GRAPHENOL PCM

Phase Change Coated Heat Spreading Graphite Film

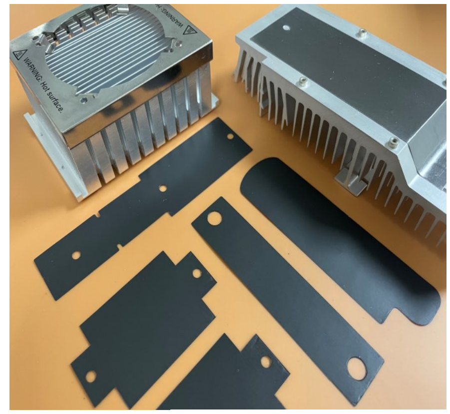
Type PCM: 50^{o}C Phase Change Coating

In-Plane Thermal Conductivity: 1,500 W/m-K

Graphenol PCM is a new dual function thermal interface material that brings together the distinct features of an ultra-high lateral heat spreading film packaged with the ultra-low surface resistance capability of our thermally conductive phase change compound. Graphenol PCM is suitable for many types of standard thermal applications or lateral heat flow requirements due to its dual function heat transfer capability (in-plane and enhanced thru-plane with the phase change coating).

Graphenol PCM differs from other pyrolytic based TIM materials on the market today by also offering signficantly better handling and installation characteristics. Graphenol PCM can be handled or processed without worry of breaks and/or shattering typically found in traditional pyrolytic graphite films. Due to its robust film design, Graphenol can be considered for applications that require the material to navigate bends and angles that may exist within interface with no impact in lateral heat spreading capability.

The unique 50C graphite filled phase change compound coating dramatically decreases surface resistance (especially at low pressures) allowing for efficient heat transfer from device into the heat spreading substrate allowing for efficient ultra-high lateral spreading along the XY plane. This same principal is true when heat traveling along the plane of the heat spreader and then dissipated through



PCM: phase change material

- PCM coating offers low surface resistance
- Double side or single side coating
- Standard and custom coating thicknesses
- Suitable for a range of flatness conditions
- Flexible—easily navigate angles and bends
- Silicone-free—solvent free compound design
- Low water absorption characteristics
- High thermal diffusivity
- Non-metallic TIM solution
- Excellent EMI-Shielding capability
- Electrically conductive film substrate
- Durable film—resistant to breaks and shatters

Typical Device Applications

- Battery Thermal Management
- High Power Density Energy Storage
- Automotive Inverter | Electronics
- Mobile Consumer Electronics
- LED Assembly
- Lighting (consumer or commercial)
- High End Computing
- Medical Electronics
- Robotics | Automation
- Microprocessor | Heat Sink
- Memory Module | Heat Sink
- EMI-Shielding

Graphenol PCM Properties

In-Plane (XY) Thermal Conductivity	1,500 W/m-K
Thru-Plane (Z) Thermal Conductivity	5.0 W/m-K
Base Material | Chemistry	Pyrolytic Graphite
Density	2.0 g/cm^3
Electrical Conductivity	14,000 S/cm
Water Absorption	< 0.1%
Bending Cycles	> 10,000 cycles
Max Operating Temperature (HS Film)	500C
Material Surface	Dry coating
Material Color	Black

For additional technical information on the HS film substrate utilized with the Graphenol PCM system, please review Graphenol HS at www.streuter.com

PCM Coating Characteristics

Phase Change Temperature	50^{o}C
Volumetric Expansion	15%
Viscosity	Thixotropic
Filler System	Graphite
Compound Design	Silicone/Solvent Free
Max Operating Temperature (PCM)	150^{o}C
PCM Code	F50

Graphenol PCM Substrate Film Thickness (HS)

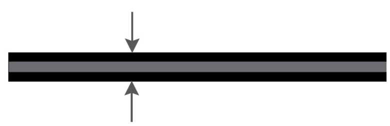
HS-32	32 microns | 1.26 mils
HS-40	40 microns | 1.57 mils

Graphenol PCM Coating Thickness

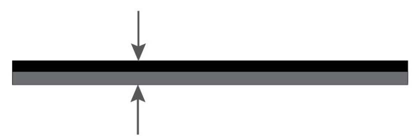
F50-05 (per side) standard	12.5 microns | 0.5 mils
F50-10 (per side)	25.4 microns | 1.0 mils
F50-13 (per side)	31.8 microns | 1.3 mils

Thicker coatings should be considered for applications that demonstrate larger flatness conditions across the interface plane.

