes a lot at higher temp > Tg



High Tj >200degC operation is stabilised by Higher Tg resin, in terms of

- **Low warpage**
- **High strength**
- **High adhesion**

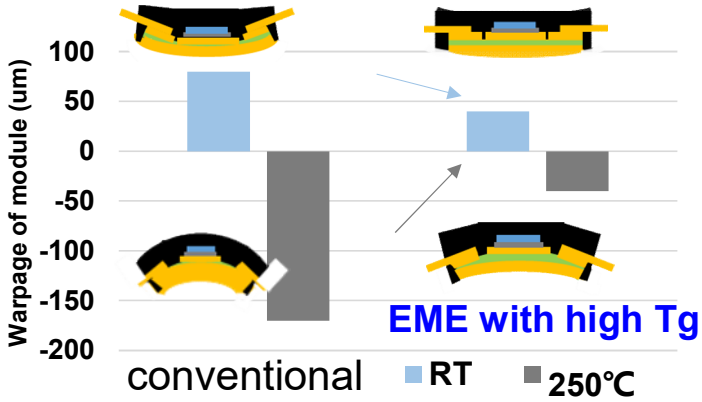
➢ High Tg and low stress resin design



Cross linking

Rigid structure

High cross linking & rigid structure raise Tg up but maintain Modulus

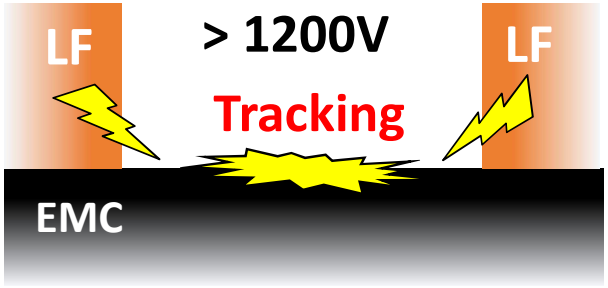


Lower warpage at RT & HT!

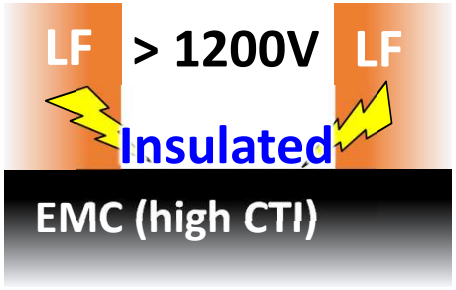
High Tg design improve the stability of the package and reduce warpage

High CTI Technology

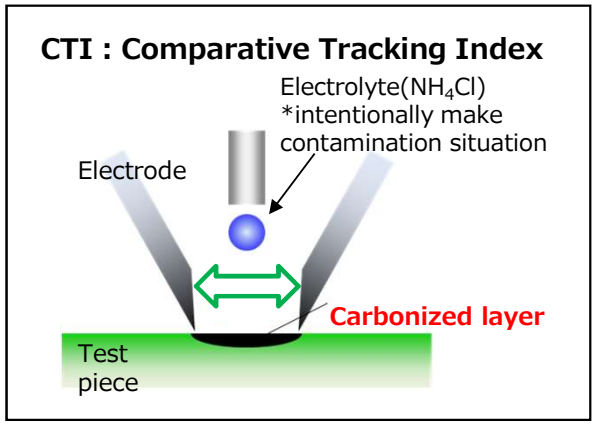
➢ Importance of high CTI



Electrical tracking may happen on the EME surface



High CTI allows the design flexible of PKG with narrow LF gap



➢ High CTI with additive

✓ **Conventional approach**
- High filler loading
- High CTI resin selection

⇒ **Limiting EMC design flexibility**

✓ **New approach using additive**

	Conventional	With additive
Image	Carbonized connection 	Prevent carbonized connection 
CTI result	PLC1 (575)	PLC 0 (600)

