

*Thermal Solutions
For Long-Term Reliability
Of Power LEDs*

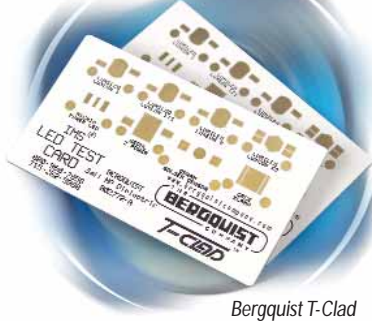
Thermal Management For LED Applications

SOLUTIONS GUIDE



THE
BERGQUIST
COMPANY

Bergquist Thermal Solutions Insure Color Consistency And Maximum Lifecycles For Your LEDs.



Bergquist T-Clad

Light Emitting Diodes (LEDs) have been around for years, primarily concentrated in such markets as cell phones, PDAs and other consumer electronics. Since most of these products have relatively short lifecycles, protecting LEDs wasn't a primary concern because the product would fail or become obsolete long before the LED failed. Today, as technological

advancements in LED design and processes are continually boosting light output to rival incandescent, fluorescent, and even halogen light sources, the need to protect the LEDs against heat build-up is greater than ever before. Three and five-watt LEDs are now commonplace, and industry experts are predicting 10-watt LED availability in the next few years. Power LEDs of greater than one-watt are almost always surface mounted devices. This is because the axial leads to the die in a leaded package do not conduct enough heat away from the LED. Chip-on-board (COB), flip chips and thermally efficient packages are emerging as the standard thermal management packaging solution for Power LEDs.



Light output of the same LED die on different circuit board materials at a maintained die temperature of 50°C.

The Effect of Temperature

The LEDs color, or wavelength, will change with temperature. As the die temperature increases, the wavelength of the color increases. This is particularly important with white light. The human eye can differentiate small color changes in white light. When Power LEDs are populated in an array, consistent thermal resistance from one die to the next assures consistent color. Because of the comparatively low thermal resistance Thermal Clad offers versus FR-4, die temperature is less affected by slight variances in the junction-to-case thermal resistance that occurs with tin eutectic or epoxy-die mounting techniques. It is also possible to pack the die more closely in an assembly that utilizes good thermal management techniques, thereby reducing the effects of temperature.

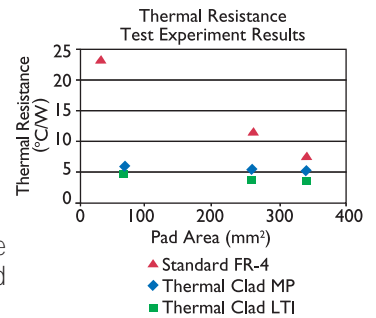
Generally, a 50 percent drop in light output for a constant-forward current indicates end-of-life for Power LEDs. With proper thermal management, Power LED lifetimes can exceed 100,000 hours.

Cost Of Heat Summary

Better thermal management allows more forward current to be applied to the LED, which means more light and possibly reducing the number of LEDs required for the desired light output. Maintaining a cooler assembly at an equivalent power equates to more light per die.

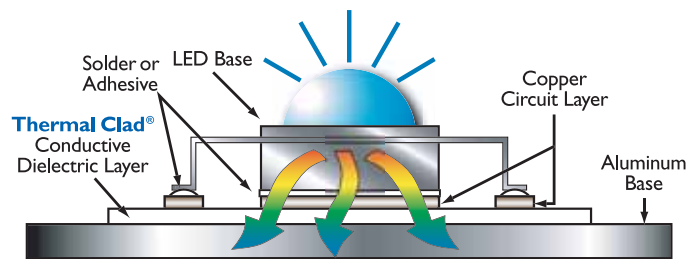
Circuit Board Comparison Models

Insulated Metal Substrates (IMS[®]) and standard FR-4 are commonly used circuit board materials in conjunction with Power LEDs. Bergquist's Thermal Clad IMS is a thin, thermally conductive layer bonded to an aluminum or copper substrate for heat dissipation (see illustration below). The key to Thermal Clad's superior performance lies in its dielectric layer. This layer offers electrical isolation with high thermal conductivity and bonds the base metal and circuit foil together. Other manufacturers use standard prepreg as the dielectric layer, but prepreg doesn't provide the high thermal conductivity and resulting thermal performance required to help assure the lowest possible operating temperatures and brightest light output for high-intensity LEDs. Thermal Clad circuit board materials are available from The Bergquist Company in three different thermal conductivities, High Temperature (HT), Multi-Purpose (MP) and Low Thermal Impedance (LTI).



