FRAIVILLIG TECHNOLOGIES COMPANY

THERMAL INTERFACE PRODUCTS

BUSINESS PLAN

FRAIVILLIG TECHNOLOGIES COMPANY
98 CHARLES STREET #1
BOSTON, MA 02114

www.Fraivillig.com

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FRAVILLIG TECHNOLOGIES'

THERMAL INTERFACE PRODUCTS

Electricity drives the modern world. It can be divided into two broad segments: electrical and electronic.

'Electrical' refers to the power generation, distribution and motor technologies. 'Electronic' refers to the use of electricity to drive appliances of all types and sizes, and is generally based on a printed circuit board (PCB) format. Electronic appliances would include tele-communications, computers, and many others.

'Power electronics' is the intersection of electrical and electronic, where raw current is converted for use in appliances. The packaging of power electronics requires demanding thermal performance, yet is very cost-sensitive.

The range of thermal management solutions offered in the market is based on mature technologies that are decades-old.

Fraivillig Technologies (FT) has developed the next-generation thermal-management solutions: *PowerSite™ products*, which provide excellent performance, cost-effectiveness, and unsurpassed design flexibility. The high value delivered to the customer by the proprietary technology enables the products to be sold at high, sustainable profit margins.

Evolution of Thermal Interface Technology	
DISCRETE POWER DEVICES	
Mica + grease	1940s
Insulator pads	1960s
PowerSite™ pads	2000
PowerVia™ columns	2002
POWER CIRCUITRY	
Ceramic	1960s
Insulated metal	1980s
PowerFlex™ circuits	2002
Dielectric Coated Copper (DCC)	2006

[NOTE: PowerSite, PowerVia and PowerFlex are all defined as 'PowerSite products', using TPI technology. Patents and patents pending.]

The key to PowerSite products is the heat-sealable TPI bond film. TPI bonds the electronic substrate to the metal heat sink. This allows the soldering of power devices directly to the heat sink, giving high thermal dissipation while maintaining electrical isolation, all without attachment hardware.

FT provides a complete range of electronic packaging solutions for demanding power applications. We expect that these products will become the industry-standard for decades into the future. When adopted, the proprietary nature of PowerSite technology offers an excellent business opportunity.

FT is seeking partners to drive the power electronics market to a new standard for thermal management.

PowerSite TPI-based products have proven their performance and durability in demanding power applications. We are now eager to scale-up.

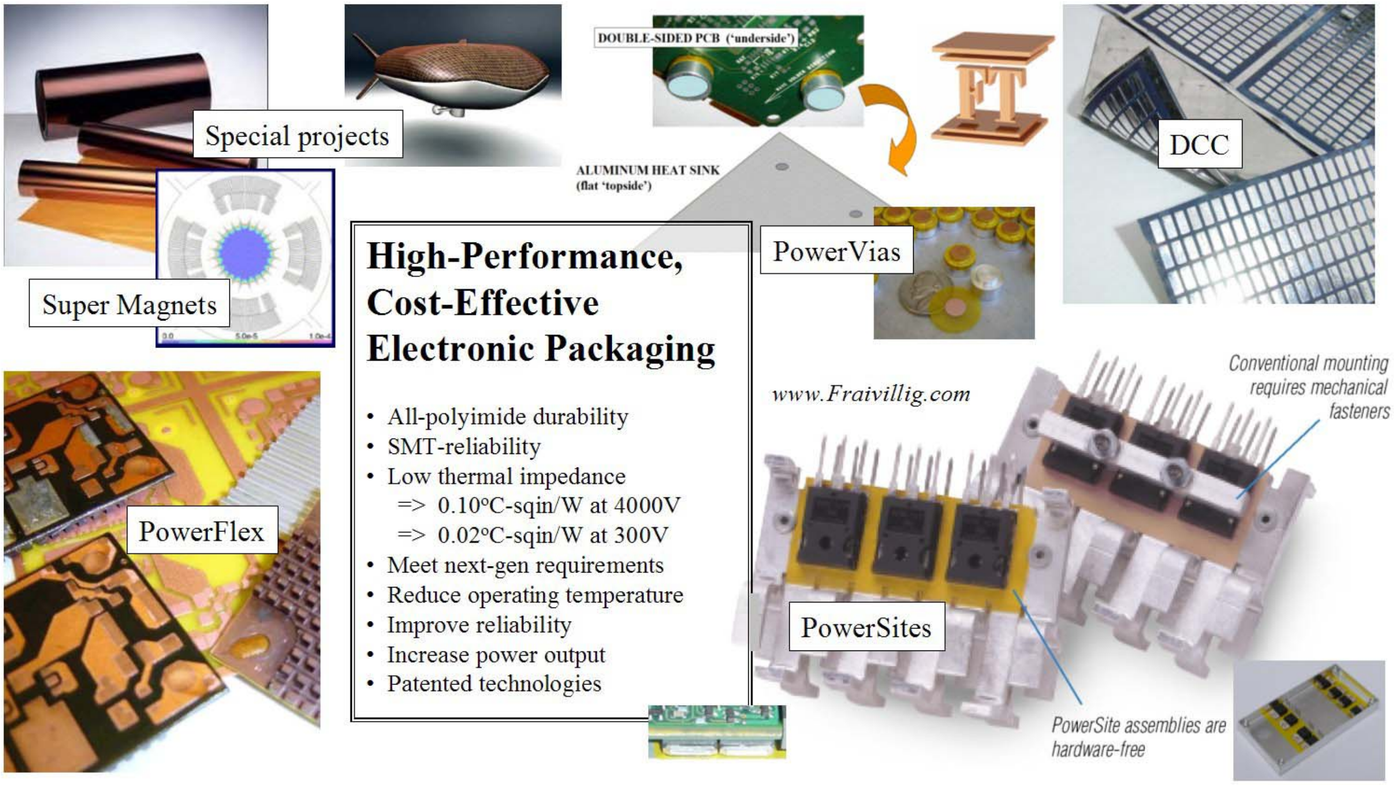
The business requirements for creating a new standard in thermal management follow:

- Leveraging adoptions in the present 'beta applications' to the broader power market
- Promotion of the PowerSite technologies through publications, advertisements, conferences and trade shows
- Identification and development of new applications at power OEMs and design centers
- A Sales/Marketing force than understands the thermal management market and the power electronics industry, and can promote and capture the value of a high-performance product
- Establishment of partnerships with contract manufacturers in Asia (where the majority of power electronics are now assembled)
- Development of additional TPI bond film products, so that more application opportunities can be pursued (such as where cost is *much* more important than performance).

All of these critical program items require both financial investment and business commitment.

If you are interested in discussing this opportunity, please contact Jim Fraivillig at 512-784-5698, or jim@fraivillig.com.

Fraivillig Technologies Company
98 Charles Street #1
Boston, MA 02114



FT's versatile product portfolio is illustrated above.

BACKGROUND: 'Power electronics' covers a wide range of industrial applications that utilize power semiconductors. These include units where electric current is transformed from AC to DC, from DC to AC, from one voltage to another, etc. (*market: power converters*)., or where electric current is transformed into physical motion (*market: controls for motion, motor, automotive*). This electrical transformation process is not 100%-efficienct and produces heat that must be dissipated, or the power semiconductors will fail.

The thermal interface material (TIM) between the power semiconductor and the heat sink is critical to the operation of these units. The interface must have high thermal conductivity between the surfaces, while maintaining reliable dielectric separation.

The power electronic market can be viewed as "electronic plumbing", carrying the current where it needs to be in the form that is required by the application – the thermal interface has to be extremely reliable, but is rarely noticed, unless something goes wrong. In some ways, thermal interface materials are analogous to household plumbing materials, but transporting heat not water. The household construction market tends to have a slow conversion to new plumbing technologies: first from wood pipe to metal pipe in the 1850s, and then from metal pipe to plastic pipe about a century later. But the adoption of a new technology in this conservative market is pretty close to permanent (within a human lifetime at least). The technology transitions in TIMs within the power electronics industry are analogous -- slow-but-steady, but with product life-cycles in decades rather than centuries.

PowerSite products are one of only a handful of thermal management technologies to have originated and been commercially-adopted in the past 30 years old.

In addition to power electronics, there are other thermal management applications in electronic packaging that could well utilize PowerSite technology: CPU modules, LEDs, thermoelectric coolers, conventional printed circuit boards. (Our primary focus is now power electronics. In the quest, to change a technical standard, it's good to start with the 'low-hanging fruit'.)

POWERSITE™ TECHNOLOGY SUMMARIZED…

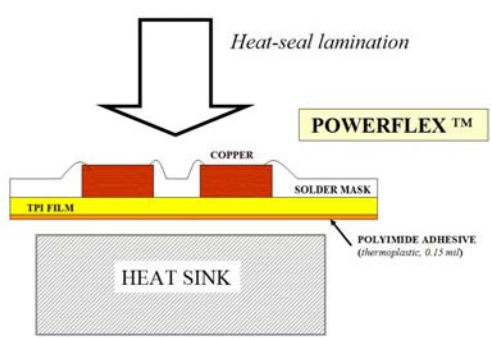
1. Heat-seal electronic substrate to the heat sink
2. Solder on the power device
3. RESULT: Metal-to-metal thermal connection

FRAIVILLIG BUSINESS MODEL SUMMARIZED…

Capture high value-in-use of next-gen performance

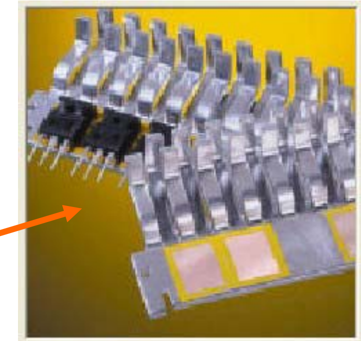
Business options, any/all of the following:

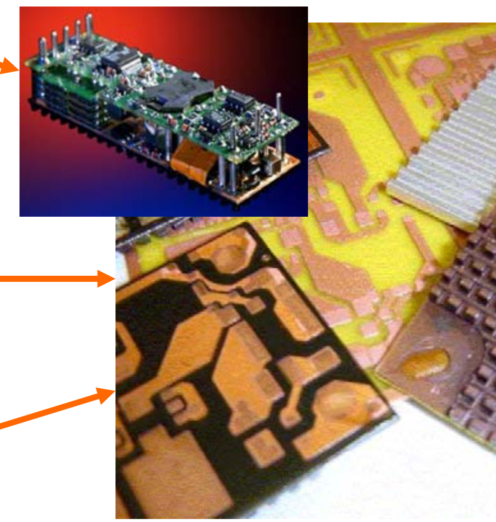
1. Sell TPI bond film and accessories
2. License PowerSite technology to manufacturers
3. Sell high-performance PowerSite subassemblies
4. RESULT: High sustainable profitability

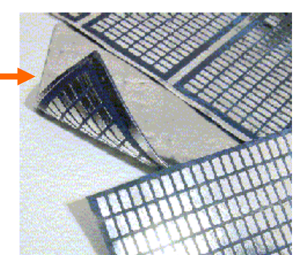


Versatile range of products for power electronics

POWER SUPPLIES • AC-DC, DC-DC, DC-AC **CONTROLS** • Motion, Motor, Auto	*Thru-hole power devices on heat sinks (High-voltage)*	**PowerSites**
	Surface-mounted power devices (High-voltage)	**PowerVias** (with FR4) **PowerFlex**
INSULATED METAL: • **Thermoelectric coolers** • **LEDs** • **Solid-state relays**	*Low-voltage*	**DCC laminate**
	High-voltage	**PowerFlex**
MULTICHIP MODULE (MCM)	*High-voltage*	**PowerFlex**
PRINTED CIRCUIT MULTILAYER-ADDITION	*Low-voltage*	**DCC**







FRAVILLIG TECHNOLOGIES’
THERMAL INTERFACE PRODUCTS

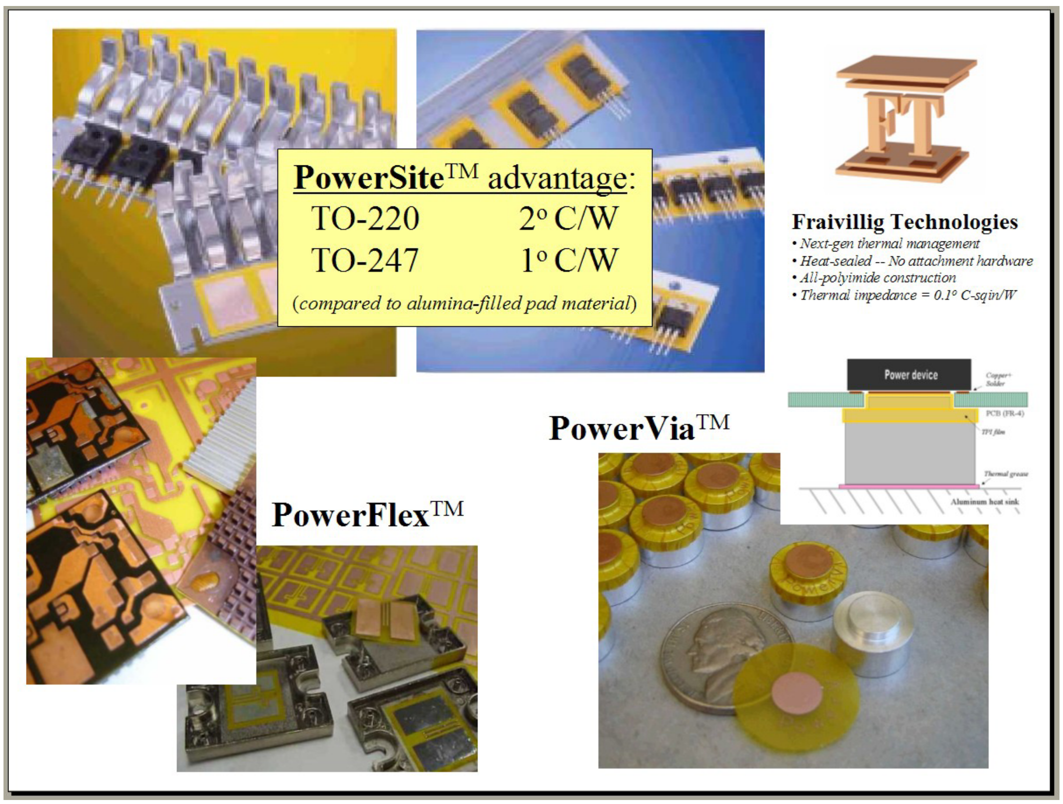
EXECUTIVE SUMMARY

The portfolio of FT products has the performance and cost-structure to become the next-generation standard in the thermal management of power electronics.

The technologies are based on the heat-sealable TPI bond film and are protected by a range of patents, awarded and pending.

The TPI materials, equipment and processes are already developed and optimized.

The performance in leading-edge power applications has been proven.



The next step is leveraging our experience --and promoting, qualifying and selling-- the technology across power electronics and other high-performance markets.

Once adopted, the high value-in-use of the proprietary TPI technology will provide profitable sales with long-term customers. This value can be captured by selling only the high-margin TPI bond film to converters and manufacturers. Or, forward-integration into electronic assemblies –even on a subcontract or license basis-- would allow greater revenue and profitability.

A forecast of potential demand for TPI bond film follows:, based on market size, along with expected penetration and product pricing by application.