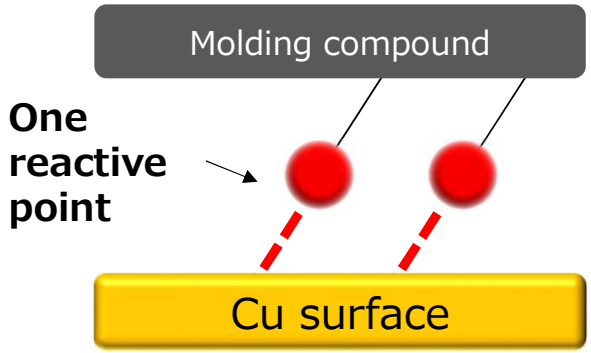
Approach using additive to achieve CTI 600V, even with low filler loading and a wide variety of resin options

High CTI additive expands the design flexibility of EMC

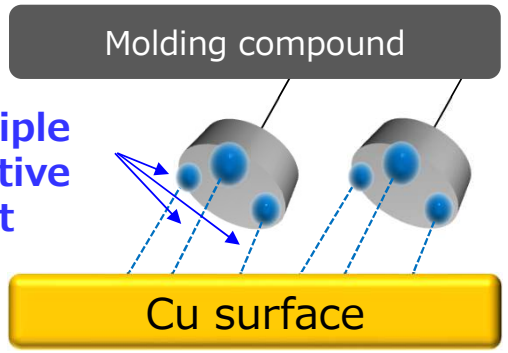
Strong adhesion under high thermal environment

➢ **Solution by adhesion promotor**

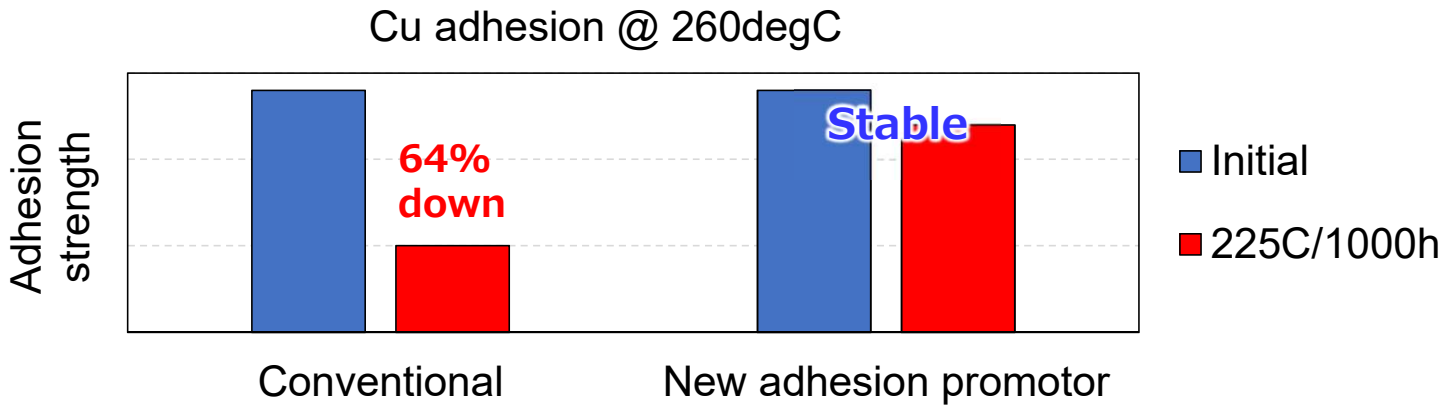
✓ **Conventional adhesion promotor**



✓ **High thermal adhesion promotor**



Multiple reactive point improves adhesion and its stability under high temperature.