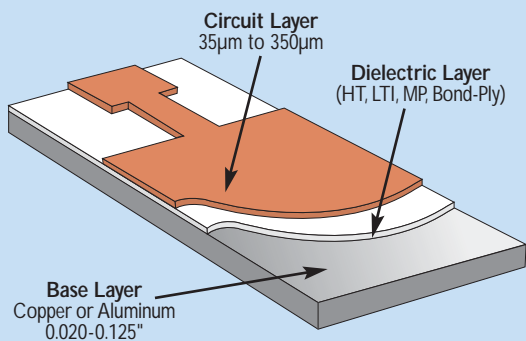
Packaging Conclusion

There are several options available for thermal management of Power LEDs. The most critical thermal path in the stack is the one with the highest thermal resistance. Good practice suggests that you reduce the thermal resistance of that layer with Thermal Clad instead of FR-4.



A Power LEDs light output and life expectancy are directly attributed to how well the LED is managed thermally. As the LED generates heat, the dielectric of the Bergquist Thermal Clad insulated metal substrate quickly transfers it to the aluminum base, significantly improving the LEDs performance.

Anatomy of a Thermal Clad Board



PRODUCT FAMILY	Part Number	THERMAL PERFORMANCE			DIELECTRIC PERFORMANCE		OTHER	
		(1) Thickness (10 ⁻³ in/10 ⁻² m)	(2) Impedance (°C/W)	(3) Conductivity (W/m-K)	(4) Operating (VAC)	(5) Breakdown (kVAC)	(6) Glass Transition (°C)	(6) UL (TI-°C)
HT	HT-04503	3/75	0.45	2.2	120	6.0	150	140
	HT-07006	6/150	0.70	2.2	960	11.0	150	140
LTI	LTI-04503	3/75	0.45	2.2	120	6.0	90	130
	LTI-06005	5/125	0.60	2.2	480	9.5	90	130
MP	MP-06503	3/75	0.65	1.3	120	8.5	90	130
BOND-PLY	TCP-1000	6.5/165	1.5	1.0	480	10.0	110	130

Method Description: 1-Visual 2-Internal TO-220 test RD 2018 3-Extended ASTM 5470 4-ASTM D149 5-Internal MDSC test RD 2014 6-UL File QMTS2-E1218882 (Temperature Index)

Bergquist Makes Thermal Management Simple For Today's High Brightness LEDs.



A complete thermal package lets you reap the benefits of today's new Power LEDs.

The Power Factor Evolves

With the era of brighter and more powerful LEDs, we are witnessing the world of lighting changing forever. Power LEDs are entering nearly every market niche as the light source of choice. Advancements in LED technology has led to a cost-effective alternative to incandescent, fluorescent and halogen lighting. With these bring significant opportunities to LED manufacturers and integrators.

Power LED packaging has evolved to adapt to higher power dissipation demands. For these Power LED packages, the lowest possible thermal resistance packaging is paramount to a long and reliable service life. By combining Bergquist thermal management materials with this new and innovative packaging, progress in both light output and light quality can be achieved.

The Bergquist Company has established itself as one of the world's foremost leaders in thermal management solutions. From innovative new products to global support, Bergquist is your total thermal management supplier. With the depth of our product portfolio, Bergquist promises to make these challenging new thermal hurdles less daunting. Whether you're a manufacturer, an integrator or a company that procures the final package, you'll benefit from a Bergquist solution.