TPI MARKET POTENTIAL		Material Demand		Material Revenue	
POWERSITE		**0.7**	M sqft/yr	**$5**	M/yr
POWERFLEX	*(taking business from…)*				
High power	IMS	0.7	M sqft/yr	$6	M/yr
	Ceramic	1.7		$14	M/yr
Auto control	PCB/PSA	3.0		$15	M/yr
Subtotal		**5.4**	M sqft/yr	**$34**	M/yr
POWERVIA		**0.7**	M sqft/yr	**$6**	M/yr
TOTAL DEMAND		**6.9**	M sqft/yr	**$45**	M/yr

These projections are based on market size, along with expected product penetration and pricing by application:

POWERSITES (thru-hole PCB)		
Discrete devices	1.0	Billion
Area/device	0.7	sqin
Total market	4.9	M sqft
Penetration	15%	
Total potential	0.7	M sqft
Avg price	$7.00	/sqft

POWERVIA (SMT PCB)		
Total automotive	20	M cars
Total appliances (‘*App*’)	500	M units
Number/car	20	cooled devices
Number/app	4	cooled devices
Penetration--Auto	10%	
Penetration--App	3%	
Area/PV	1	sqin
Total area	0.7	Msqft
Average film price	$8.00	/sqft
Material revenue	$5.6	M
Average PV price	$0.20	

POWERFLEX (SMT PCB)			
IMS	Total market	150	M USD
	Cost/area	0.3	USD/sqin
	Total area	3.5	M sqft
	Penetration	20%	
	Total potential	0.7	M sqft
	Avg price	$8.00	/sqft
Ceramic	Total market	1000	M USD
	Cost/area	0.4	USD/sqin
	Total area	17.4	M sqft
	Penetration	10%	
	Total potential	1.7	M sqft
	Avg price	$8.00	/sqft
PCB/PSA	Total market	20	M cars
	Area/car	1	sqft
	Total area	20	M sqft
	Penetration	15%	
	Total potential	3.0	M sqft
	Avg price	$5.00	/sqft

Reaching market penetrations of 3% or 10% with a revolutionary new technology in a conservative market takes time, effort and resources. Based on the proven performance and the competitive cost-structure of the TPI technology, we believe that these are realistic medium-term goals.

<u>Profitability</u>

TPI bond film has a gross margin of 60-75%, depending on the application and volume. (For instance, with a $1000 sale of TPI film, the total cost of materials and processing is only $0.25-0.40.)

As with any new material, expense for marketing and technical support would be required to build the business.

With forward-integration into subassemblies, the absolute profitability potential increases, but the relative margin falls. The sustainable mark-up on purchased hardware materials for subassemblies --such as heat sinks and power devices-- generally is 15-30% in competitive, high-volume applications.

PowerSite TPI technology is unparalleled in the system performance-vs-cost in many thermal management applications. In addition, it is proprietary and patented. This could provide licensing opportunities, in which royalties are paid by qualified manufacturers on sales of their units. (This might slow adoption rates, but could dramatically increase profitability.)

BUSINESS MODEL and INVESTMENT

Owning the standard for thermal management in power electronic packaging provides a substantial business opportunity. The PowerSite TPI technology is proprietary and patented. Profit margins products are high. Once widespread adoption is underway, sales revenue potential would be a decided by the owner of the TPI technology: What level of pricing is appropriate to garner the widest profitable sales?

The business model could be as simple as selling a single type of TPI bond film in roll form. The amount of value-addition could be decided based on incremental profitability: from supplying the TPI in sheets or punched shapes –to-- building custom baseplates with soldered components. As the TPI technology results in a 'better power supply', licensing opportunities could also exist for exclusive agreements with selected subcontractors and even OEMs.

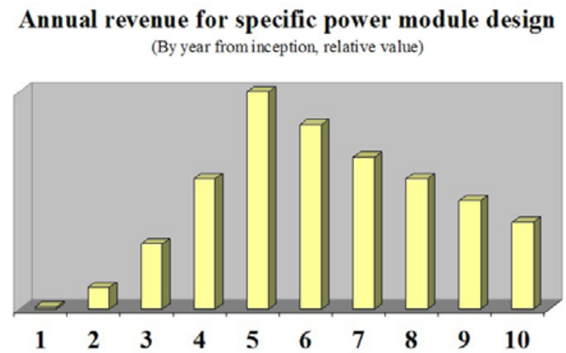
The product and process development of the PowerSite TPI technology has already been done for most enduse applications. The technology has already been tested, qualified and commercialized. Investment would be required mainly to expand the market and develop the brand. In addition, this TPI technology may already have synergy with existing product lines with manufacturers, and can be sold to existing customers.

As reviewed in the Introduction section, the business requirements for creating a new standard in thermal management follow:

- Leveraging adoptions in the present 'beta applications' to the broader power market
- Promotion of the PowerSite technologies through publications, advertisements, conferences and trade shows
- Identification and development of new applications at power OEMs and design centers
- A Sales/Marketing force than understands the thermal management market and the power electronics industry, and can promote and capture the value of a high-performance product
- Establishment of partnerships with contract manufacturers in Asia (where the majority of power electronics are now assembled)
- Development of additional TPI bond film products, so that more application opportunities can be pursued (such as where cost is *much* more important than performance).

Power electronics –the main market-focus for the PowerSite products at this stage—tends to be conservative in the adoption of new materials. The upside of this conservatism is that once entrenched, a product's market position tends to remain secure. New products are typically evaluated on a next-generation design of a power module. Even if everything goes smoothly in the module's prototype, qualification and overseas manufacturing, the sales revenue for a material in that module might still lag due to many reasons. For instance, the OEM's *customers* for power supplies also tend to be conservative and wary of betting on new technology (mostly the power supply, not the insulation material).

A representative revenue stream for a material in a specific (theoretical) power module design is shown opposite. Sales for many designs might not peak for 4-5 years. After the product matures, sales flatten while the next-generation design is introduced to the market by your customer, and his customers begin to adopt the new design.



The market development plan should reflect this adoption and product lifetime cycle. The early adoptions, before a product becomes established, are the toughest to garner.

Much of this, of course, comes as no surprise. Manufacturers of high-tech materials are generally very familiar with the requirements and steps to drive a new technology into the market. There will be incremental cost associated with the following:

- Building the PowerSite TPI 'brand' – like practically all markets, power electronics market is brand-conscious. Advertising in industry magazines, literature mailings, trade shows and conference papers all provide important exposure and leads. The technology's cost-effectiveness and design-flexibility should be emphasized.

- Marketing and Sales organizations – incremental cost can be minimized by using existing Marketing organizations and Sales channels. There will be a need for specialized training and technical support with even the most technically-advanced sales force. The marketing force would also lead the effort to identify and develop other markets beyond conventional power electronics.

- Supply chain – the success of the PowerSite TPI technology is dependent on its proper usage and the competitive pricing of the electronic subassemblies that utilize it. An experienced and qualified supply chain is critical in all regions. Identifying and supporting the PowerSite TPI converters and manufacturers (of PCBs and heat sinks) will require resources, especially during scale-up. Supply-chain partners will require specialized equipment and tooling for TPI bonding. Expertise and comfort with custom equipment is a critical.

- Product development – to best take advantage of the market opportunities, a TPI bond film product line with tiered price-vs-performance will be required. This product structure, of course, allows differential pricing based on the trade-off between cost and performance. For example, we already have some excellent candidates for a lower-cost TPI bond film, which could be priced one-half of the standard all-polyimide TPI film, and still be very profitable. (Its thermal impedance and durability would not be as good as the standard TPI, but would work great in many low- and mid-range applications.) There would be minor costs associated with developing, testing and qualifying this and other new thermal interface products.

The amount of resources that would be required to develop, grow and support the PowerSite TPI business depend –in a large part-- on the capabilities of the existing organization and supply-chain partners.

The incremental marketing and development expenses (reviewed above) to support the business would be invested efficiently. Since its inception, Fraivillig Technologies has practiced lean manufacturing, lean R&D, lean sales/marketing, lean technical service and support. This experience can be brought-to-bear on the business moving forward.

TECHNICAL SUMMARY

PowerSite™ technology has the potential to revolutionize the thermal management of power electronics and other demanding applications. It provides a robust method of attaching power electronics as close as possible –both physically and thermally—to the metal heat sink and ambient cooling air. One OEM refers to PowerSite technology in their press releases as "*metal-to-metal bonding*"… and except for 1.3 mils of ceramic-filled polymer, that is literally true. And this is accomplished with 4000Vdc dielectric strength, no attachment hardware and no pressure dependency.

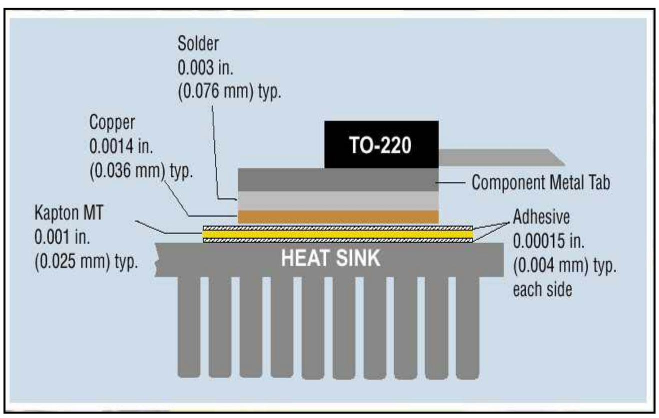
The beauty of the PowerSite technology is its simplicity. Despite a wide range of end-use product formats for PowerSite, PowerFlex and PowerVia constructions, a single bond film can satisfy practically *all* applications. Our standard bond film product is 130TPI, which is a ceramic-filled Kapton® polyimide film with 0.15 mil of thermoplastic polyimide adhesive on both sides, and could be used in all applications.

Typical properties for a PowerSite made with 130TPI are shown in the adjacent chart. This construction includes processes of heat-seal bonding copper foil to an aluminum heat sink, and then soldering-on of a power device. (See schematic below; PowerFlex and PowerVia formats would have equivalent properties.)

TYPICAL PROPERTIES

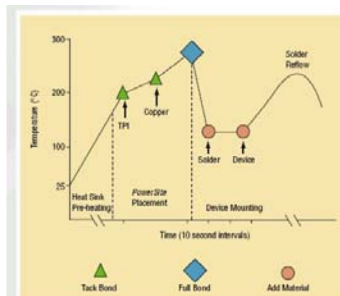
	Property	PowerSite Laminate	Test Method
CONSTRUCTION	Copper Thickness, inch (mm)	0.0014 (0.036)	ASTM D374
	Thermoplastic Polyimide (TPI) Adhesive Thickness, inch (mm)	0.00015 (0.004)	ASTM D374
	Kapton MT Dielectric Thickness, inch (mm)	0.001 (0.025)	ASTM D374
	Thermoplastic Polyimide (TPI) Adhesive Thickness, inch (mm)	0.00015 (0.004)	ASTM D374
THERMAL	Laminate Thermal Impedance, °C-in²/W (°C-cm²/W)	0.1 (0.65)	ASTM D5470-95
	Dielectric Thermal Conductivity, W/m-k	0.38	ASTM D5470-95
	Operating Temperature Range, °C	–50 to +200	—
	Junction-to-Heat Sink Thermal Resistance, Rj-s,°C/W* TO-247 TO-220	 0.67 2.67	JEDEC Std 51 using Analysis Tech Thermal Analyzer
ELECTRICAL	Voltage Breakdown, Vac	5000	ASTM D149
	Volume Resistivity, ohm-cm	1×10^{14}	ASTM D257
	Capacitance, pF/in² (pF/cm²)	500 (78)	ASTM D150
	Permittivity, 25°C @ 1kHz	4	ASTM D150
	Dissipation Factor, 25°C @ 1kHz	0.003	ASTM D150
MECHANICAL	Tensile Strength, psi (mPa) Room Temp 150°C	 600 (4.1) 200 (1.4)	ASTM D412
	Shear Strength, psi (mPa) Room Temp 150°C	 4000 (27.6) 2000 (13.8)	ASTM D412
	UL Recognized	Pending	—

*Includes component's internal junction-to-case thermal resistance.



On a micro-level, where the thermal transfer happens, the PowerSite construction is practically always the same: copper foil intimately-bonded to aluminum.

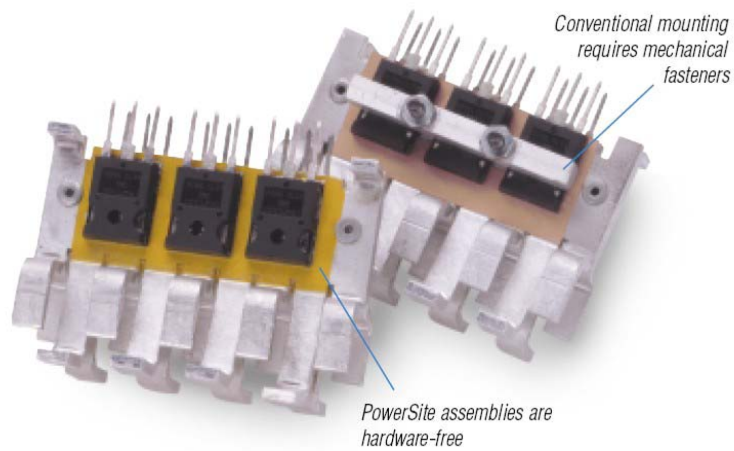
The PowerSite process is always the same: heat-sealing the copper foil to the aluminum heat sink. The tooling and process conditions can vary, for both the bonding and the soldering operations, based on the heat sink configuration. A schematic of the typical PowerSite processing is shown opposite.



PowerSite process conditions are the same regardless of equipment configuration.

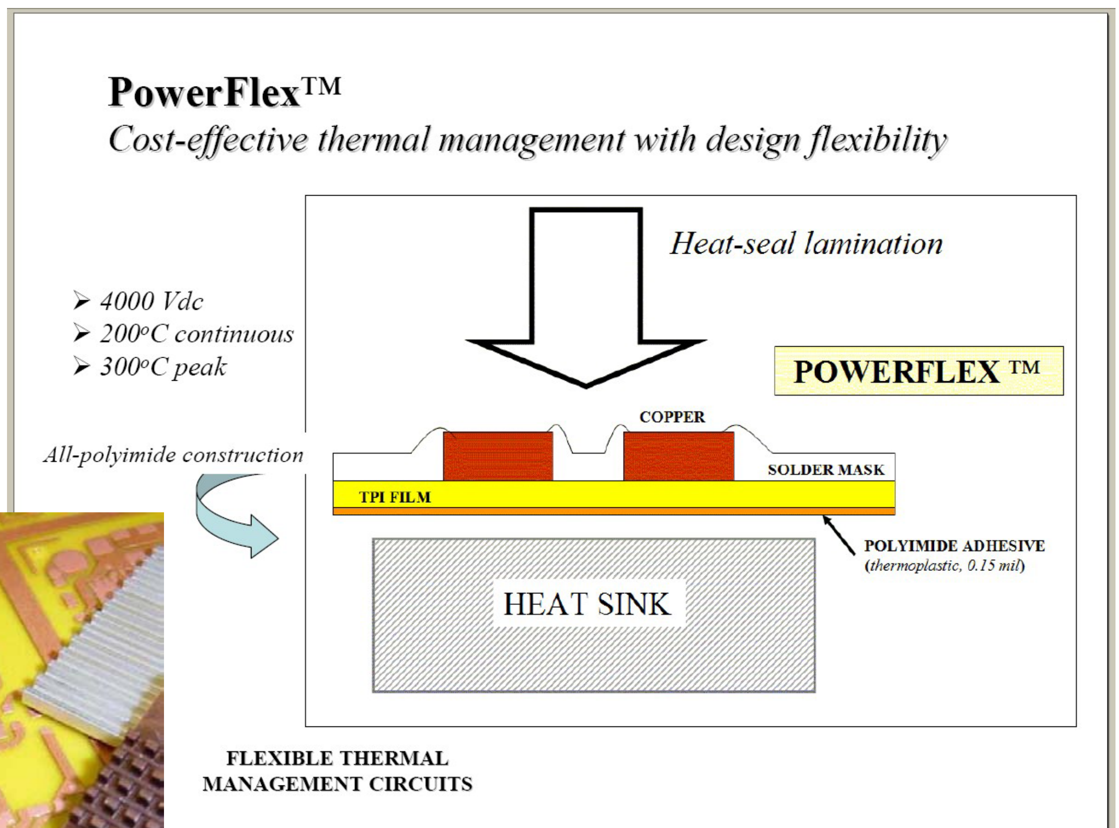
The equipment required for PowerSite processing is very simple. It's all about heat and pressure: the polyimide-adhesive bonding is done up to 300°C and 600 psi. Dwell time at full-pressure is short, typically 15-30 seconds. For high-volume, the PowerSite process is easy to automate.