Graphenol PCM Double Coated



Graphenol PCM Single Side Coated



PCM Delivery Formats

- Master rolls
- Sheets
- Die cut individuals
- Die cut continuous reels

Graphenol PCM Thermal Impedance (coated PCM vs uncoated HS)

Thermal impedance testing performed per ASTM D5470—50mm x 50mm specimen | 100 watt input

For single side coated materials, PCM coated side faced towards heat source.

HS-32 (1.26 mils)		**32-F50-05 (2.24 mils)**		**32-F50S-05 (1.75 mils)**	
Uncoated—Dry		**0.5 mil PCM both sides**		**0.5 mil PCM single side**	
5 PSI	0.299 ^{o}C-in^2 / W	5 PSI	0.049 ^{o}C-in^2 / W	5 PSI	0.092 ^{o}C-in^2 / W
10 PSI	0.290 ^{o}C-in^2 / W	10 PSI	0.043 ^{o}C-in^2 / W	10 PSI	0.085 ^{o}C-in^2 / W
20 PSI	0.193^{o}C-in^2 / W	20 PSI	0.036^{o}C-in^2 / W	20 PSI	0.067^{o}C-in^2 / W
40 PSI	0.074^{o}C-in^2 / W	40 PSI	0.029^{o}C-in^2 / W	40 PSI	0.049^{o}C-in^2 / W
80 PSI	0.028^{o}C-in^2 / W	80 PSI	0.024^{o}C-in^2 / W	80 PSI	0.027^{o}C-in^2 / W
100 PSI	0.025^{o}C-in^2 / W	100 PSI	0.022^{o}C-in^2 / W	100 PSI	0.024^{o}C-in^2 / W

HS-40 (1.57 mils)		**40-F50-05 (2.24 mils)**		**40-F50S-05 (2.07 mils)**	
Uncoated—Dry		**0.5 mil PCM both sides**		**0.5 mil PCM single side**	
5 PSI	0.328 ^{o}C-in^2 / W	5 PSI	0.052 ^{o}C-in^2 / W	5 PSI	0.110 ^{o}C-in^2 / W
10 PSI	0.315 ^{o}C-in^2 / W	10 PSI	0.046 ^{o}C-in^2 / W	10 PSI	0.098 ^{o}C-in^2 / W
20 PSI	0.226^{o}C-in^2 / W	20 PSI	0.040^{o}C-in^2 / W	20 PSI	0.073^{o}C-in^2 / W
40 PSI	0.117^{o}C-in^2 / W	40 PSI	0.034^{o}C-in^2 / W	40 PSI	0.064^{o}C-in^2 / W
80 PSI	0.047^{o}C-in^2 / W	80 PSI	0.027^{o}C-in^2 / W	80 PSI	0.041^{o}C-in^2 / W
100 PSI	0.036^{o}C-in^2 / W	100 PSI	0.026^{o}C-in^2 / W	100 PSI	0.034^{o}C-in^2 / W

* Thermal impedance comparison curve (PCM vs HS) shown on Page 2.

All data is for 0.5 mil coating thickness (both sides of single side).
Contact us for thermal impedance data for 1.0 mil and 1.3 mil coating thicknesses.

Graphenol PCM Thermal Impedance (coated PCM vs uncoated HS)