A Bright New Chapter Unfolds

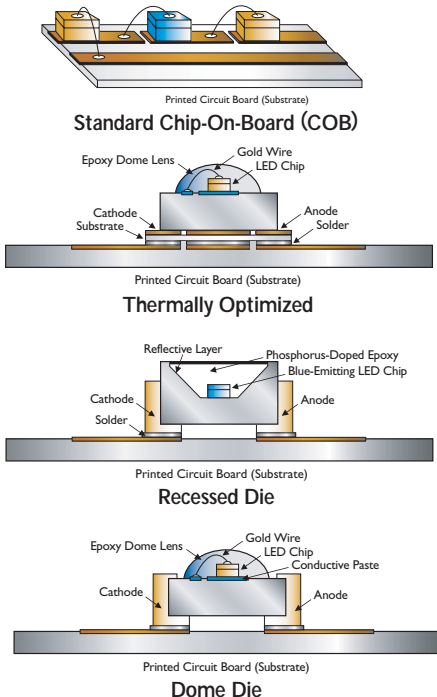
Now that Power LEDs are capable of unprecedented levels of white LED brightness and efficacy they are being used in many products that are part of our daily lives. Although today the initial cost of Power LEDs is higher, many applications have demonstrated LED lighting as the most cost or energy efficient solution for future installations. Equipment manufacturers worldwide are making devices with Power LEDs for both the commercial and consumer segments.

With smaller footprints, our products lead the way in reducing the buildup of heat and maximize the LEDs potential benefits. Bergquist provides critical thermal management support for a myriad of Power LED applications that include: medical, military, signage, signal, transportation, aircraft, automotive, security, portable, theatrical, commercial and residential lighting.



Bergquist thermal products are hard at work keeping the world's best known products reliably cool.

Typical Types Of LED Packages



Whether above or below ground, the range of uses for Power LEDs is ever expanding. Leading automotive manufacturers have not only begun to move Power LEDs into interiors and signals, but forward LED lighting is now available on an ever increasing number of vehicles. Bergquist's silicone-free materials are an excellent choice for automotive and submersible applications. By using copper based Thermal Clad, along with Silicone-Free Gap Pad, unique agency requirements for UL approval in underwater lighting applications, such as pools, can be met. As a one-source supplier, this right combination of thermal interface and substrate materials allows customers to quickly meet their objectives.

Easing The Thermal Issues Ahead

Be confident specifying your Power LEDs at their maximum power levels by partnering with an expert in thermal management. Our vast experience in the thermal field, coupled with our solid customer-focused solutions, makes us the best choice for thermal design choices. Rely on Bergquist to stay on top of Power LED packaging and continue to innovate and market thermal material solutions for this rapidly expanding technology. Extend performance, durability and reliability by including us in your Power LEDs equation.



Thermal Clad® Insulated Metal Substrates (IMS)



Thermal Clad® PrePreg Rolls and Sheets

Bond-Ply TCP-1000 is a B-stage prepreg designed to meet the thermal management challenges of Power LED applications. With its superior thermal performance, Bergquist's Bond-Ply TCP-1000 effectively competes with epoxy glass on aluminum constructions. It combines ease of processing with the high performance characteristics of a thermally conductive polymer dielectric.

It is specifically intended as a high performance alternative to epoxy glass on aluminum constructions. The thermal performance is better than traditional epoxy glass constructions by at least 3.5x thus allowing for performance levels needed to increase lumens per watt output while effectively managing LED device temperature.

- 18" (457.2mm) roll standard (custom sizes available)
- Maximum roll length of 500 feet (152.4m)
- Sheets 18"x24" (457.2mm x 609.6mm) and 20"x24" (508mm x 609.6mm)

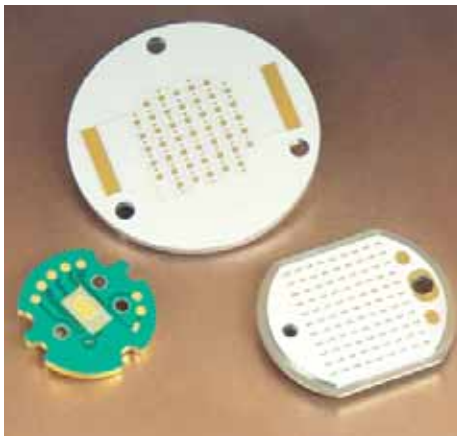


Thermal Clad® Panels

Thermal Clad is a dielectric (ceramic-polymer blend) coated metal base with a bonded copper circuit layer. Improved reliability, processing advantages and exceptional cost performance makes Thermal Clad a superior alternative to traditional FR4 and non-thermally conductive constructions.