The performance-vs-cost ratio delivered by PowerSite technology is unparalleled:



⇒ *Competing against insulation pads+hardware for mounting power devices…* PowerSite technology has much higher thermal transfer at comparable cost.

⇒ *Competing against metal-clad PCBs for thermal circuitry…* PowerSite technology has comparable thermal transfer and more design flexibility, at lower cost.



The performance of PowerSite pads is compared with conventional technologies in the adjacent chart:

THERMAL INTERFACE TECHNOLOGIES COMPARISON					
Application	**Device Mounting**			**Power Circuitry**	**Die Mounting**
System	**MICA/GREASE**	**INSULATOR PADS**	**PowerSite™ (SIMS)**	**INSULATED METAL SUBSTRATE**	**DIRECT BOND COPPER**
Introduced	pre-1940	1960s	2001	1980s	1960s
Insulation Construction	Mica wafer with thermal grease on both sides	Filled silicone binder coated on glass fabric or Kapton film	Polyimide adhesive-coated Kapton MT film	Polymer/ceramic blend	Ceramic wafer
Typical Dielectric Layer Thickness, inch (mm)	0.002 to 0.005 (0.05 to 0.13)	0.005 to 0.020 (0.13 to 0.51)	0.0013 (0.033)	0.006 to 0.012 (0.15 to 0.30)	0.015 to 0.040 (0.38 to 1.00)
Device Attachment	Hardware compression	Hardware compression	Soldering	Soldering	Soldering
Typical Thermal Performance	High $0.1°C\text{-}in^2/W$ ($0.65°C\text{-}cm^2/W$)	Low 0.3 to $0.5°C\text{-}in^2/W$ (1.94 to $3.23°C\text{-}cm^2/W$)	High $0.1°C\text{-}in^2/W$ ($0.65°C\text{-}cm^2/W$)	High $0.1°C\text{-}in^2/W$ ($0.65°C\text{-}cm^2/W$)	Highest $0.05°C\text{-}in^2/W$ ($0.32°C\text{-}cm^2/W$)
Advantages	High thermal performance Low cost	Low cost, clean installation Design versatility Easiest rework	Automated Hardware-free Finned and non-planar heat sinks Copper applied only at device site Consistent thermal transfer Eliminates substrate-to-heat sink interface Polyimide durability and high dielectric strength	Automated Hardware-free Simultaneous device pad and circuit pattern etch Consistent thermal transfer	Very high thermal performance Automated Hardware-free Simultaneous device pad and circuit pattern etch Can accommodate thick copper layer
Potential Disadvantages	Messy, time consuming Attachment hardware Inconsistent, uneven coverage Dry out over time Contamination of adjacent circuitry	Attachment hardware Thermal transfer is pressure-dependent Heat sink modifications (holes, etc.) High mounting pressure can cause cut-through failures	Assembled with special process equipment Rework requires solder reflow	Dielectric variability, reliability Rework requires solder reflow Large, flat panels only Brittle - limits design, processing De-panelizing step required Can require heat sinks Copper etch process required	Rework requires solder reflow High cost Brittle - limits design, processing Can require heat sinks Processed in small panels Copper etch process required

Conventional thermal management technologies are mature. There is little room for any improvement, other than 'incremental bumps' in performance. (See 'Intellectual Property' section for in-depth review of both PowerSite technology and that under-development at the market leaders.)

PowerSite technology can still benefit from improvements in thermal performance and cost-effectiveness. In the chart below, TPI modification options are reviewed for altering (1) the thickness of the substrate, (2) the composition of the substrate and (3) the adhesive type. The impact on the electrical and thermal performance, along with the relative cost, is given for each candidate.

PowerSite™ TPI Bond Film Design Modifications				
Modification	Thickness (total, mil)	**Thermal impedance** (°C-sqin/W)	Dielectric strength (Vdc, minimum)	**Cost** (relative)
Thinner substrate *(same ceramic-loading)*	1.0	**0.08**	3000	**1.2**
Standard (FT's 130TPI)	1.3	**0.10**	4000	**1X**
Unfilled substrate *(no ceramic-loading)*	1.0	**0.12**	4000	**0.8**
	1.3	**0.15**	5000	**0.7**
Unfilled substrate + *Hybrid adhesive*	1.3	**0.15**	5000	**0.5**

In high-end applications requiring the maximum thermal transfer, customers will eagerly pay a higher price for PowerSite bond film.

In many other applications, however, customers would want to minimize their cost (*especially where PowerSite performance exceeds their requirements*) and would gladly use the lower-cost bond film.

The option listed last on the above chart –the bond film with '*Unfilled substrate + Hybrid adhesive'*— will also be attractive from a processing standpoint. This hybrid adhesive activates at a considerably lower heat-seal temperature than the thermoplastic polyimide adhesive on the other bond film candidates. (However, a post-bake in a oven is required then to fully-cure the hybrid adhesive before device soldering.)

OTHER CONSIDERATIONS

Moisture absorption

All polyimides absorb moisture, which must be dry before exposure to extremely high temperatures, such as those experienced during PowerSite heat-sealing and device soldering. After heat-seal bonding (and before soldering), PowerSite heat sink assemblies need to be kept in a sealed, dry environment to prevent water absorption from ambient air. If water absorption has occurred, the PowerSite assembly should be baked before soldering. [NOTE: *In general, moisture release is only a problem if it has nowhere-to-go, such as when it trapped between metal layers, whether in the application or process. Blistering then can result.*]

Moisture evolved from condensation reaction *(during heat-sealing only)*

The TPI thermoplastic polyimide adhesive is partially-cured until exposure to the high-temperature heat-sealing process, where the conversion from polyamic acid to polyimide polymer is completed. During heat-up in the bonding fixture, this moisture from the polyimide chemistry's condensation reaction --along with the moisture from water absorption-- needs to escape before full-pressure is applied. If this is *not* allowed to occur, blistering will occur in the bondline, which is detrimental to both physical and thermal integrity. Proper drying typically only requires a fraction of a minute at the elevated PowerSite temperatures. The PowerSite heat-sealing equipment and processes are designed for this product characteristic.

Solder

As in any surface-mount application, PowerSite pads require a thin layer of solder to adhere the power device to the copper. To minimize cost, we recommend –and can supply at a nominal charge—solder pre-forms for this process. Especially in applications that require lead-free solder, the cost of conventional no-lead solder paste is considerably greater than rolled solder pre-forms.

Dielectric Durability

In some rare applications where the metal surfaces that are heat-sealed (solderable surface and/or heat sink) have a significant amount of surface roughness, the dielectric integrity of the PowerSite might be compromised, due to physical damage. In these cases, we would supply a TPI bond film with a thicker substrate.

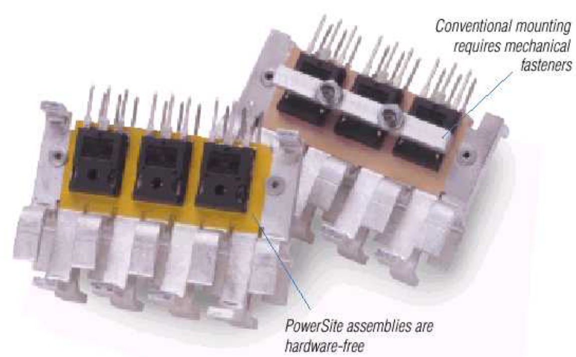
Corona-Resistance

In some power supply applications (continuous AC exposure > 500Vac), corona-resistance of the PowerSite polyimide-based dielectric becomes critical. For these instances, we would supply a TPI bond film with enhanced properties for corona-resistance. This filled polyimide substrate has about 100X the corona-resistance of conventional unfilled polyimide films of equivalent thickness and slightly lower thermal transfer.

POWERSITE™ SOLDERABLE PADS

PowerSite pads are copper patches bonded to heat sinks with TPI bond film. Discrete power devices, such as TO-220s and TO-247s, can be soldered to the copper patch. No attachment hardware is required. Thermal impedance for a PowerSite made with FT's flagship all-polyimide 130TPI bond film is only about 0.1°C-sqin/W.

The temperature level in power electronic packaging is high and continues to climb. Semiconductor die temperature must be kept below 150 °C, or the power device, and therefore the entire power supply, will fail. The use of PowerSites –versus a conventional insulating pad and attachment hardware—can reduce device operating temperature by 2 °C/Watt for a TO-220 or 1°C/Watt for a TO-247. The more thermally-efficient PowerSite can allow the design and operation of power supplies with more power, more reliability, more compact design.



In conventional applications with insulation pads, attachment hardware is required to hold the power device onto the heat sink at high pressure (which ensures its thermal transfer). As noted earlier and shown in the illustrations, PowerSites uses a heat-sealed bond film and copper pad + solder to adhere the device directly to the heat sink. This aspect also eliminates the need for modifying the heat sink to accept attachment hardware, as well as gives more UL clearance around the heat sink subassembly in the power supply.

High-end power supplies often use power devices that are \$1 to \$2 or more per device. The cost of the PowerSite is a small fraction of this, and can be well justified in many applications.

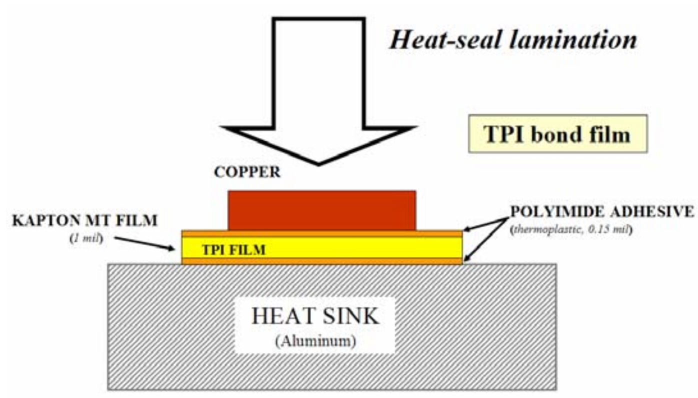
Benefit of owning the PowerSite technology:

- PowerSites are the highest performing insulation pads on the market.
- The technology is patented, with other patents pending.
- As PowerSites provide high value-in-use… yielding excellent performance which enables the OEM to market a premium product… therefore, the materials can be sold at a high margin.
- In addition, profits from manufacturing proprietary power subassemblies can be obtained. (This could include technology licensing.)

- When power electronic applications move to PowerSite technology, it becomes very difficult for an OEM to 'switch back' to the old design, due the high thermal performance and the elimination of hardware.

<u>Product description</u>:

The key to the PowerSite technology is the bond film. Our flagship product, 130TPI, is an all-polyimide construction of thermally-conductive Kapton film with a very thin coating of thermoplastic polyimide on both sides. The total thickness is 1.3 mils, or 33 microns. This is one-half the thickness of a human hair. Yet the dielectric strength is over 4000 Vdc.



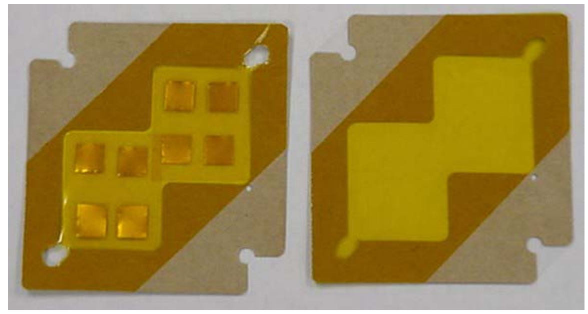
The copper foil used in PowerSites is a custom-grade with a low-profile treatment on one side (to accommodate the thin adhesive coating during bonding) and a durable tarnish-resistant coating on the opposite side to guarantee solderability.

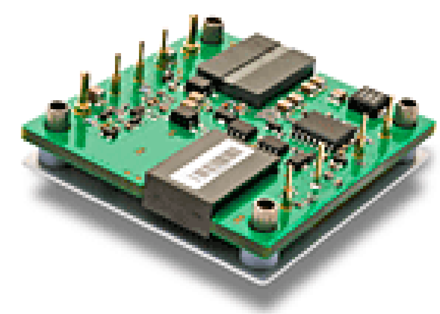
The solder used in PowerSites can be either paste or pre-forms. Rolled pre-forms are preferred for high-volume applications, due to cost, especially with the transition to lead-free solder.

Heat-sealing equipment for PowerSite assemblies are simple custom designs with heated platens and an air-pressure cylinder. Custom fixturing is required for each job. A single heat-sealing station can produce several PowerSite units per minute with a single operator. The cost of the heat-sealing station would be about $10-15K. The run-rate depends on the size of the assembly, but manufacturing time per assembly is typically about 2-to-4-per-minute-per-station.

The soldering of the power devices to the heat sink is done with a hot-plate system that moves the assemblies through the process and reflows the solder. The cost of the soldering station is about $5-10K. Run-rate is dependent on the size of the assembly, but 4-12 per-minute is typical. (Rate is typically limited by the manual placement of the solder and power devices on the heat sink.)

Placement templates are often required to ensure accurate positioning of the PowerSite patches through the bonding process. These templates would also be sold to the customer, and are a disposable item. An example of a disposable template is shown opposite. The power supply construction –PowerSite baseplate soldered to the PCB—are shown below.





Performance:

PowerSite pads use solder to attached power devices directly to heat sinks. No hardware is used, and therefore pressure dependency --to ensure thermal transfer-- is eliminated. The thermal transfer of PowerSites is much better than insulation pad materials + hardware (even with ideal pressure). A chart comparing PowerSites, generically described as ‘Laminated copper’ below, to various insulation pads appears below.

THERMAL PERFORMANCE: Junction Temperature and Thermal Resistance								
	TO-220 (8 watt)				**TO-247 (15 watt)**			
Interface Material	**Tj (°C)**		**Rj-s (°C/W)**		**Tj (°C)**		**Rj-s (°C/W)**	
(Air Flow, lfm =>)	0	100	0	100	0	100	0	100
Mica / grease	94.4	74.5	3.53	3.46	112.8	81.4	1.02	0.99
BN-filled silicone sheet	103.5	81.4	4.14	4.05	114.4	84.0	1.16	1.16
Kapton MT / phase change	100.0	79.3	3.87	3.84	112.4	81.8	1.00	0.94
Kapton MT / BN-filled silicone	104.7	93.7	4.46	4.41	116.5	85.1	1.27	1.22
Alumina-filled silicone sheet	107.8	87.0	4.94	4.89	120.8	90.4	1.71	1.67
Laminated copper	90.8	69.5	2.70	2.64	108.4	77.5	0.66	0.68

Note that PowerSites run cooler with the same heat-load, due to the low thermal impedance across the interface.