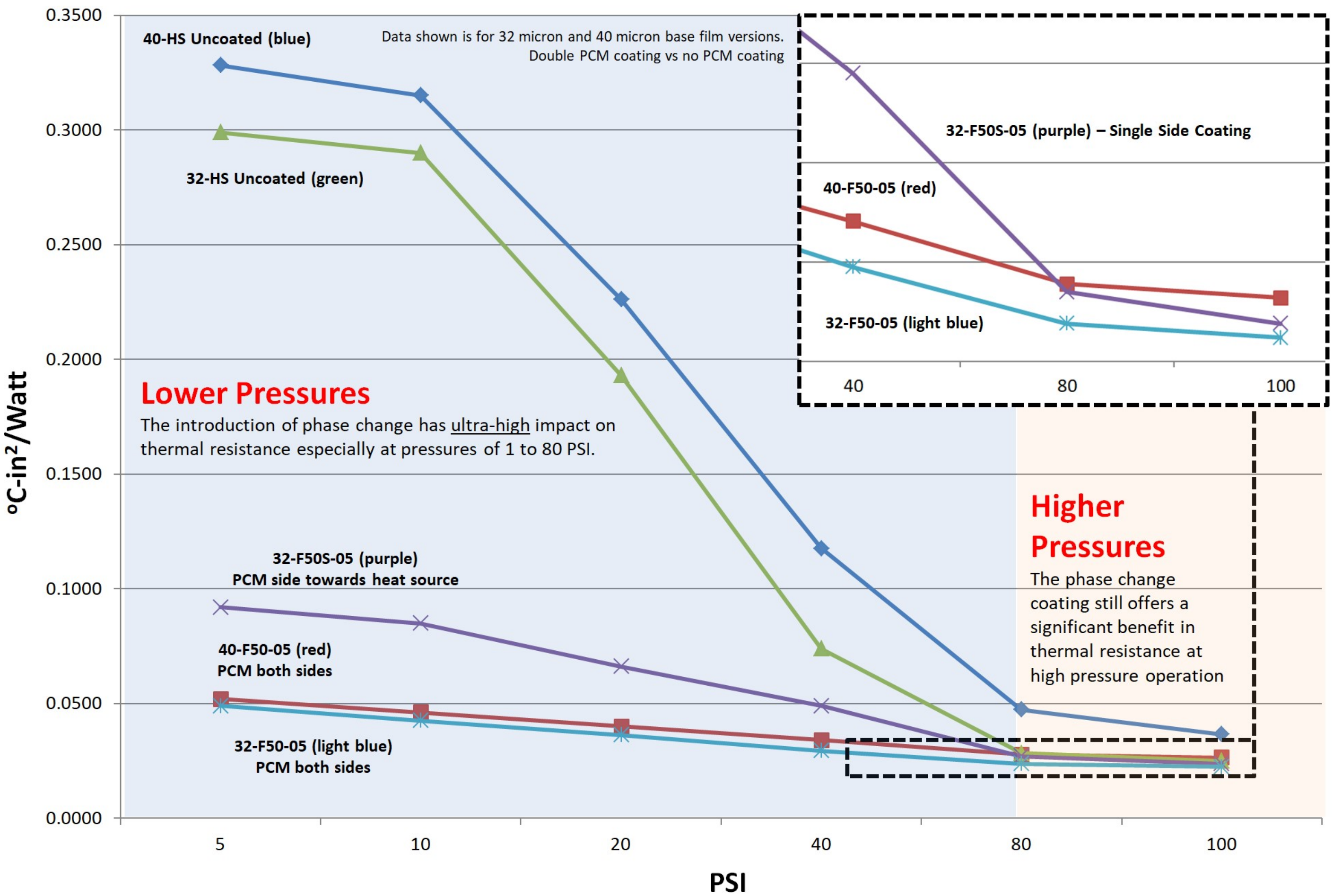
Thermal impedance testing performed per ASTM D5470—50mm x 50mm specimen | 100 watt input

For single side coated materials, PCM coated side faced towards heat source.

Applying the F50-05 type phase change compound coating to both sides of the Graphenol HS film substrate dramatically decreases surface resistance and offers a significant reduction in thermal impedance especially at low pressures. Single side phase change also provides a significant decrease in surface resistance between the device (heat source) and substrate film at lower pressures when a dry film is required on the cold side (point of dissipation).