Thermal Clad substrates are available in a variety of thicknesses depending on the base metal and circuit foil thickness. Standard sheet sizes are 18" x 24" and 20" x 24". Material selection should be based on thermal, dielectric and mechanical application requirements.

- Circuit layer - 35µm to 350µm
- Dielectric layer - HT, LTI, MP
- Base plate copper or aluminum 0.020"-0.125" (0.5mm-3.2mm)

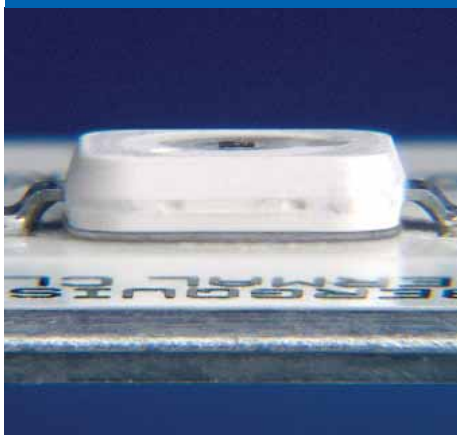


Thermal Clad® Printed Circuit Boards (PCB)

Bergquist Thermal Clad circuit boards are the answer for designers wanting the best of both worlds. Power LED light output and lifecycles are directly attributed to how well the package is managed thermally. A Thermal Clad board offers superior heat transfer. As a metal based material Thermal Clad can be configured for shapes, bends and thicknesses allowing installation in virtually any application. With a Thermal Clad board you're assured of the lowest operating temperature, maximum LED color consistency and life.

- Circuit layer - 35µm to 350µm
- Dielectric layer - HT, LTI, MP
- Base plate copper or aluminum 0.020"-0.125" (0.5mm-3.2mm)

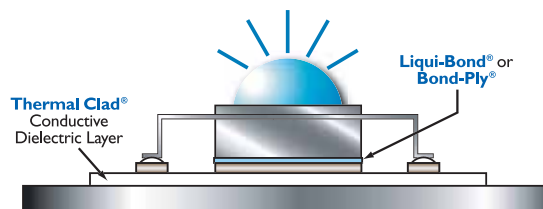
Thermally Conductive Adhesives



Liqui-Bond® Adhesive

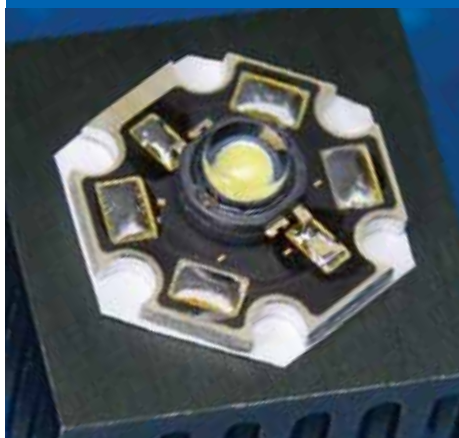
Liqui-Bond is a thermally conductive liquid silicone adhesive that cures to a solid bonding elastomer. Liqui-Bond features excellent low and high-temperature mechanical and chemical stability. It can be supplied in either a tube or mid-sized container form.

- High thermal conductivity
- Easy dispensing
- Can achieve a very thin bond line
- Heat cure





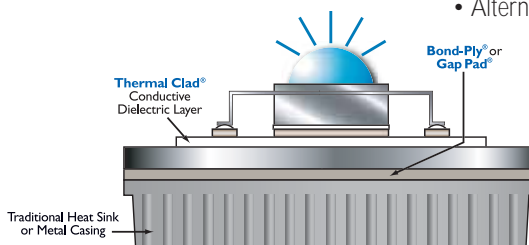
Thermally Conductive Adhesives



Bond-Ply® Adhesive

Bond-Ply is a thermally conductive, pressure sensitive adhesive tape, available in either fiberglass reinforced or unreinforced. With its ability to have a high bond strength, it can eliminate the need for screws, clipmounts or fasteners.