PowerSite thermal impedance is only 0.1^{o}C-sqin/W. This lower impedance translates to a considerable thermal advantage over conventional insulation pads:

POWERSITE THERMAL ADVANTAGE (*over alumina-filled pads + hardware)*	
TO-220	2^{o}C/W
TO-247	1^{o}C/W

Example: *A TO-220 device with 10 Watts of dissipated heat will run about 20^{o}C cooler with PowerSite mounting.*

For OEMs, this advantage can translate into power supplies with higher output and improved reliability. This allows OEMs to make higher margin on their unit-sales.

<u>Supply chain</u>:

TPI bond film consists of thin coatings of high-temperature, heat-sealable adhesive on both sides of a high-temperature dielectric film.

Kapton polyimide film is purchased from the DuPont Company. Alternative substrates would also work in most applications (and could be preferred in very cost-sensitive cases) – these would include Ultem film and generic polyimide film.

Adhesives used by FT are proprietary formulations. Toll manufacturing is done in New Jersey and Chicago. Adhesive formulations are trade-secrets. (The adhesive must bond quickly in a heat-seal operation, but then be able to withstand high-temperature soldering in the next process step – this characteristic makes the adhesive's properties unique.)

Film coating is done on a toll-basis in New Jersey.

EIS Fabrico of Kennesaw, GA provides value-added conversion services and markets the PowerSite technology to OEMs. EIS also designs PowerSite process equipment and runs prototype production.

PowerSite subassemblies are built by several companies in Asia. Union Bridge of Guangdong, China has been a qualified PowerSite supplier for several years. GMTS of Taipei, Taiwan should receive full-qualification shortly. Other suppliers are in the process of being evaluated as well.

Competitive position:

PowerSites must compete with the wide range of thermal insulating pad suppliers. These include Bergquist, Loctite Power Device, Parker Chomerics, among many others. As this is a mature and often very competitive market, prices can be quite low.

Even with extremely good thermal performance, PowerSites must be close in total cost to the conventional insulation pad designs, which include the pad, the attachment hardware (with required heat sink modifications), and the assembly labor. With low-cost Asian labor and a lower-cost FT bond film, we should be able to 'compete on price' in power applications where cost considerations are paramount.

PowerSite technology provides excellent thermal performance and durability in thermal management applications. Once production-volume processing is established, the cost of PowerSites is very competitive with the existing insulation pad + hardware technology. A comparison chart is shown below for the system costs of commodity- and premium-grades of both PowerSite and conventional insulation pads.

THERMAL MOUNTING COSTS for TO-220 DEVICE
(*Asia-based high-volume assembly operation*)

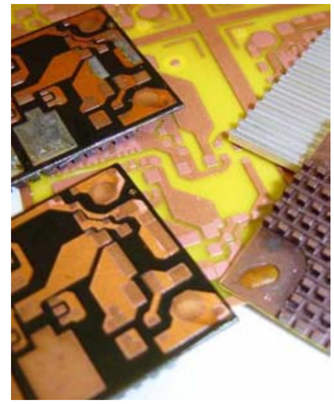
	POWERSITE		INSULATION PADS	
Component	Commodity	Premium	Commodity	Premium
Insulation material	$0.05	$0.10	$0.03	$0.10
Hardware	0	0	$0.01	$0.10
Heat sink modification	0	0	$0.01	$0.05
Assembly labor	$0.05	$0.05	$0.03	$0.05
TOTAL	$0.10	$0.15	$0.08	$0.30

Note: These are general estimates. Specific applications will vary.
Material cost for larger TO-247 devices will be higher.

Note that PowerSites are cost-competitive in both (1) materials and (2) total system cost with the conventional insulation pad + hardware. This parity is a requirement in the hyper-cost-sensitive Asian power supply market, where most OEM units are now assembled. When PowerSites are designed-in for their improved performance, there would be no incentive to switch back. In fact, in applications where the higher thermal transfer of a PowerSite is utilized in the design, switching to insulation pads + hardware would require downgrading the rated performance of the unit, which of course OEMs would be very reluctant to do.

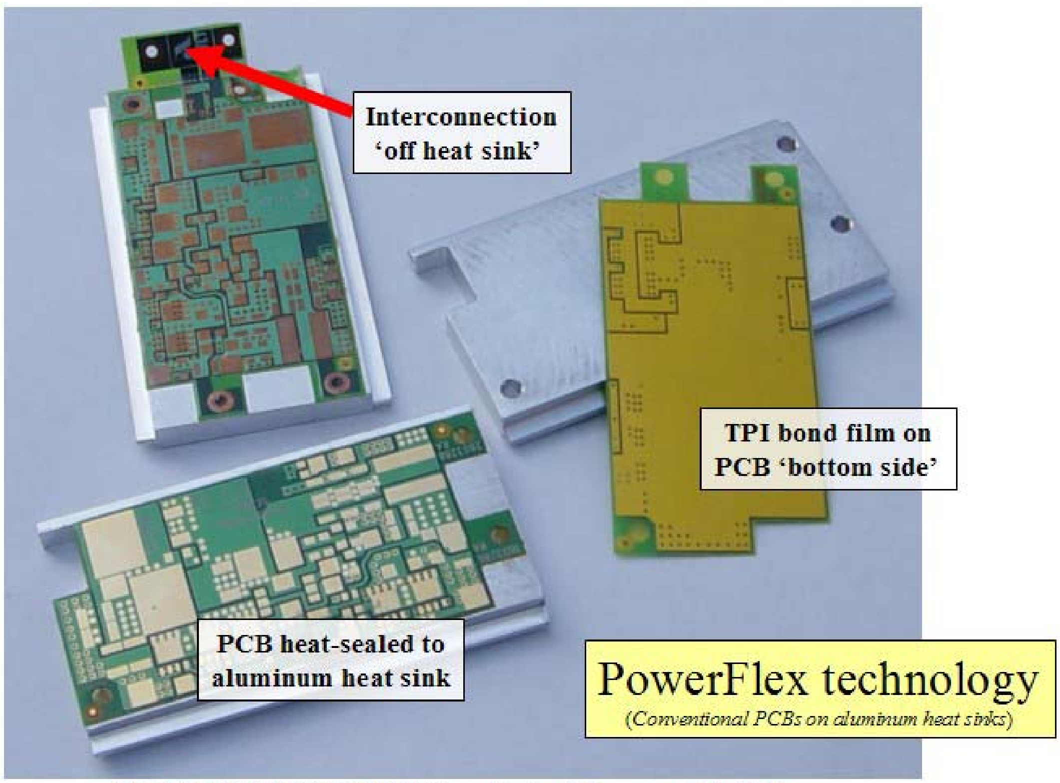
PowerSite technology is protected by patents awarded and pending. If an unlicensed overseas supplier was identified as using patent-protected technology –without FT materials and/or permission-- shipments of the entire assembly (such as a power supply) could be stopped by US Customs.

POWERFLEX™ THERMAL CIRCUITS



PowerFlex thermal circuits provide next-generation, high-performance thermal management, using conventional materials and processes. They utilize conventional printed circuits, such as FR4, bonded with FT's proprietary TPI bond film to aluminum heat sinks.

The thermally-conductive Kapton substrate and thin coating of polyimide adhesive of the TPI bond film yield a construction where the copper conductors are bonded within 1.3 mils of the heat sink (thermal impedance of about 0.1^{o}C-in2/W), while providing over 4000 Vdc dielectric strength.



FRAIVILLIG TECHNOLOGIES Boston, MA www.fraivillig.com

PowerFlex yields the following advantages over existing thermal management substrates, which include --at the 'high-end'-- Insulated Metal Substrate (IMS) and Direct-Bond Copper ceramic wafer (DBC):

- Higher thermal transfer than conventional mounting methods of flexible and rigid printed circuit boards to heat sinks at comparable cost.

- Elimination of assembly hardware – the printed circuit can be bonded directly to the heat sink.

- Lower cost than IMS and DBC constructions. We can use standard commodity FR4 and standard punched or extruded heat sinks.

- Higher thermal transfer than more-expensive IMS and DBC constructions in many applications. The PowerFlex printed circuit can be bonded *DIRECTLY* to the heat sink -- the thermal interface resistance resulting from the mechanical attachment of the IMS and DBC to the heat sink is eliminated.

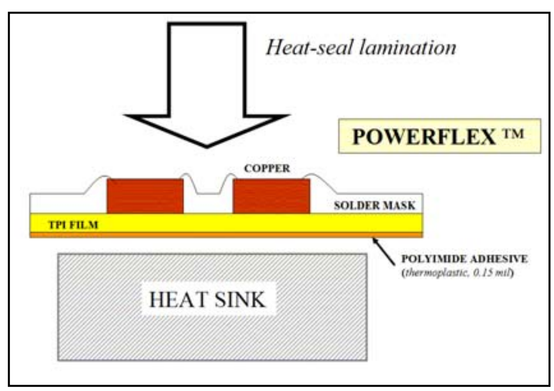
- Greater design flexibility than IMS and DBC constructions:
  - Physically flexible (plastic film dielectric)
  - Inexpensive addition of additional circuitry layers (standard print-and-etch)
  - Can be bonded directly to practically any shape or size or material type heat sink
  - Allow circuitry to extend past the edge of the heat sink (perhaps connecting to other subassemblies)
  - Use conventional circuit processing equipment and materials
  - Physically robust ('unbrittle' plastic film or fabric dielectric and metal heat sink)
  - Can be made into literally any dimension (width or length).

Benefits of owning or licensing the PowerFlex technology:

- PowerFlex has thermal comparable performance to IMS, but can be manufactured at lower cost. In addition, the design flexibility options help 'lock-in' the customer.
- The technology is proprietary (patents pending and trade-secrets).
- As PowerFlex technology provides high value-in-use, the TPI materials can be sold at a high margin.
- In addition, profits from manufacturing proprietary power subassemblies can be obtained. (This could include technology licensing.)
- Practically any PCB shop can be 'qualified' to manufacture PowerFlex assemblies.

<u>Product description</u>:

PowerFlex uses TPI bond film and a heat-sealing process to mate the PCB and the heat sink (see 'PowerSites' for details).



For multilayer applications, the TPI is tack-bonded to the back-side of the finished FR4 panel. The individual circuits are then depanelized. The TPI, already on the PCB, allows heat-sealing to the aluminum heat sink. The same bonding and solder reflow equipment is used as with PowerSites.

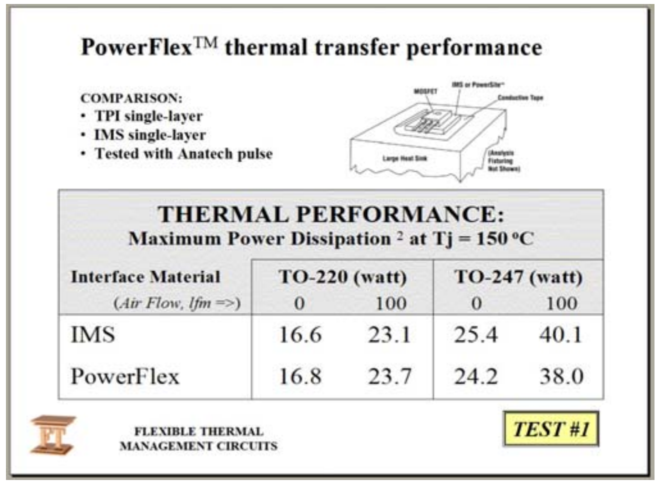
Performance:

PowerFlex TPI bond film has very low thermal impedance: 0.1°C-sqin/W. This is about the same value as alumina-based IMS. (See studies show opposite.)

In addition, PowerFlex circuits can be bonded directly to practically any aluminum heat sink. IMS plates need to be attached with hardware and interface materials. This adds cost, labor assembly thickness, and thermal resistance.

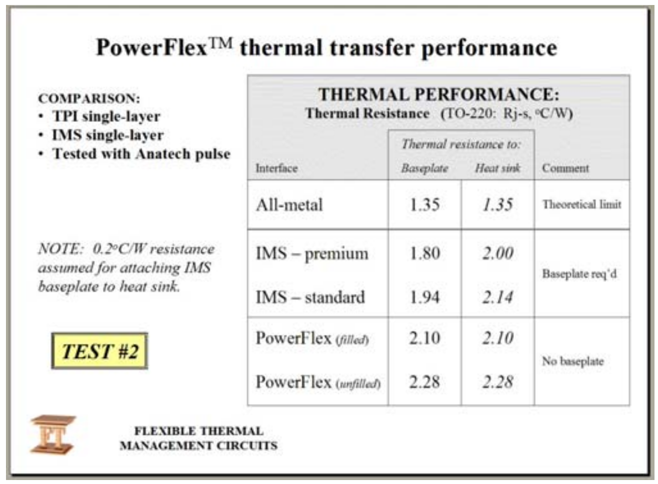
For multilayer constructions, FR4 can be used for the conductive circuit layers, in conjunction with TPI bond film. Thermal vias between layers provide excellent heat transfer to the TPI bond film.

The all-polyimide performance of TPI bond film allows higher operating temperatures, up to 200°C continuous. Other metal clad baseplates are epoxy-based, and are limited to about 135°C. This feature will become more important as future electronics become more densely populated, and need to run hotter and hotter.



THERMAL PERFORMANCE:
Maximum Power Dissipation ² at Tj = 150 °C

Interface Material	TO-220 (watt)		TO-247 (watt)	
(Air Flow, lfm =>)	0	100	0	100
IMS	16.6	23.1	25.4	40.1
PowerFlex	16.8	23.7	24.2	38.0



THERMAL PERFORMANCE:
Thermal Resistance (TO-220: Rj-s, °C/W)

Interface	Thermal resistance to: Baseplate	Heat sink	Comment
All-metal	1.35	*1.35*	Theoretical limit
IMS – premium	1.80	*2.00*	Baseplate req'd
IMS – standard	1.94	*2.14*	
PowerFlex *(filled)*	2.10	*2.10*	No baseplate
PowerFlex *(unfilled)*	2.28	*2.28*	

Supply chain:

PowerFlex uses the same supply chain for TPI as PowerSites.

Circuit board work can be provided by any practically any FR4 shop, but experience with thin substrates is generally preferred.

EIS Fabrico of Kennesaw, GA provides value-added conversion services and markets the PowerFlex technology to OEMs. EIS also designs process equipment and makes limited prototypes runs.

PowerFlex subassemblies are built by several companies in Asia. Union Bridge of Guangdong, China has been a qualified PowerSite supplier for several years. GMTS of Taipei, Taiwan should receive full-qualification shortly. Other suppliers are in the process of being evaluated as well.

Competitive position:

The existing products, both IMS and DBC, have set fairly high price expectations in the market.

PowerFlex is well positioned to provide comparable performance at lower-cost, and with more design and manufacturing flexibility. This is especially true in multilayer constructions, where commodity FR4 can provide comparable thermal performance to IMS on inner-layer thermal resistance – with thermal vias in the FR4, all the heat in the PCB rushes to the bond film interface, where TPI can match the IMS layer.

PowerFlex™ relative cost

RELATIVE SYSTEM COST (Area Basis)

Interface	PCB layers: *Single-*	*Double-*	Comment
PowerFlex	*1*	*1.5*	No baseplate, Bonding req'd
IMS (standard)	*1.5*	*3*	With baseplate, Hardware req'd
DBC	*2.5*	*5*	Hardware req'd

NOTE:
- IMS baseplate and DBC need to be adhered to a heat sink with hardware and thermal compound.
- PowerFlex can be bonded directly to a heat sink.
- The cost of heat sink processing (bonding the PowerFlex, or hardware-attaching the IMS or DBC) are application-dependent and are not considered above.

FLEXIBLE THERMAL MANAGEMENT CIRCUITS

Due to its high value-in-use, TPI can command a high margin and still provide an electronic packaging system that is much lower in cost than IMS or DBC.

For cost-competitive applications, such as low-end power supplies and automotive control circuitry, FT is developing a lower-cost TPI bond film (with lower thermal transfer) to displace the assembly adhesives now being used.