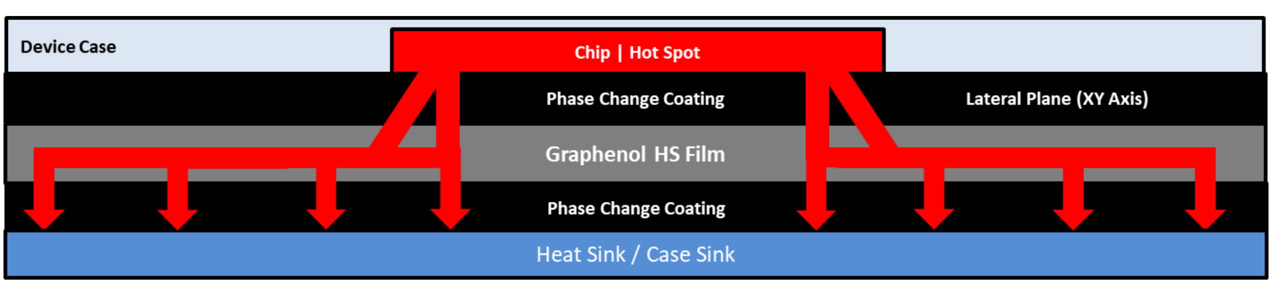
The F50-05 type phase change compound coating allows for effective heat transfer of the heat into the spreader substrate itself followed then with ultra-high efficient lateral heat spreading along the XY plane. This same principal is true when heat traveling along the plane of the heat spreader is then dissipated at the heat sink/case sink (cooling) location.

The reduction in surface resistance get the heat into the heat spreader film significantly quicker than an uncoated film with a dry (no phase change) interface junction.



Graphenol PCM within in Traditional Device | Sink Setup

Even though the phase change coating does not increase the already ultra-high in-plane (XY) thermal conductivity of 1,500 W/m-K found in the HS film substrate, it enhances the efficiency of getting the heat into and out of the heat spreader film substrate through a significant reduction in surface resistance between device and film substrate….and then film substrate into sink.



GRAPHENOL PCM

Phase Change Coated Heat Spreading Graphite Film

Type PCM: 50°C Phase Change Coating

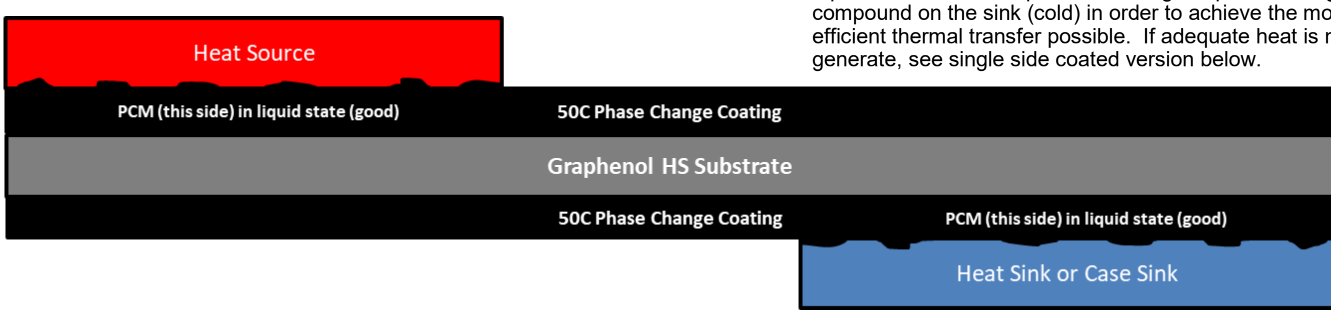
In-Plane Thermal Conductivity: 1,500 W/m-K

Graphenol PCM within in Lateral Device / Sink Setups

Applications where the heat source and heat sink/case sink are located laterally from one another (lateral distance between the two), the interface (contact) temperature on the cooling side must generate enough heat to phase change the thermal compound coating.

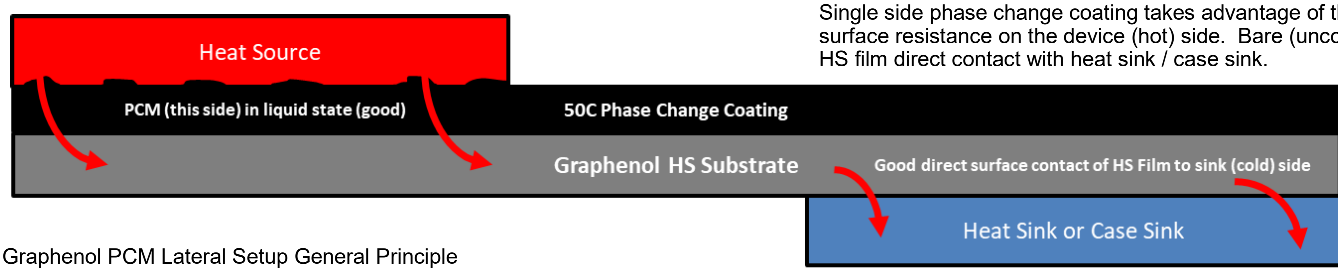
Optimal Scenario for double coated PCM composition

Input watts must be capable of flowing the phase change compound on the sink (cold) in order to achieve the most efficient thermal transfer possible. If adequate heat is not generate, see single side coated version below.