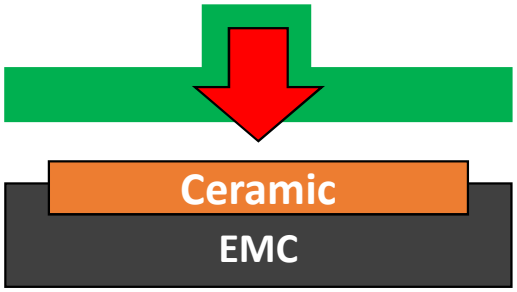


Multiple reactive points maintain adhesion even under high thermal conditions

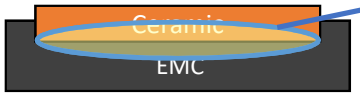
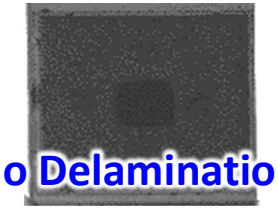
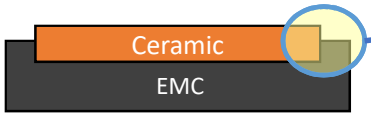
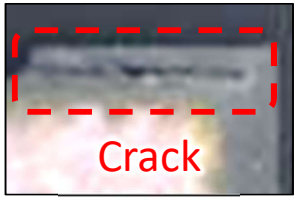
Verification Test

➢ Evaluation condition

Press mount
230degC / 15MPa / 3min



Under full sintering process, test PKG was subjected to high-temperature conditions with applied pressure.

Grade		Conventional	New
Resin type		Conventional multi functional resin	**High cross linking & rigid structure**
Adhesion promotor		Single reactive point	**Multiple reactive points**
Property			
Tg	℃	195	**240**
Modulus	GPa	17.0	**13.5**
Cu Adhesion @260degC	MPa	2.3	**2.8**
Reliability test			
Delamination Checked by CSAM 			
Crack 			

New technologies improve the robustness of the package

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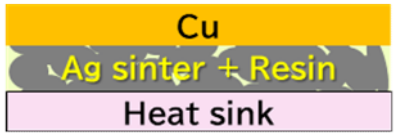
Overview of Thermal Interface Materials (TIM)

➢ The introduction of semi sintering material as TIM

High Temperature Operation	Internal damage to package	High Reliability
✓ Thermal Dissipation ▪ Low thermal resistance by thin layer ✓ Resistance to Stress ▪ Low modulus	✓ Moderate and simple process ▪ Lower temperature process ▪ Press less condition	✓ Robustness ▪ Low modulus ✓ Low stress ▪ Moderate process

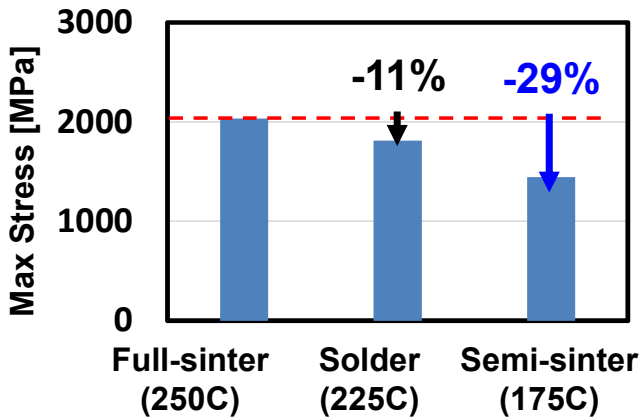
Thin BLT & No BSM



BLT (um)	50
Elastic modulus (GPa)	6
Thermal resistance (mm2K/W)	2.5

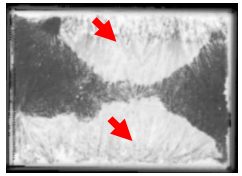
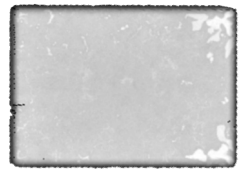
Low modulus design with low thermal resistance