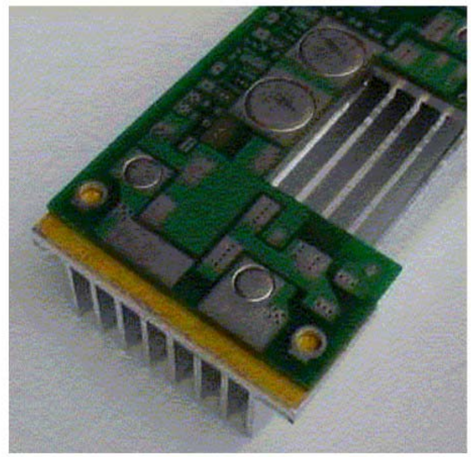
FT has patents pending on the PowerFlex technology. In addition, the adhesive formulations are trade-secrets.

POWERVIA™ THERMAL COLUMNS

PowerVia™ thermal columns are solid-metal, electrically-isolated thermal vias. When used in a conventional surface-mount printed circuit board (PCB), PowerVias can dramatically improve power device cooling, and offer design options and enhanced manufacturability in electronic packaging.

PowerVias allow the attachment of a fully-assembled FR4 printed circuit board onto a heat sink with the thermal path between the power device and the heat sink impeded by only 1.3 mils of dielectric film, which is integrated into the PCB. The thermal resistance of the PowerVia is 1-2^{o}C/W, depending on the model.

PowerVias for D2Paks



PowerVias inserted into PCB

PowerVias can eliminate the need for through-hole mounting of power devices into a surface-mount PCB. This avoids the subsequent (often clumsy) grappling with the independent cooling and electrical isolation requirements of the through-hole devices.

PowerVias offer the following advantages versus existing plated-through thermal via technology, including:

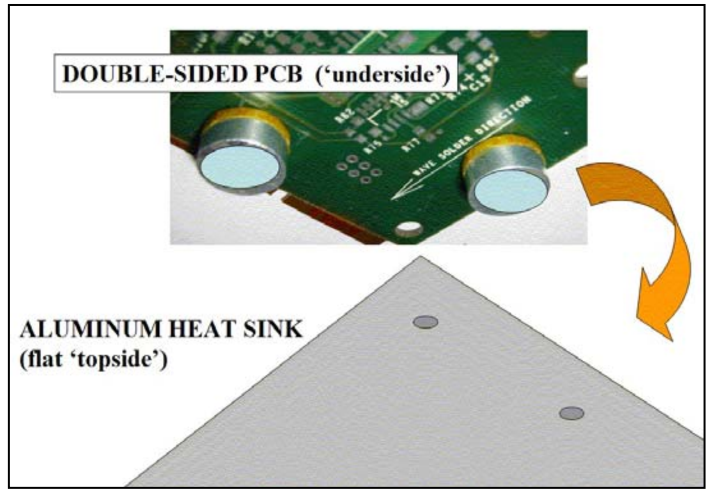
- Higher thermal transfer, mainly due to its solid metal structure
- Eliminates pressure dependency of thermal transfer
- Component mounting on *both* sides of the PCB with a flat heat sink surface
- Addition of ‘thermal mass’ to the PCB, allowing short-term full-strength electrical testing.

Benefits of owning the PowerVia technology:

- PowerVias can convert a simple thick FR4 board –easily mated with a planar heat sink surface-- into a high-performance thermal management system.
- PowerVias are a proprietary technology, with high thermal performance and unique design capabilities. Once adopted, these features ‘lock-in’ the customer.
- As PowerVia technology provides high value-in-use, the units can be sold at a high margin.
- PowerVias can be offered in standard sizes, for off-the-shelf availability.

Product description:

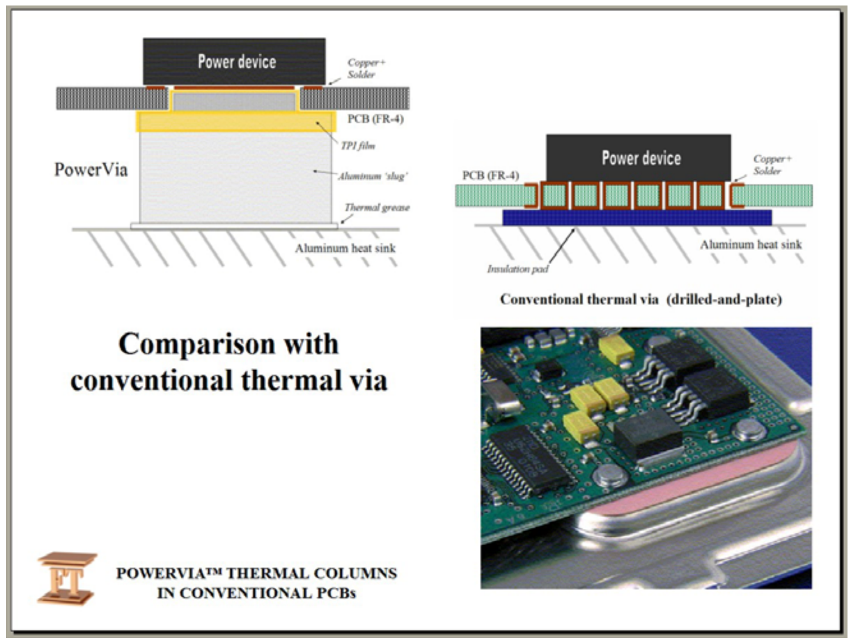
PowerVias use TPI bond film (see 'PowerSites' for details) that adhere a solderable copper patch to the top of an aluminum column.



The PowerVias are inserted into the underside of the PCB, and then the power components are soldered onto the PowerVias copper surface (which poke through the PCB).

The fully-assembled PCB can then be attached with hardware to the heat sink (but with no pressure-dependency). Thermal compound – either thermal grease or phase-change material—ensure heat transfer to the heat sink during operation.

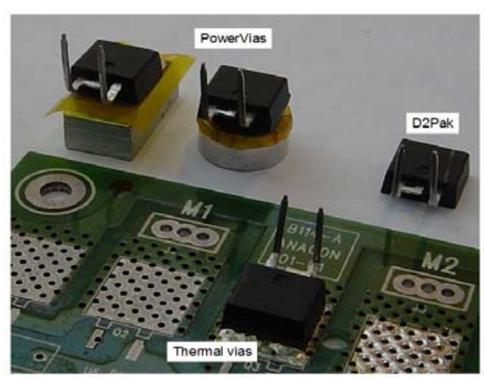
The PowerVias can allow for double-sided PCBs, as they provide a stand-off from the heat sink.



In comparison, conventional mounting of PCBs with plated-thru thermal vias requires insulation pads, where high-pressure must be applied to the PCB to ensure heat transfer to the heat sink. (See comparison opposite.)

Often, conventional mounting requires a contoured heat sink, if double-sided PCBs are to be used. This adds cost and complexity. (See opposite.)

Performance:



The thermal transfer performance difference between PowerVias and conventional mounting with plated-thru vias and insulation pads is significant.

The following chart shows that PowerVias can reduce the heat of D2Pak device as much as 7-8°C/W.

Thermal resistance comparison [5] *Control board with soldered-on D2Pak, bolted to heat sink*		
Thermal method	**Active area**	**Rj-s**
PowerVia (circular footprint)	0.08 => 0.20 sqin (Face-to-base)	4.4 ^{o}C/W
PowerVia (rectangular footprint)	0.20 => 0.30 sqin (Face-to-base)	2.7 ^{o}C/W
Thermal via + pad	0.30 sqin	11.4 ^{o}C/W

In addition, PowerVias can add enough 'thermal mass' to the subassembly that the fully-assembled PCB can be tested at full power, *before* the unit is attached to the heat sink. This feature streamlines the manufacturing process.

Supply chain:

PowerVias use the same supply chain for TPI as PowerSites.

The aluminum columns can be sourced from any precision machine shop that works with extruded and screw-cut metal rods. For high-volume supply, sourcing from Asia is recommended.

The assembly heat-seal bond process for converting the aluminum columns into PowerVias can be designed for automation or high labor content (which becomes efficient when the per-hour charge is low).

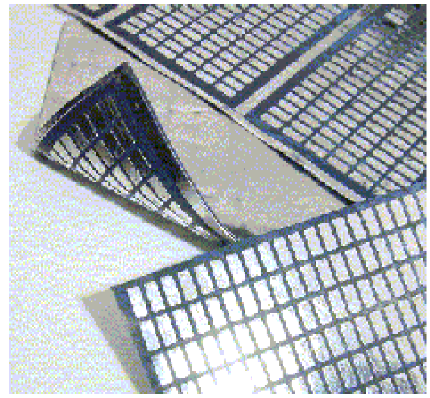
Competitive position:

An FT patent protects PowerVia technology. In addition, the adhesive formulations and the PowerVia manufacturing process are trade-secrets.

DIELECTRIC COATED COPPER

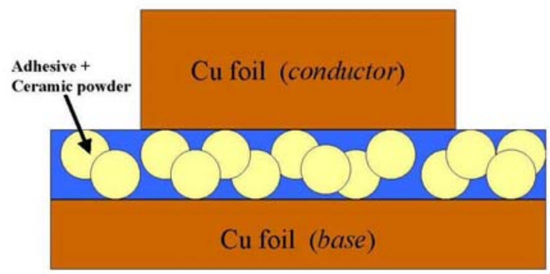
Dielectric-coated copper (DCC) provides excellent cost-effective layer addition in a wide range of compact, low-voltage electronic packaging applications. The conventional substrate material of fiberglass or plastic film is eliminated. Dielectric strength is provided by the combination of ceramic filler and polymeric coating. Features include:

- Ultra-thin layer addition
- Extremely low thermal impedance
- Tailored dielectric strength
- Highly-flexible packaging (with selected polymers)
- Enhanced processing:
  - Easy lay-up
  - Fast lamination cycles (selected polymers)
  - Fast, clean laser ablation
  - Fast chemical etching
- Cost-effective, vs comparable substrate constructions



Benefits of owning the DCC technology:

- This technology provides the ultimate in high thermal-transfer, low-cost substrates for low-voltage applications, and could replace DBC ceramic and IMS.
- DCC technology can also be applied to conventional PCB manufacturing for multilayer addition.



Dielectric-Coated Copper Properties	
Customization	System properties are dependent on the type of polymer and its coating thickness and on the type of ceramic filler, its loading level and particle size. Properties reported below are representative of typical performance.
Dielectric thickness	0.2 to 5+ mil (5 to 125+ micron)
Dielectric strength	50-1000 volts (minimum) 200-2000 volts (average)
Thermal impedance (dielectric layer)	0.02 – 0.2 °C-sqin/W
Thermal resistance (polyimide, epoxy/phen.)	200°C (continuous) 300°C (exposure)
Bond strength	*Depends on polymer and loading*

Product description:

The term 'Dielectric-Coated Copper' is self-explanatory. This is a simple-yet-proprietary concept, applied to demanding high-end thermal applications, where only several hundred volts isolation is required. (NOTE: 'Dielectric overdesign' enacts a penalty in both the cost of the required materials and thermal resistance of those 'extra materials'.)

After the copper has been coated with the polymer with ceramic loading –serving as both a dielectric and adhesive—the foil is bonded to a metal substrate layer of either aluminum or copper. The copper is then printed and etched by conventional PCB manufacturing. The resultant circuitry can then be used as an electronic substrate for soldering power components. Heat generated by these components is quickly drained away to the metal substrate layer, which can be attached to a larger heat sink.

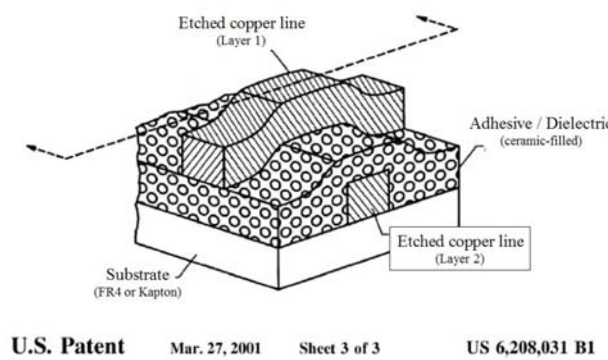
Supply chain:

DCC laminates use the same supply-chain polymer formulation and coating operations as PowerSites, except for the contract sheet-lamination of the coated copper and substrate plate. Long-term, it probably would be optimal to do the lamination and printing-and-etching in Asia, close to the power electronics manufacturing.

Competitive position:

An FT patent protects DCC technology. In addition, the adhesive formulations are trade-secrets.

As disclosed in the FT patent (see opposite), the ceramic particles maintain the spacing and dielectric separation between the conductive layers. Other coated copper systems --such as IMS-- are much thicker, using the bulk of the overall material to ensure spacing and dielectric strength between the conductive layers.



TARGET MARKETS and APPLICATIONS

The core of PowerSite technology is the heat-sealable TPI bond film, which is used in PowerSite solderable patches, PowerFlex thermal circuits and PowerVia thermal vias. We expect that this revolutionary technology will become the standard of the next-generation thermal management for mounting power semiconductors to heat sinks.

The power electronics market is a natural target for PowerSite technology, especially applications with high power density, which dramatically increases the need for thermal management.

Power supply units are used where electrical current must be converted from one form to another. These 'power conversion' modules are not 100%-efficient, and this inefficiency results in heat that must be dissipated, or the power semiconductors will fail.

For instance, a 300-Watt power supply might be 85%-efficient. This means that there will be 45W of heat to be dissipated [= 300 x (1-0.85)]. Much of this waste heat is generated in the power semiconductors, which have very small footprints. So the heat must be removed quickly and efficiently from these tiny packages. If the silicon chip (or 'die') in the power semiconductor exceeds 150^{o}C, it is in danger of failing. Even at temperatures less than this critical point, the rule-of-thumb is every 10^{o}C in increased operating temperature corresponds to a doubling of the failure rate of the power devices.

In general, PowerSite technology has the best applicability and competitive advantage in demanding applications:

- Where the power supply manufacturer wants to push his design to the limit, to increase revenue. Often, the switch to PowerSite technology will allow the same power supply design to operate with a higher output power, with the same hardware. For instance, producing an output of 350W instead of 300W. As power is often sold by-the-Watt, this is a significant feature. In addition, the same power supply design becomes 'higher-density' at the higher power, and high-density units typically sell for higher-margin.

- Where ambient operating temperatures are high, and therefore there is less 'driving force' to cool the power devices. Many power supplies need to use an ambient air temperature as hot as 75-85^{o}C (167-185^{o}F) to *cool* their heat sinks.

- Where power density is high (expressed in Watts-per-volume of the module), as this raises the temperature of the entire package.

- Where attachment hardware for the power devices is bulky, expensive, encroaches on UL electrical clearance, or is hard-to-install and/or tighten. Or maybe, where the manufacturer just doesn't want to worry about thermal interface pressure-dependency at all.

Fraivillig Technologies has focused on the power conversion market: the manufacture of power supplies. But other high-power applications offer opportunities as well.

(NOTE: The series of charts shown opposite show applications and US-based OEMs that design and/or manufacture power supplies. The 2003 charts are slightly out-of-date.)