Optimal Scenario for single side coated PCM composition

Single side phase change coating takes advantage of the low surface resistance on the device (hot) side. Bare (uncoated) HS film direct contact with heat sink / case sink.



Graphenol PCM Lateral Setup General Principle

The further the distance the heat source and point of dissipation, the higher the power density required on the input side to adequately phase change (transition from a solid to a liquid) the compound coating on the cooling (sink) side. For applications that do not generate enough heat for phase changing of the compound coating on the device (hot) or sink (cold) side, see Graphenol HS (uncoated—dry) material.

Additional Graphenol PCM Material Options

Adhesive Backing Options

LT05	low tack (repositionable)	12.5 microns | 0.5 mils
T20	thermally conductive (high adhesion)	50.8 microns | 2.0 mils

100% adhesive surface backing applied to single side coated (uncoated side)
Discrete adhesive placement (outside of primary thermal via) for single or double coated version

Dielectric Film Lamination Options

MT	Kapton ® MT	1.0 mil to 3.0 mil
MT+	Kapton ® MT+	1.5 mil to 2.0 mil
HN	Kapton ® HN	1.0 mil to 3.0 mil
PET	PET (polyester) Film	1.0 mil to 5.0 mil

Dielectric film applied to single side coated (applied to uncoated side)
Nominal adhesive tie layer utilized between HS and film layers

Non-Dielectric Foil Lamination Options

AL	Aluminum Foil	0.5 mil to 5.0 mil
CU	Copper Foil	1.0 mil to 5.0 mil
SS	Stainless Steel	0.5 mil to 3.0 mil

Foil applied to single side coated (applied to uncoated side)
Nominal adhesive tie layer utilized between HS and foil layers

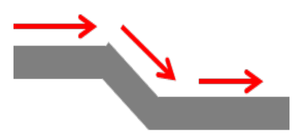
Conformable SILTEL Film & Gap Pad Lamination Options

SF	SILTEL Silicone Films	Several thicknesses and types
SG	SILTEL Silicone Gap Pads	Several thicknesses and types
NSG	SILTEL Silicone-Free Gap Pads	Several thicknesses and types

SILTEL applied to single side coated (applied to uncoated side)
Nominal adhesive tie layer utilized between HS and SILTEL layers

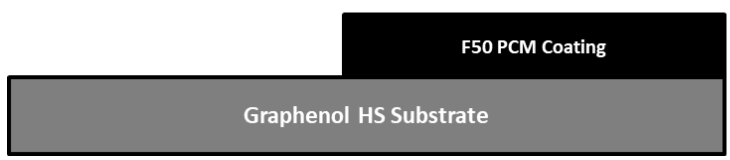
Graphenol PCM—Flexibility and Durability

The flexibility and durability of the Graphenol PCM material is suitable for applications that require the TIM material to follow various angles and slopes with no change in lateral heat spreading capability. Full 180° ultra-sharp crease scenarios may impact lateral heat flow.



Graphenol PCM can be installed without worry of breaks or shattering that is typically found in more traditional pyrolytic graphite films. Graphenol PCM has been cycle tested and able to withstand > 10,000 bends without substrate breaks or shattering. Test stopped after 10,000+ bends.

Graphenol PCM—Discrete Compound Placement



Graphenol PCM can be manufactured with discrete shapes / placement of the phase change thermal compound. Contact us for more information on our discrete phase change compound placement.

Other Information

Compliance	RoHS | REACH | Halogen Free
Die Cut Individual Dimensional Tolerance	+/- 0.010" (0.25mm) typical
Die Cut Continuous Reel Tolerance	+/- 0.020" (0.50mm) typical
Roll Width (32 micron substrate version)	5.50" (140mm)
Roll Width (40 micron substrate version)	7.50" (178mm)
Storage Temperature	60°F to 80°F (15.5°C to 26.6°C)
Storage Condition	Cool, Dry Location until use
Shelf Life	2 years from date of manufacture