Maximum stress value



Less stress in process

* TC condition : -40℃⇔125℃/15min hold
* SAT : C-scan

Solder	
Semi sintering	

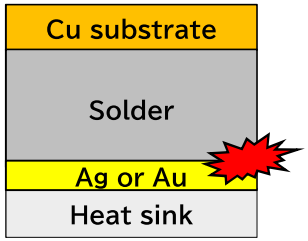
No delamination after TC

Semi sintering is introduced as a solution for high robust TIM material

Balance of Thermal Conductivity and Low Modulus

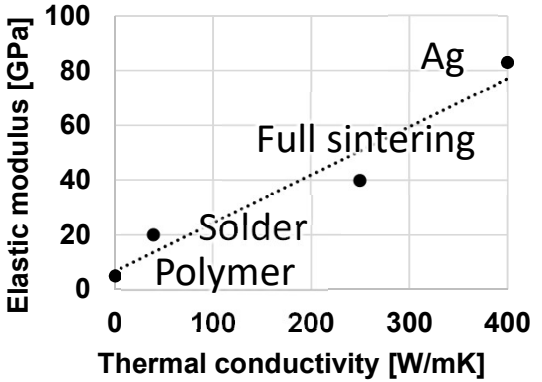
➢ Challenge in interface material for high Tj era

✓ SAT image of the interface after TC

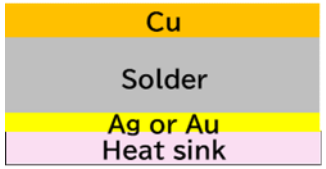
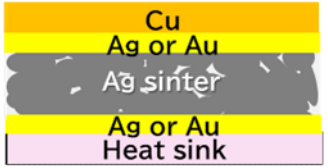
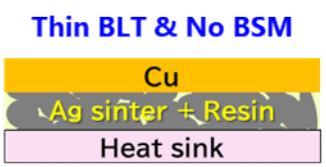


High Tj causes high stress, resulting in delamination on the interface

Trade off : TC vs Modulus



➢ Solution by semi sintering process

	Ref. Solder	Full Sintering	Semi Sintering
Image after mounting			
Elastic modulus (GPa)	20	40	**6**
BLT (um)	300	300	**50**
Thermal conductivity (W/mK)	40	250	**20**
Thermal resistance (mm2K/W)	7.5	1.2	**2.5**

Low modulus and high adhesion enable high reliability even with **thin BLT**, resulting in low thermal resistance.