Power Electronics

POWER SUPPLIES

- DC/DC “bricks” (*change voltage*)
- AC/DC boxes (*AC=>DC*)
- DC/DC boxes (*change voltage*)
- Inverters (*DC=>AC*)
- RF amplifiers (*telecoms*)
- Uninterupptible Power Supplies (“*UPS*” *for computers, telecoms*)
- Chargers
- Test equipment
- Fuel cells

ELECTRONIC CONTROL

- Motion control
- Motor control

AUTOMOTIVE

- Voltage regulators
- Control boards

=> engine, transmission, brakes

MULTI-CHIP MODULES

Incorporates multifunctions onto single solid-state board

Fraivillig Technologies

The main application presently for our technology is compact DC-to-DC modules that are plugged into large circuit boards: “Board-mounted power”, or BMP. This specific power format is know as a ‘*brick*’, which has become a standard footprint with many power end-uses, such as telecom base stations, servers and military applications. These ‘brick’ design engineers have very tough thermal requirements, and are relatively more receptive to new technology (once they feel comfortable with its robustness).

DC/DC “*brick*” power supplies

- Products: ***PowerFlex, PowerSites and PowerVias***

Artesyn (Eden Prairie, MN)
Astec (Carlsbad, CA)
Broadband Telcom (Santa Ana, CA)
BTC Power (Costa Mesa, CA)
C&D Tech (Raleigh, Tucson)
Calex Mfg (Concord, CA)
Celestica (Toronto, Canada)
Cherokee (Tustin, CA)
Condor (Oxnard, CA)
Core Tech (Westlake, OH)
Data Device (Bohemia, NY)
Datel (Mansfield, MA)
Ericsson (Richardson, TX)
Galaxy Power (Westboro, MA)
Innoveta (Plano, TX)
Martek (Brockton, MA)
Modular Devices (Shirley, NY)
NetPower (Plano, TX)
Pico (Pelham, NY)
Power General (Canton, MA)
Power-One (Camarillo, CA)
Rantec (Los Osos, CA)
RO Associates (Sunnyvale, CA)
SynQor (Westboro, MA)
TI PowerTrends (Warrenville, IL)
Tyco Power (Mesquite, TX)
Vicor (Andover, MA)

As the thermal demands increase in all types of power supplies, the attractiveness of a PowerSite technology is manifest. In addition, our ongoing efforts to reduce the installed cost of the PowerSite technology --through process and product improvements-- will also pay dividends in adoptions.

AC/DC and DC/DC “*box*” power supplies

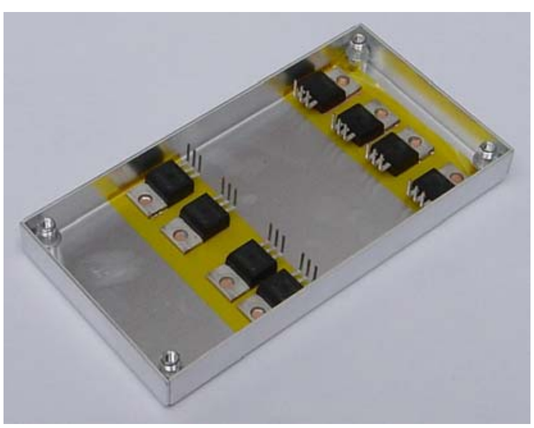
- Products: ***PowerSites and PowerVias***

Absopulse (Carp, ON)
Acopian (Easton, PA)
Advanced Power Solutions (CA)
Advanced Tekris (La Mesa, CA)
Agilent
AHV (El Cajon, CA)
Alacrity
American High Voltage (Elko, NV)
American Power Design (NH)
American Reliance (Arcadia, CA)
American Skynet (Milpitas, CA)
Artesyn (Eden Prairie, MN)
ASI (Carlisle, PA)
Ault (Minneapolis, MN)
Autec (Simi Valley, CA)
Avansys
Bertran (Hicksville, NY)
Best Power (Necedah, WI)
Carlo Gavazzi (Brockton, MA)
Condor (Brentwood, NY)
Condor (Oxnard, CA)
Converter Concepts (Longwood, FL)
Cosel USA (Santa Clara, CA)
CPS (Tigard, OR)
Datel (Mansfield, MA)
Del Electronics (Valhalla, NY)
DigitalD Power
Dunamis Power (San Jose, CA)
Eagle-Picher (Joplin, MO)
Electro Industries
Emco High Voltage (Sutter Cek, CA)
EOS (Camarillo, CA)
Extech Instruments (Waltham, MA)
Extreme Power (Pleasanton, CA)
Friwo
Gamma High Voltage (Ormond, FL)
Glassman High Voltage (NJ)
Globtek (Northvale, NJ)
HC Power (Irvine, CA)
Integrated Power Designs (W-B, PA)
Interpoint (Redmond, WA)
Invensys (Raleigh, NC)
ITT (Fort Wayne, IN)
James Electronics (Chicago, IL)
Jerome Industries (Elizabeth, NJ)
Keithley (Cleveland, OH)
Kepco (Flushing, NY)
Lambda (Melville, NY)
Lambda Novatronics (Pompano, FL)
Ling Electronics (Anaheim, CA)
Logitek (Ronkonkoma, NY)
LZR
Magna-Power (Boonton, NJ)
Magnetek / Chatworth
Martek Abbott (Los Angeles, CA)
Martek Power Switch (Lodi, NJ)
Marway (Orange, CA)
Newport Components (Raleigh, NC)
OnLine Power Supply (Auburn, MI)
OTE (Grand Prairie, TX)
Pioneer Magnetics (CA)
Polytron Devices (Paterson, NJ)
Power General (Canton, MA)
Power Solutions (Roslyn, NY)
Power Ten (Los Gatos, CA)
Powerbox (Bloomfield, CO)
Powercube (Chatsworth, CA)
PowerDec (Sunnyvale, CA)
PowerDsine (Farmingdale, NY)
Power-One (Camarillo, CA)
PowerVolt (Addison, IL)
Schaefer
Schaffer (Springfield, NJ)
Sierra West (Las Cruces, NM)
Sorenson (San Diego, CA)\
Spellman (Hauppauge, NY)
SSI (Anaheim, CA)
Switching Power (Ronkonkoma, NY)
Taiyo Yuden (San Marcos, CA)
Tamura (Temecula, CA)
TDI (Hackettstown, NJ)
TDK (Mt Prospect, IL)
Technology Dynamics
Tetrol
Tyco Power (Mesquite, TX)
Unipower (Coral Springs, FL)
Universal Voltronics (Mt Kisco, NY)
Vectron (Norwalk, CT)
Volgen (Milpitas, CA)
Voltex (N Amitville, NY)
Wall Industries (NH)
Xantrex (Bellingham, WA)
Xentek (San Marcos, CA)

In addition to power conversion, other industries have electronic systems with similar cooling requirements. These markets also would offer significant potential for PowerSite technology.

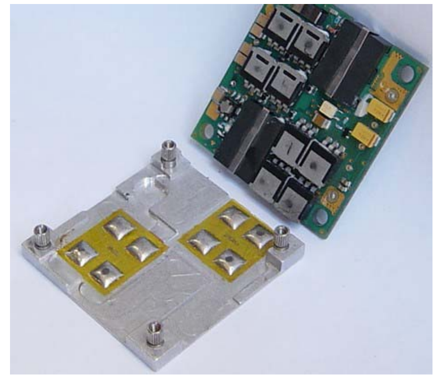
Application		*Potential Target Accounts*	
INVERTER PowerSites, PowerVias		• Exeltech (TX) • Advanced Conversion (NJ)	
RF AMPLIFIER PowerSites		• PowerWave (CA) • Lucent (NJ) • Richardson (IL)	• Microwave Power (NY) • RF Power (NJ)
UPS PowerSites, PowerVias		• APC (MA, RI) • Invensys (NC) • Behlman (NY)	• NOVA Electric (NJ) • Active Power (TX)
CHARGER PowerSites, PowerVias		• Ibex (RI) • Diversified Power (TN)	• Schaefer
TEST EQUIPMENT PowerSites, PowerVias		• Agilent (CA) • National Instrument (TX) • B+K Precision (CA) • California Instrument (CA) • Hipotronics (NY) • Pacific Power (CA)	• Tektronics (OR) • Trek (NY) • Arbin (TX) • Digatron (CT) • Lake Shore Cryotronics (IL) • PTS (MA)
CONTROL PowerSites, PowerVias	Motion Control Motor Control	• Parker Hannifin • Anacon	
AUTOMOTIVE PowerSites, PowerVias	Voltage Regulators	• Transpo • Renard	
	Control Boards ⇒ Engine ⇒ Transmission ⇒ Brakes	• Motorola • Delphi • GM	• DaimlerChrysler • Visteon
MCM PowerFlex		• Omnirel (MA) • Powerex (PA) • Semikron (NH)	• Trace Tech (CA) • Automotive • Computers

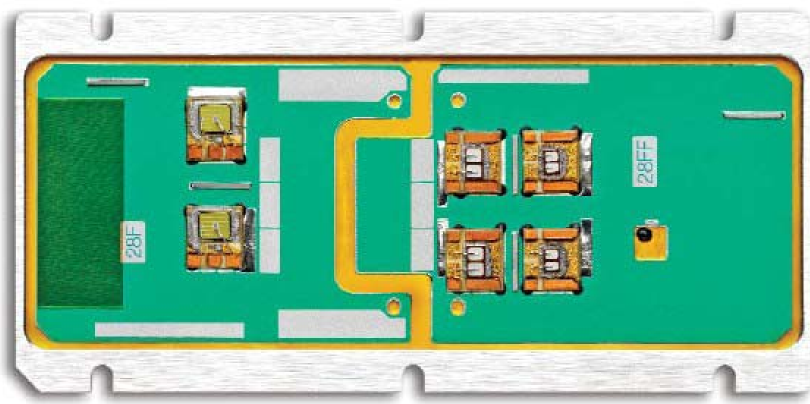
PowerSite technology has been adopted in demanding commercial applications. With few exceptions, these are all high power-density applications, mostly DC/DC brick converters.



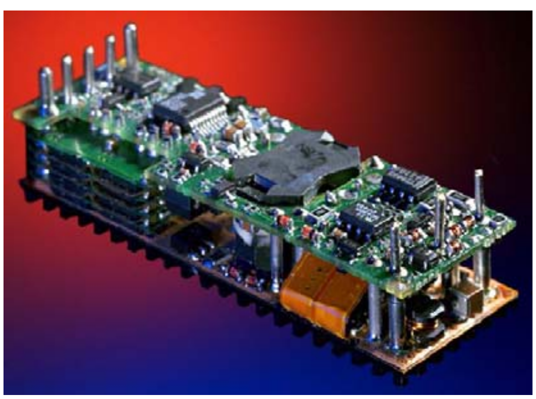
A DC/DC full-brick baseplate, where the power devices run about 20^{o}C cooler with PowerSites than the next-closest high-performance thermal interface system. In addition, installing the attachment hardware for insulation pads was problematic.

A DC/DC half-brick using PowerSites to solder the assembled PCB to the aluminum baseplate. Runs about 25^{o}C cooler than insulation pads+thermal compound+hardware. With the old system, applying sufficient pressure was problematic.

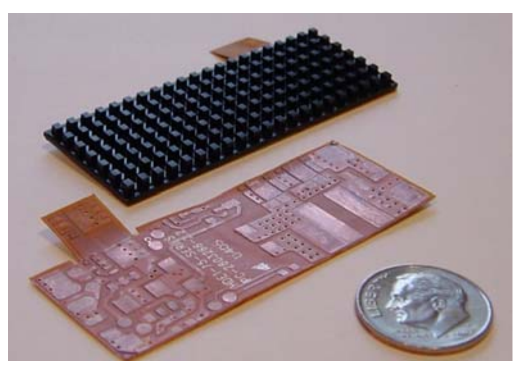


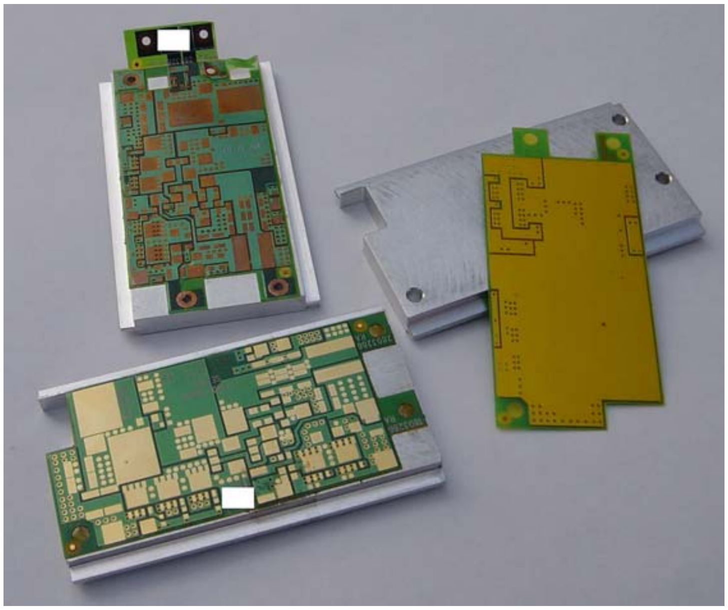


A DC/DC full-brick with solderable plates for direct-die attach, bonded in a routed pit in the aluminum baseplate.

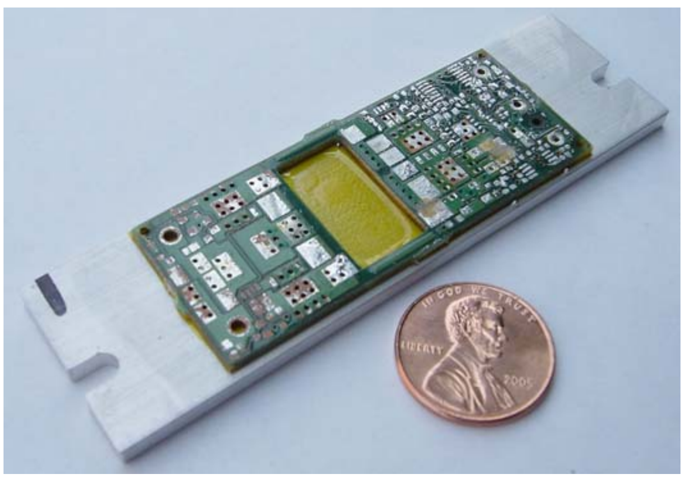


A DC/DC eighth-brick using PowerFlex to mount the power circuitry directly to a finned baseplate. The manufacturer reports 15% more power output than the comparable design with IMS+heat sink.



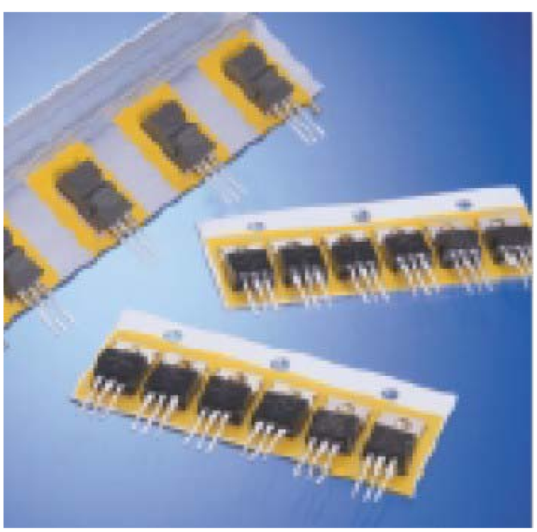


Power adaptor that can generate 125W from a 12V car outlet. PowerFlex with thin FR4 PCB bonded to a thick heat plate. Cooled only by potting compound’s conduction to ambient case.