- Good thermal performance
- Immediately bonds to target surface
- Eliminates need for mechanical fasteners or screws
- Alternative to heat-cure adhesives



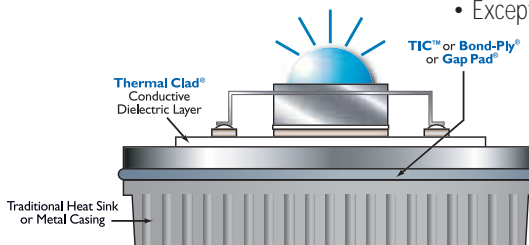
Thermal Interface Compounds



TIC® Thermal Interface Compound

TIC is a high performing, thermally conductive grease designed for use as a thermal interface between an aluminum base and a heat sink or metal casing. The compound wets-out the thermal surfaces and flows to produce the lowest impedance for your LED application.

- High thermal performance
- Good thermal conductivity
- Can be screened
- No post "cure" required
- Room temperature storage
- Exceptional value



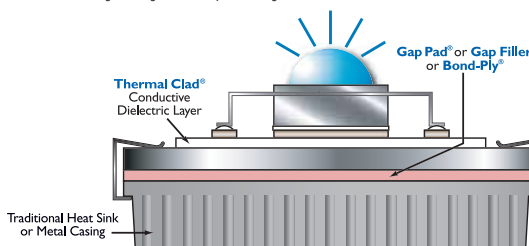
Thermally Conductive Gap Filling Materials



Gap Pad® and Gap Filler

Gap Pad and Gap Filler are cost-effective, filled, thermally conductive interface materials. With shock dampening abilities, the Gap Pad line is recommended for applications that require a minimum amount of pressure between components. It's "gel-like" modulus makes it well suited in areas where conformity may be a priority.

- Exceptional thermal conductivity
- Electrically isolating
- Highly conformable, low hardness
- Efficient gap filling material for minimizing component stress



Gap Pad® and Gap Filler Silicone-Free

Gap Pad and Gap Filler are also available in a silicone-free form. These thermally conductive polymers are designed to have similar mechanical benefits as silicone materials. They are ideal for sensitive applications that do not allow silicone, such as underwater pools and automotive lighting applications.

- Good thermal conductivity
- Highly conformable, low hardness
- Naturally tacky on both sides
- Ideal option for silicone sensitive applications

Superior Technology For Tomorrow's Thermal Challenges

The Bergquist Company - Leading The Way to High Performing Solutions for the World.



Headquartered in Chanhassen, Minnesota, The Bergquist Company is a privately held, family-owned business founded in 1964. The company started as a modest midwest electronics distributor and is now a world leader in thermal management and consists of five main divisions.

Bergquist's Thermal Products Group is the world's leading developer and manufacturer of thermal management materials and provides solutions to manage heat in electronic assemblies and printed circuit boards. These materials include an extensive line of standard Sil-Pads[®]; thermally conductive insulators, and many specialty materials

which include Bond Ply[®], Gap Pads[®], Gap Fillers and a complete family of Hi-Flow[®] phase change grease replacement materials. Bergquist's Thermal Division is the global source for the processing of Thermal Clad[®] IMS circuits and is ISO9001:2000 certified. Their products are used by a myriad of industries worldwide including automotive, computer, military, aerospace, telecommunications, power supply and motor control.

Bergquist manufacturing facilities are located in the United States with additional facilities overseas.

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Summary Of Dielectric Characteristics

Part Number	Thickness ¹ [10 ⁻³ in/10 ⁻⁶ m]	THERMAL PERFORMANCE			DIELECTRIC PERFORMANCE			OTHER		
		Impedance ² [°C/W]	Impedance ³ [°C in ² /W]	Conductivity ⁴ [°W/m-K]	Typical Proof Test ⁵ [VDC]	Breakdown ⁶ [kVAC]	Permittivity ⁷ [Dielectric Constant]	Glass Transition ⁸ [°C]	UL Index ⁹ [°C]	Peel Strength ¹⁰ [lb/in]
HT-04503	3/75	0.45	0.05	2.2	1500	6.0	7	150	140/140	6
HT-07006	6/150	0.70	0.07	2.2	2500	11.0	7	150		
LTI-04503	3/75	0.45	0.05	2.2	1500	6.5	7	90	130/130	6
LTI-06005	5/125	0.60	0.09	2.2	2000	9.5	7	90		
MP-06503	3/75	0.65	0.09	1.3	1500	8.5	6	90	130/140	9
CML-11006*	6/150	1.1	0.21	1.1	2500	10.0	7	90	130/130	10