Semi sintering provides low modulus with high thermal dissipation by thin layer

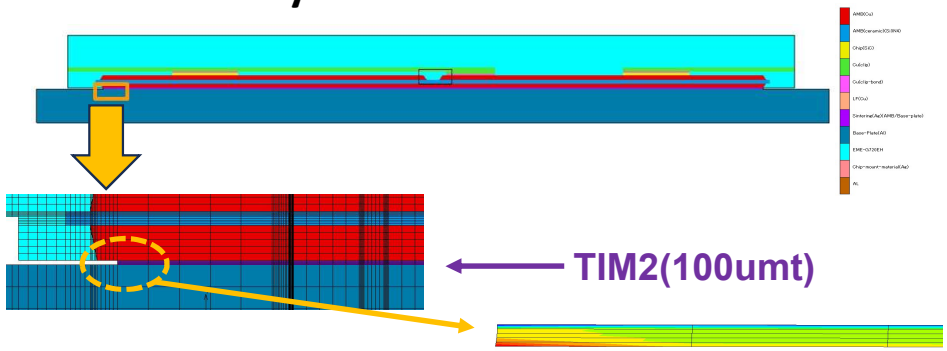
Simple and Moderate Process

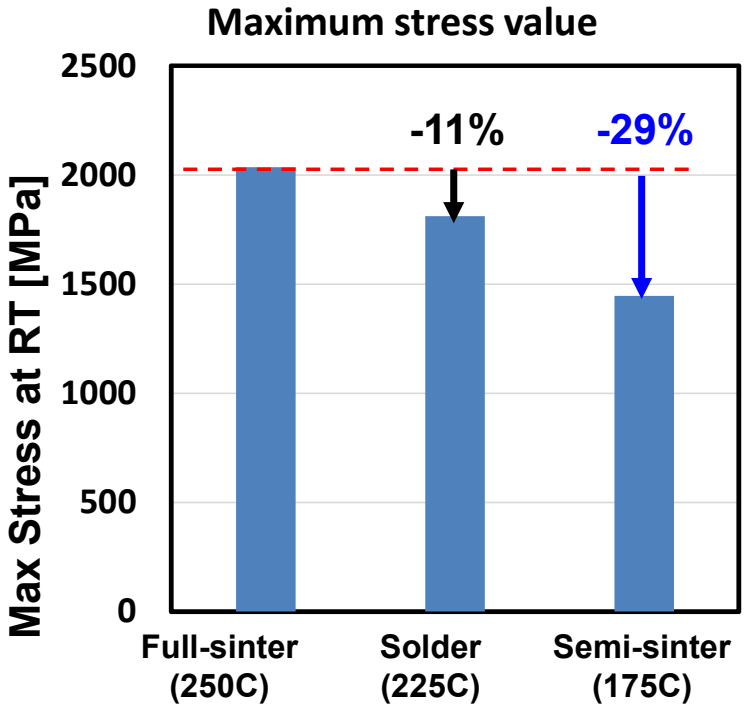
Adhesive	Process	Key point
Solder (Melting)	Dispensing /Printing → Heat sink Mount 220°C< → Heat sink	• Warpage • Heat damage
Full sintering (Press)	Printing → Heat sink Dry 80-150°C → Heat sink Press mount 15MPa, <250~300°C → Heat sink	• Warpage • Heat damage • Press damage
Semi sintering (Non press)	Dispensing /Printing → Heat sink Mount RT → Heat sink Oven <200°C → Heat sink	• Low warpage • Heat damage less • Press damage less

Semi sintering allows moderate process that minimizes damage caused by heat and pressure

Stress simulation

➢ **Simulation by 2D model**





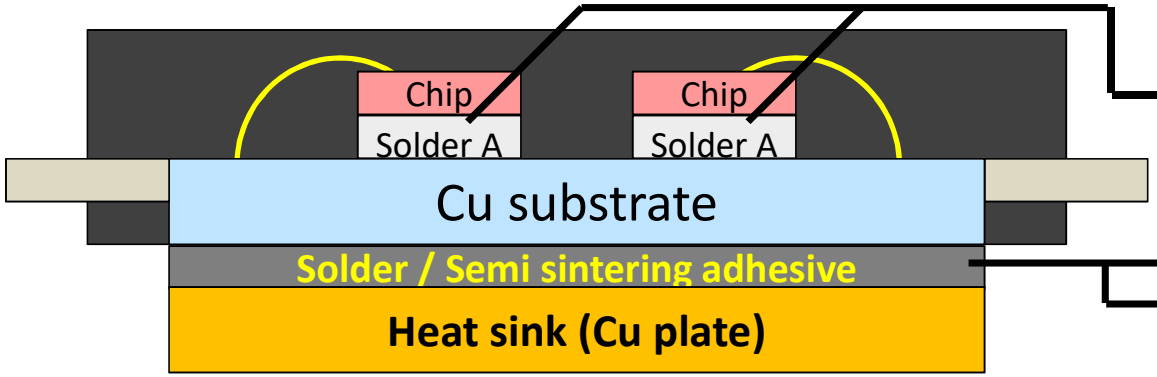
➢ **Property table used in the simulation**

		Full-sinter	Solder	Semi-sinter
E1	MPa	44000	41600	13900
E2		22000	41600	2900
CTE1	ppm	20	22	40
CTE2		20	22	90
Tg	℃	-	-	60

Mold(175C)→TIM2 attach at 175~250C
(25C(Smile warp.), High temp.175~250C (Cry warp.))
→Stress analysis on TIM2 at 25C