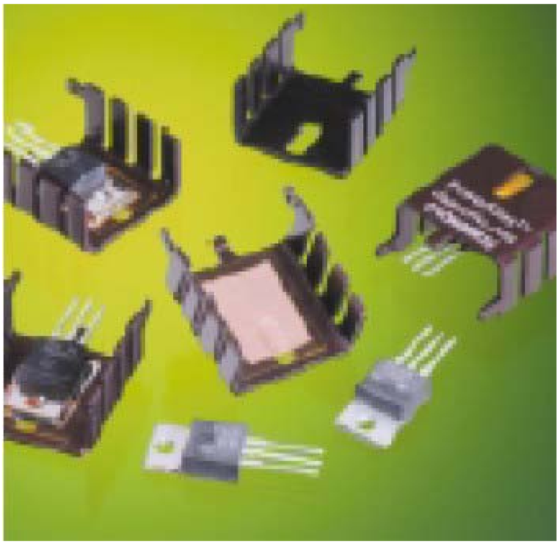


DC/DC eighth-brick PCB bonded to thick baseplate baseplate (prototype demo unit). PowerFlex with thick, six-layer FR4 PCB.

This is a classic configuration of power devices mounted to a heat sink. The power devices are aligned in an linear array, and plugged into a PCB in a 'box' power supply (a classic example is the 'silver box' in the back of a personal computer). A high-speed fan blows or sucks air threw the power supply, and removes the dissipated heat from the heat sinks. A rack-mounted, hot-swappable AC-to-DC power supply is shown below. This format is often used in large banks of power supplies in the telecoms industry.



Another heat sink format used in box power supplies: an array of power devices are mounted to a metal baseplate, and then –after the devices' electrical leads are plugged into, and soldered onto, the PCB-- the metal baseplate is screwed up against the wall of the power supply enclosure (literally, the inside of the metal box). The dissipated heat is then managed externally to the power supply.



In many power-density applications, single power devices are mounted on individual heat sinks, and this mini-subassembly is then plugged into the PCB. A small percentage of these units have high thermal dissipation demands and could benefit from PowerSite technology. But even where the thermal demands are low, PowerSite technology – *competitively-priced, of course*—would offer design and manufacturing advantages, versus dealing with insulation pads and clumsy attachment hardware.

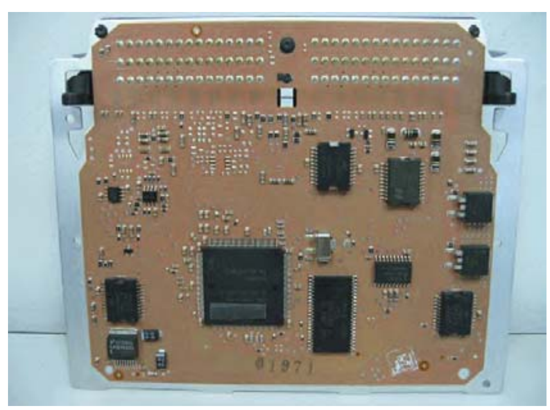
MOTOR and MOTION CONTROL

Motor controls and motion controls (for automation) have electronic packaging that is very similar to that in power supplies. This includes the need for optimal thermal management. The markets for motor and motion control are not as large as the power supply market, but much of the manufacturing has remained in the US, and price pressures are lower.

AUTOMOTIVE CONTROLS

This is the biggest application for thermal management of power electronics in the world. Power electronics now control the car's engine, transmission, brakes and (soon) steering – virtually, drive-by-wire.

Until recently, the power density has been low for these modules, and designers did not need a high-performance thermal system. On many applications, they've been using a system that has 5-8X the thermal resistance of PowerSite technology: PCB soldermask for electrical insulation with a layer of pressure-sensitive adhesive to mate with the aluminum baseplate. The state-of-the-art, sort of: *Circuits have been bonded down to heat sinks with Scotch tape*. An example of this design in shown opposite.

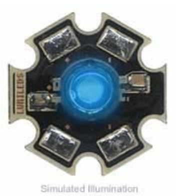


The automotive market is dramatically increasing the power requirements in cars (not even including hybrid and fuel-cell designs), while moving to more compact electronic packaging to save space and weight. Historically, when the going-got-tough thermally, automotive designers would use ceramic-based substrates. But these are very expensive and not design- and manufacturing-friendly.

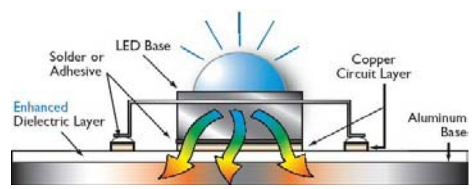
Another trend that enhances the attractiveness of PowerSite technology in automotive: *the ecologically-driven transition to lead-free solder.* This increases the solder reflow temperature, where the metal alloy goes liquid and bonds the electronic component to the PCB (both physically and electrically). This higher reflow temperature is beyond where many of the old-style packaging formats with the “Scotch tape” bond film can survive. PowerSite technology can survive these high temperatures with ease.

The time is right for the next-generation in thermal management of automotive power electronics. PowerSite technology products, with their cost-efficient nature and design flexibility, are well-positioned.

LIGHT DISPLAYS (LEDs)



Light-Emitting Diode (LED) technology enables lighting systems that are highly-effective and energy-efficient. LEDs are now moving beyond light displays and taillights (where they need to be bright and visible) to automotive headlights (where they actually *project* light).



An illustration of the use of LEDs in automotive taillights and headlights from an industry publication is shown below.

Figure 1 Bright LED's small dimensions allow automakers to design CHMSLs (center, high-mount stop lights) into trunk lids, which, for some body styles, provides better visibility (top). Bright-LED brake lights provide greater safety by eliminating the 200-msec turn-on time tungsten bulbs require. Their size and low-temperature operation allow greater flexibility in tail-light design (bottom) (courtesy Fairchild Semiconductor).

As LEDs have gotten brighter and brighter, their power requirements have increased, and with that, the need for thermal dissipation. Like power semiconductor devices, if the LED exceeds a temperature of 125°C, it is in danger of failure.

Next-generation LEDs are now being designed with IMS substrates, moving away from standard FR4 hardboard packaging. These applications are a prime target for both PowerFlex and DCC technologies:

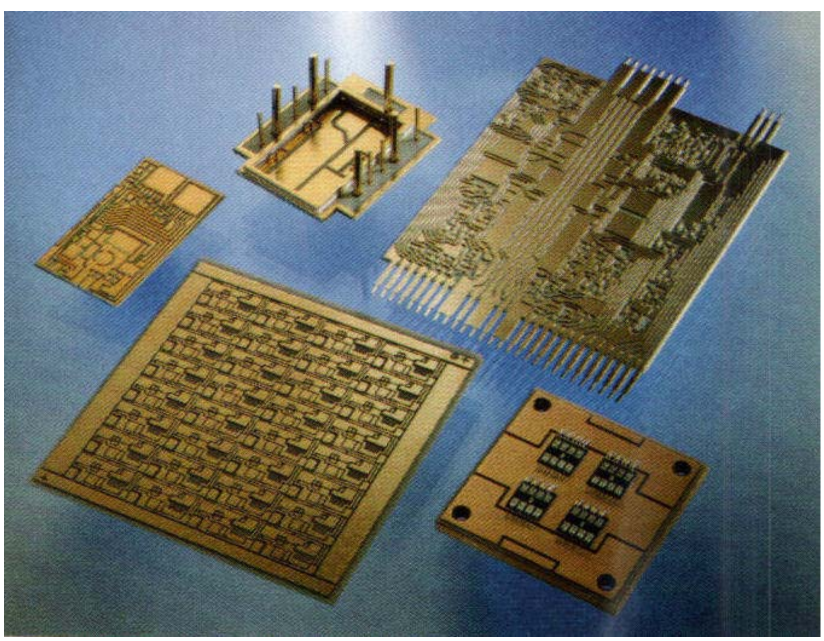
- PowerFlex technology combines standard PCB packaging with high-performance thermal management, and IMS-like thermal transfer performance. In addition, TPI film allows the bonding of the circuitry to a larger heat sink, to which the IMS needs to be adhered anyway.

- Dielectric-coated technology (DCC) – LEDs have very low voltage requirements and very high thermal dissipation requirements… a perfect fit for DCC as a drop-in replacement for IMS.

CERAMIC ELECTRONIC PACKAGING

Ceramic is the grandfather of high-performance thermal management of electronic packaging.

Ceramic substrate combines electrical dielectric insulation properties with high thermal transfer. (Examples of ceramic substrates are shown below.) However, ceramic packages are expensive, tough-to-process and are brittle, of course.



In addition, ceramic packages also require mechanical attachment to a much larger metal heat sink to dissipate the heat to atmosphere.

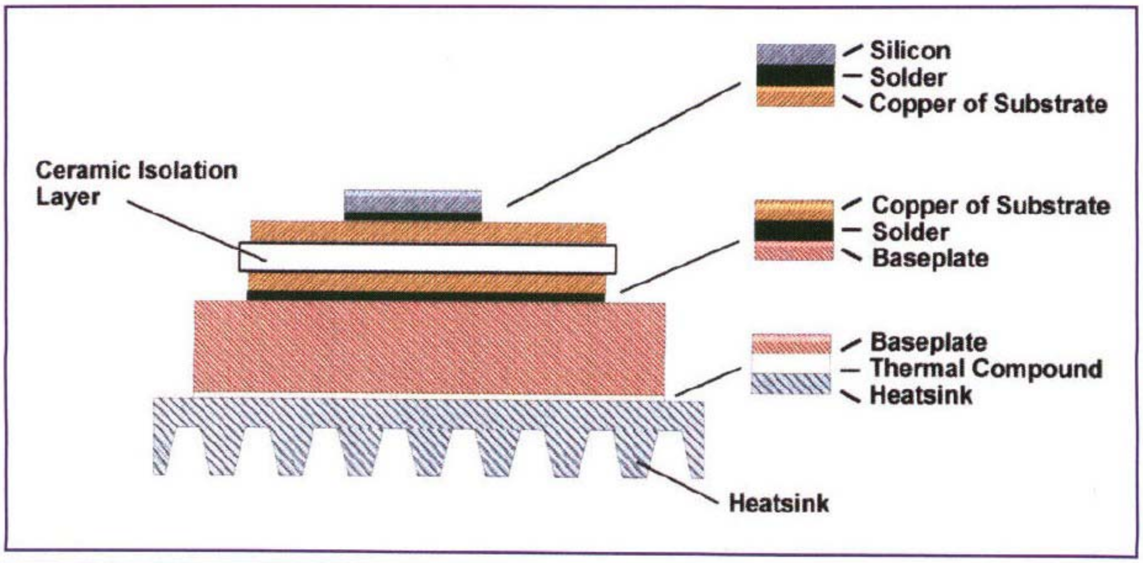


Figure 1. DCB substrate in power semiconductor module.

A 'relative newcomer' in comparison to ceramic substrates, IMS has made much progress in converting ceramic applications to polymer-based insulation systems for printed circuits. (Insulated metal substrate, or IMS, is ceramic-powder-filled epoxy resin that bonds copper foil to aluminum plate.)

FT's PowerFlex and DCC technologies could garner significant share of the present ceramic market where the packaging requirements include:

- Low-voltage dielectric – many high-power applications have high electrical currents, but are at low voltage. Many cases only require 3-100Vdc. DCC could provide the same thermal performance as the very-best ceramic, at a fraction of the cost.

- Multilayer circuitry – building multilayer ceramic circuits is notoriously difficult and expensive. PowerFlex with thin FR4 (with thermal vias) can approach the thermal performance of the commodity alumina substrates, and if the PowerFlex can be bonded *directly* to the companion metal heat sink, the overall thermal resistance can even below lower than with the ceramic system. In addition, the mechanical hardware or adhesive bonding required to mate the ceramic package to the metal heat sink is eliminated.

There are many applications within the ceramic substrate market…

Power semiconductor devices
- IGBT- MOS Modules
- Diode-,Thyristor Modules
- Solid-State-Relays
- Discrete devices

Automotive electronics
- Ignition
- Electronic assisted steering
- ISAD-integrated starter/alternator
- Diesel pump control
- Servomotor control
- Air condition control

Telecommunication
- Power supply SAT
- Power supply base stations

Industrial electronics
- Frequency converter
- Welders
- Pump control
- Traction drives/power supplies
- Drive control
- Cooling technology (Peltier/laser)

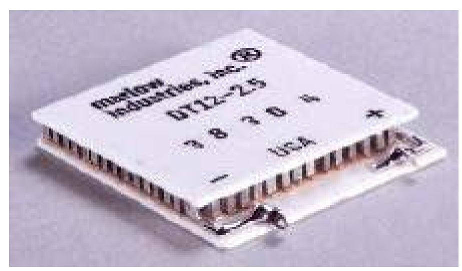
Aerospace
- Servomotor control
- Solid state switches
- Radar

Power supplies
- DC/DC converter
- AC/DC converter
- RF amplifier

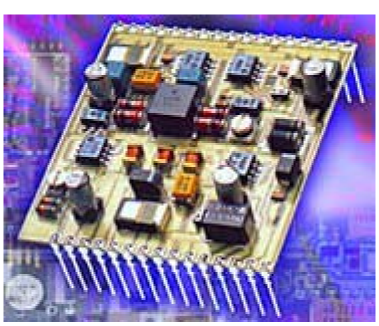
…however, several could be deemed 'low-hanging fruit' for targeting. These applications would have one or more of the following attributes: cost-sensitivity, low-voltage, packaging complexity.

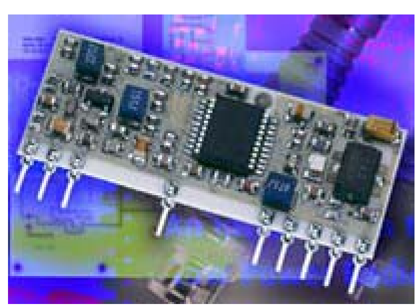
For example:

Thermoelectric coolers (TECs) are an excellent example of an application that uses a ceramic substrate, where an FT DCC substrate could work better thermally and cost considerably less. These typically run on only 3-14Vdc. [NOTE: FT already has a DCC development underway with Marlow Industries, the market leader in TECs.]

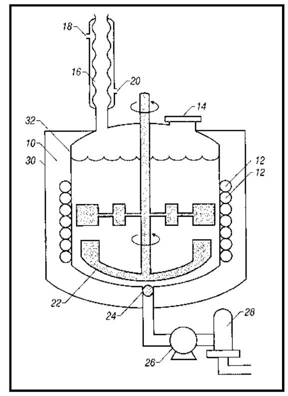


Automotive ceramic packaging runs at only 12-42Vdc. This market represents another significant potential for DCC (where single-layer circuits are required) and perhaps PowerFlex (where circuit complexity drives cost).





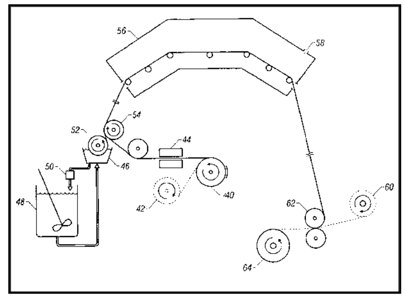
SUPPLY-CHAIN



TPI bond film uses standard adhesive-formulation and film-coating processes, and its manufacture is out-sourced to competent specialists.

The thermoplastic polyimide adhesive (property of FT) is formulated by Lubrizol Dock Resins in Linden, NJ. A schematic of a representative reactor is shown opposite.

The polyimide adhesive is coated on polyimide film by Lamart Corporation in Clifton, NJ. A schematic of a representative coating operation is shown below.



Both Lubrizol and Lamart offer their services on a toll-basis (per batch or hour).

The film is slit-to-width by Lamart or Metlon Corporation (Cranston, RI).

The film is punched into custom shapes by EIS Fabrico of Kennesaw, GA.

EIS also builds subassemblies (qualification prototype quantities) with PowerSite technology with heat-sealing and soldering equipment. They also provide technical support and drawings for other companies to build subassemblies with PowerSite technology (so that EIS can sell customers the TPI and related materials).