Method Description

- 1 - Optical
- 2 - Internal TO-220 test RD 2018
- 3 - Calculation from ASTM 5470
- 4 - Extended ASTM 5470
- 5 - 500V/sec ramp, 5 sec hold
- 6 - ASTM D149
- 7 - ASTM D150
- 8 - Internal MDSC test RD 2014
- 9 - UL 746 E
- 10 - ASTM D2861

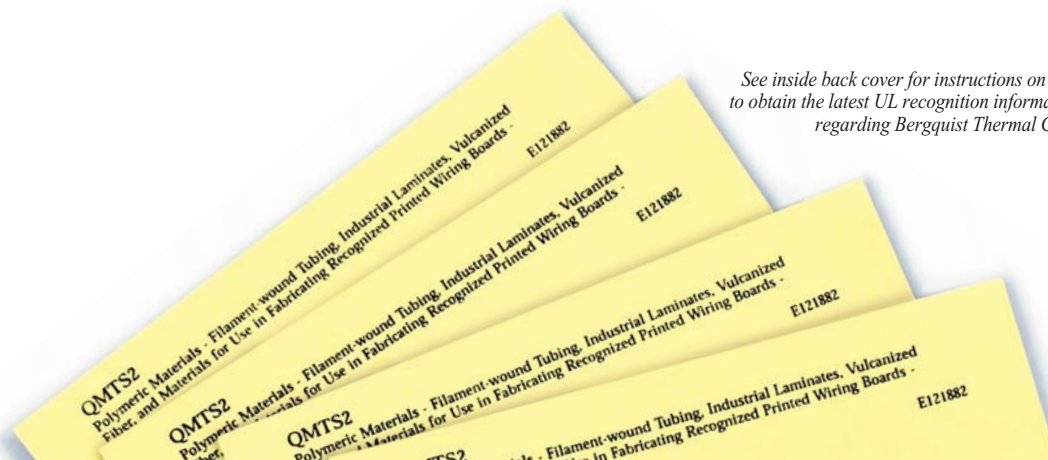
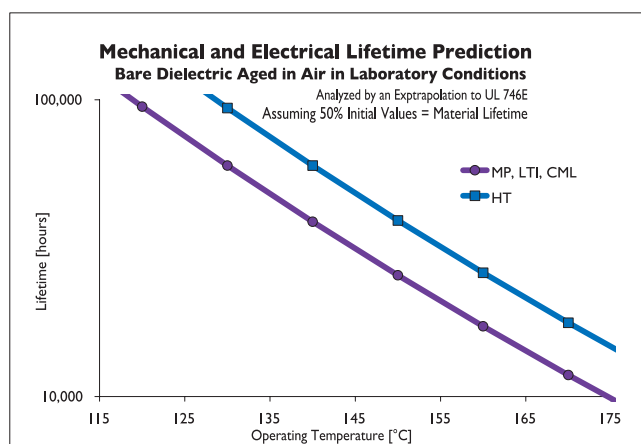
Note: For applications with an expected voltage over 480 Volts AC, Bergquist recommends a dielectric thickness greater than 0.003" (75µm).
Note: Maximum test voltage is a function of material and circuit design. Typical proof test does not represent the maximum.

*CML is available in prepreg form.

Operating Temperatures

Choose the dielectric that best suits your operating temperature environment. For high temperature applications, such as automotive, HT offers the right solution. All of our dielectrics are UL recognized.

MATERIAL	UL RTI - ELECTRO / MECHANICAL
HT	140°C / 140°C
LTI	130°C / 130°C
MP	130°C / 140°C
CML	130°C / 130°C



See inside back cover for instructions on how to obtain the latest UL recognition information regarding Bergquist Thermal Clad.