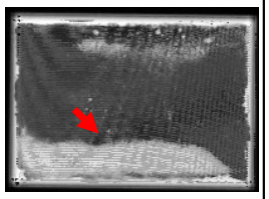
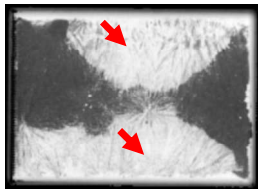
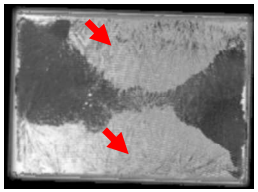
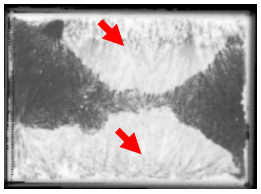
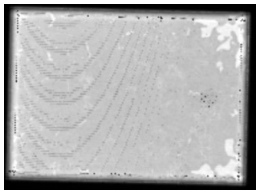
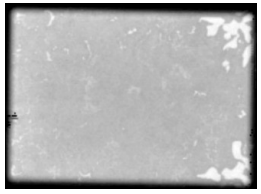
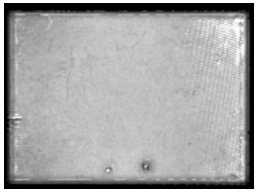
Stress simulation indicates lower stress during semi-sintering process

Verification Test



<Chip attach>
・Solder A

<Heat sink attach>
・**Solder B**
・**Semi sintering adhesive**

	TC0	TC250	TC500	TC1000
Solder (BLT : 50um)				
Semi sintering (BLT : 50um)				

* Size : 28 x 39 mm
* TC condition :
  -40℃⇔125℃/15min hold
* SAT : C-scan

Semi-sintering significantly enhances the robustness of the package

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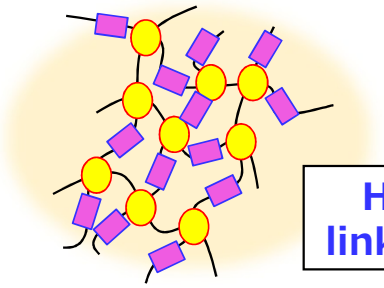
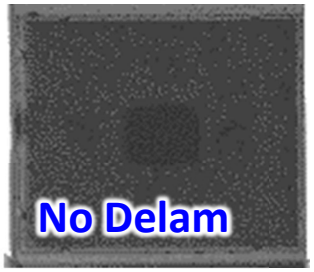
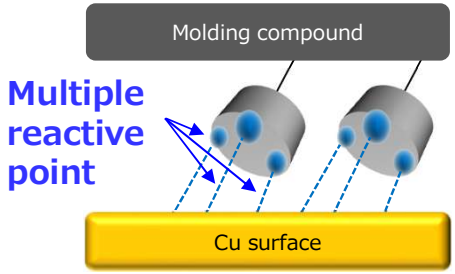
Conclusion

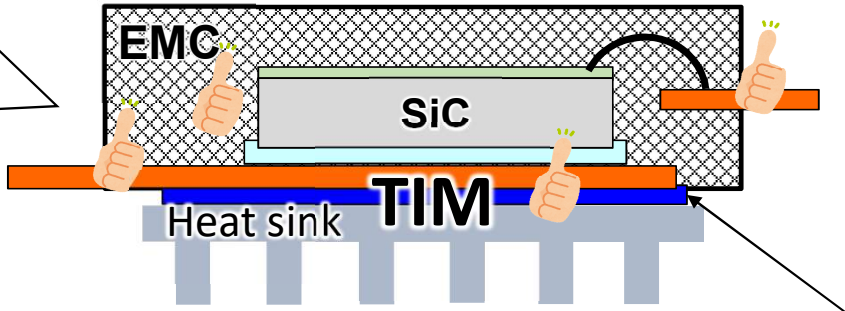


High cross linking & rigid

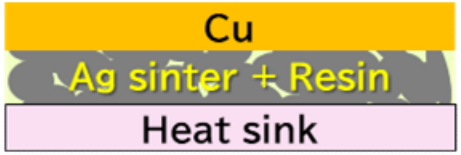




Prevent carbonized connection by additive



Thin BLT & No BSM



	Si	SiC
Apply voltage	< 650 V	**> 1200 V**
Junction temperature	< 175 degC	**> 200 degC**

BLT (um)	**50**
Elastic modulus (GPa)	**6**
Thermal resistance (mm2K/W)	**2.5**

High Tg EMC and semi-sintering TIM provide an effective solution for SiC PKG applications

pcim
ASIA SHANGHAI

Thank you