We have two qualified PowerSite technology assemblers in Asia with custom process equipment built to our specifications: Union Bridge (Hong Kong and Guangdong, China) and GMTS (Taipei, Taiwan). We are qualifying other Asian companies as demand increases.

Goals for supply-chain licensees and suppliers:

- "*Easy to do business with*" (pardon the grammar) – the 12,000 miles and the 12-hour difference with Asia is a challenge enough. We look for companies to partner with that "*say what they'll do, and then do what they've said*".
- Fair pricing – don't take advantage of the sole-source position of the technology. Where possible, standardize pricing. We are focused on driving this proprietary technology to become the market standard, and need to maintain the OEMs' trust – if they feel that they are being 'held hostage', they'll run the other way.
- Responsive service – from quoting prototypes to after-sales issues.
- Appreciation of the honor of being qualified to provide a next-generation technology. (This should especially have meaning/value in Asia.)
- Promotion of the technology to existing customers and to the wider market in their region.
- Process equipment – can build bonding and soldering machines to print. Can design and build tooling. Experience with simple automation could also be required for high-volume manufacturing.
- Printed circuitry – economical sourcing of PCBs with thick copper (power requirement), thin FR4, gold- or tin-plating. Fast quoting. Fast prototype turnaround.
- Heat sink / baseplates – economical sourcing of stamped and extruded aluminum (and other metals), including machining. Fast prototype turnaround.
- Circuit board assembly – has capability (or close business connection) to place and solder electronic components onto PowerSite and PowerFlex subassemblies.
- Sub-Contract Manufacturing (SCM) – there will also be opportunities to provide entire assemblies, such as power supplies or adaptors, with OEMs. Providing this service, or managing this supply chain, could enhance profitability and/or ease-of-doing-business.

FT ‘INTELLECTUAL PROPERTY’ PORTFOLIO

United States patents are critical to protecting a company’s ‘Intellectual Property’ (IP). Their reach extends beyond the specific technology of a material or process for a subassembly, all the way to the final OEM product. This coverage provides a deterrent to patent violation that can be enforced if a module is shipped to the US for sale from a country that is ‘IP-challenged’ (such as China).

This section reviews the Fraivillig Technology patent portfolio, and how our proprietary technology is protected.

In addition, the patent portfolios of the market leaders in the thermal management –*Bergquist, Parker Chomerics and Laird Thermagon*— are reviewed for comparison. Comparing patent portfolios of these established companies with that of FT clearly demonstrates the innovative, market-changing nature of our technologies.

The US patents, both awarded and pending, owned by Fraivillig Technologies are summarized in the chart below. The Patent Number and Patent Title are listed on US Patent and Trademark Office’s website. The generic Description and target application-usage (‘*Cools*’) were added for reference. We are very confident that the pending patents will also be awarded, due to the absence of relevant prior art.

FRAIVILLIG PATENTS (awarded and pending)

Patent Number	***Description***	***Cools***	***Patent Title***
6208031	Ceramic particles ensure dielectric separation between conductive layers with thin coatings	*PCBs*	Circuit fabrication using a particle filled adhesive
6129260	Bonding solderable foil to heat sinks for intimate thermal contact	*Devices*	Solderable structures
6015607	Thermoplastic polyimide adhesive	*N.A.*	Flexible laminates and method of making the laminates
(Pending)			
20040055152	Bonding multi-layer PCBs to heat sinks for intimate thermal contact	*PCBs*	Bonding of a multi-layer circuit to a heat sink
20020092163	Bonding PCBs to heat sinks for intimate thermal contact	*PCBs*	Mounting a flexible printed circuit to a heat sink

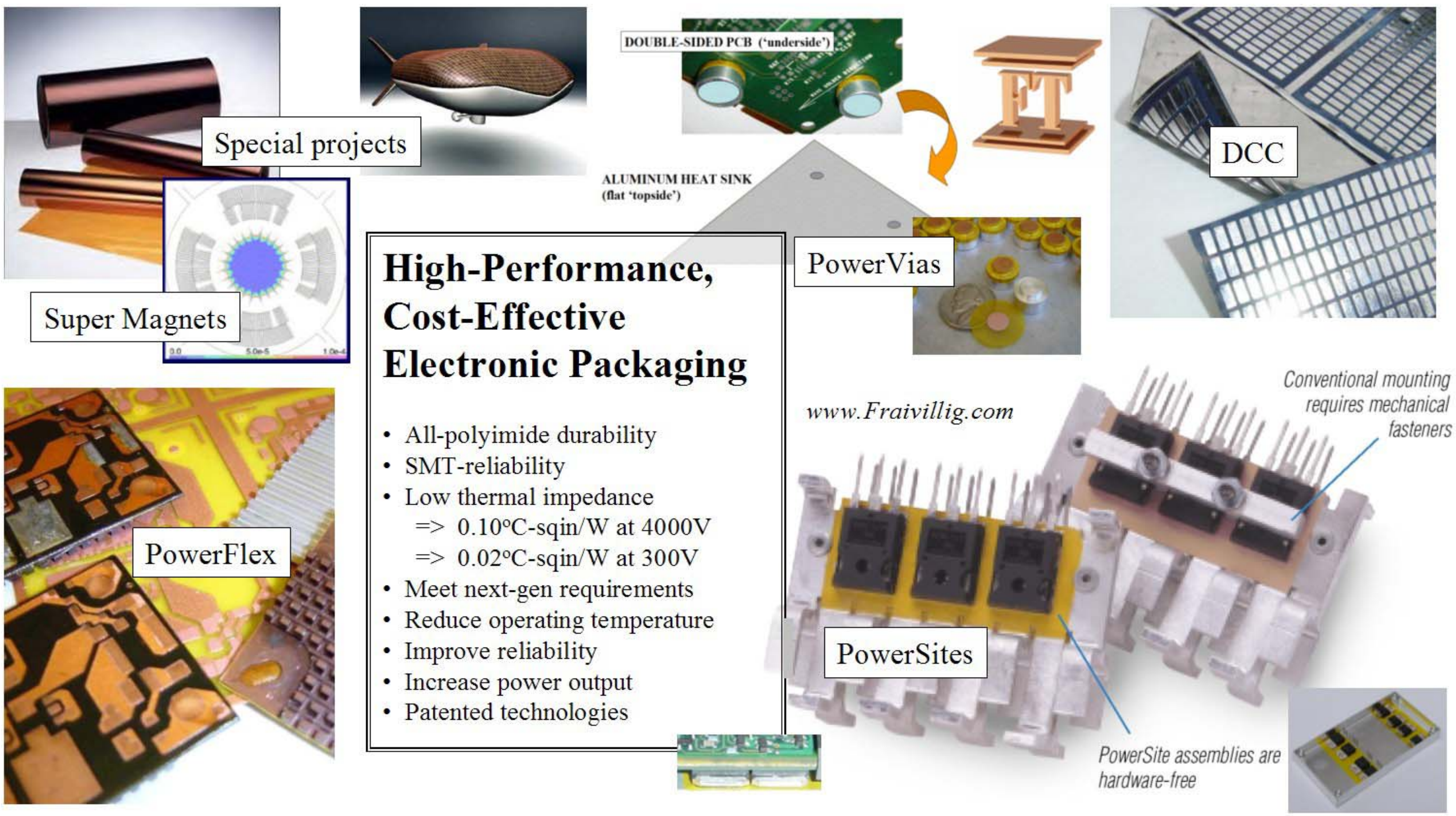
Patent Protection of Fraivillig Technology products:

PowerSite™ solderable-pad technology is protected by US patent number 6129260, which defines the construction and process. PowerSites will gain additional protection --where the copper patches are formed by printing-and-etching-- with the award of US pending patent application 2002/0092163.

PowerFlex™ thermal printed circuit technology is protected by US patent number 6129260, which definites selective bond processes. US pending patent applications 2002/0092163 and 2004/0055152 will provide construction and process protection. As noted earlier, we are confident that these will be awarded by the USPTO. [Details can be provided upon request.]

PowerVia™ thermal column technology is protected by US patent number 6129260, which define the construction and manufacturing process of these units.

Dielectric-Coated Copper (DCC) technology is protected by US patent number 6208031, which defines the unique functionality of the construction.



'INTELLECTUAL PROPERTY' of MARKET LEADERS

Bergquist and Chomerics were pioneers in the thermal management industry. Chomerics evolved from the high-end military-side; Bergquist from the high-volume commercial-side. Both were established in the 1960s. In additional to thermal products, each has sizable, unrelated businesses. Bergquist has a significant touch-screen business. Chomerics is also the market leader in electronic shielding.

Bergquist has the widest product line of thermal products in the world, including everything from commodity insulation pads (of all thicknesses) to premium 'Insulated Metal Substrate' printed circuit boards (IMS). To protect this business, Bergquist has a considerable list of thermal management patents. Their patents back through 1986 are listed on the following pages.

Their development efforts have been focused on the material composition of their existing conventional constructions, incrementally boosting thermal performance. In addition, ,there are no significant innovations in the "patent pending" pipeline.

Interestingly, Bergquist was awarded a patent in late 2003, #*6649325*, that was innovative from a conceptual standpoint -- *using classic thermoplastic resins as adhesive/dielectrics in laminates*-- but this technology would be problematic in use. (Been there, tried that.) Based on FT experience over a variety of applications: *fully-cured thermoplastic resins –even polyimide—do not perform well in soldered electronic-packaging*. [Details available upon request.]

Chomerics has focused their development efforts on insulation pads (all thicknesses) and thermal compounds. Again, this entails incremental improvements of existing conventional products. Chomerics' patents are listed on a following page. Chomerics was purchased by Parker in the 1990s from W.R. Grace, who purchased them in the 1980s from the founder and employees.

Thermagon entered the thermal market in the early 1990s, and has gained sizable share in CPU thermal pads and metal-substrate PCBs.

Until recently, their technology was 'protected' only by trade-secrets, and no US patents were issued. Since 2002, however, Thermagon has focused considerable patent effort on a single product: using low-temperature solder as a phase-change material. This is a simple-yet-truly-innovative product, but its applicability beyond CPU-cooling in PCs might be limited. Thermagon was purchased by Laird (UK) from the founder and employees in 2004.

NOTE: *There are other thermal management companies in the world market, but most of their R&D efforts are also focused on incremental improvements in the performance of existing conventional products.*

BERGQUIST PATENTS (awarded)

Patent Number	***Description***	***Cools***	***Patent Title***
6898084	Heat spreader (hardware)	*Devices, CPUs*	Thermal diffusion apparatus
6797758	Conductive paste, combo of solder, ceramic, wax	*CPUs*	Morphing fillers and thermal interface materials
6657297	Conductive pad, with skin layer	*Devices, CPUs, PCBs*	Flexible surface layer film for delivery of highly filled or low cross-linked thermally conductive interface pads
6650215	Improved high-end heat sink (hardware)	*Devices, CPUs*	Finned heat sink
6649325	Thermoplastic-coated copper laminate	*Printed circuits*	Thermally conductive dielectric mounts for printed circuitry and semi-conductor devices and method of preparation
6624224	Composite pads w/ solder, ceramic, oil	*Devices*	Method of preparing thermally conductive compounds by liquid metal bridged particle clusters
6399209	Composite pad w/ ceramic, wax	*Devices, CPUs*	Integrated release films for phase-change interfaces
6339120	Composite pads w/ solder, ceramic, oil	*Devices*	Method of preparing thermally conductive compounds by liquid metal bridged paiticle clusters
6197859	Composite pad w/ ceramic, wax, plasticizer	*Devices*	Thermally conductive interface pads for electronic devices
6165612	Composite pad w/ ceramic-filled film, plasticizer	*Devices*	Thermally conductive interface layers
6090484	Composite pad w/ rubber, ceramic, plasticizer	*Devices*	Thermally conductive filled polymer composites for mounting electronic devices and method of application
5950066	Phase-change material, based on wax with ceramic or metal powder	*All*	Semisolid thermal interface with low flow resistance
5679457	Silicone rubber with ceramic filler	*All*	Thermally conductive interface for electronic devices

BERGQUIST PATENTS (awarded and pending)

Continued…

Patent Number	*Description*	*Cools*	*Patent Title*
5463530	Mounting power devices on both sides of a heat spreader	*Devices*	Dual sided laminated semiconductor mounting
4810563	Mounting power devices on single side of a heat spreader	*Devices*	Thermally conductive, electrically insulative laminate
4853763	Unified design for mfg of heat sink with insulation pad	*Devices*	Mounting base pad means for semiconductor devices and method of preparing same
4842911	Silicone rubber with ceramic filler on glass	*Devices (flanged)*	Interfacing for heat sinks
4755249	Unified design for mfg of heat sink with insulation pad	*Devices*	Mounting base pad means for semiconductor devices and method of preparing same
4685987	Silicone rubber with ceramic filler on glass	*Devices (flanged)*	Method of preparing interfacings of heat sinks with electrical devices
4666545	Unified design for mfg of heat sink with insulation pad	*Devices*	Method of making a mounting base pad for semiconductor devices
4602678	Silicone rubber with ceramic filler on glass	*Devices (flanged)*	Interfacing of heat sinks with electrical devices, and the like
4602125	Insulation pad with flanges for the mounting holes	*Devices (flanged)*	Mounting pad with tubular projections for solid-state devices
4574879	Silicone rubber with ceramic on polyimide film	*Devices (flanged)*	Mounting pad for solid-state devices
(Pending)			
20030187116	Thick interface pad with solder, metals, ceramic, wax, etc.	*Devices, CPUs, PCBs*	Thermal interface pad utilizing low melting metal with retention matrix
20030027910	Interface materials with solder, ceramic, wax, etc.	*Devices, CPUs, PCBs*	Morphing fillers and thermal interface materials

CHOMERICS PATENTS (awarded, none pending)

Patent Number	*Description*	*Cools*	*Patent Title*
6835453	Interface pad of 'tin foil' with wax and ceramic	*CPUs, devices*	Clean release, phase change thermal interface
6705388	Heat spreader plate with PSA	*CPUs, devices*	Non-electrically conductive thermal dissipator for electronic components
6644395	Release liner for interface materials	*CPUs*	Thermal interface material having a zone-coated release liner
6835453	Release liner for interface materials	*CPUs*	Clean release, phase change thermal interface
6432497	Interface pad of double-sided tape	*CPUs, devices*	Double-side thermally conductive adhesive tape for plastic-packaged electronic components
6096414	Silicone rubber with ceramic filler on glass	*Devices*	High dielectric strength thermal interface material
6054198	Interface pad with wax and ceramic	*CPUs*	Conformal thermal interface material for electronic components
5550326	Heat spreader plate with PSA	*Devices*	Heat dissipator for electronic components
5510174	New ceramic filler	*All*	Thermally conductive materials containing titanium diboride filler
5298791	Improved heat sink surface for thermal transfer	*All*	Thermally conductive electrical assembly
5213868	Improved heat sink surface for thermal transfer	*All*	Thermally conductive interface materials and methods of using the same
4869954	Urethane with ceramic	*All*	Thermally conductive materials

THERMAGON PATENTS (awarded and pending)

Patent Number	*Description*	*Cools*	*Patent Title*
6849941	Heat spreader with solder interface	*CPUs*	Heat sink and heat spreader assembly
6761928	Interface pad of copper with solder	*CPUs*	Multi-layer structure and method for forming a thermal interface with low contact resistance between a microelectronic component package and heat sink
6617517	Interface pad of copper with solder	*CPUs*	Multi-layer structure having a thermal interface with low contact resistance between a microelectronic component package and a heat sink
6372997	Interface pad of copper with solder	*CPUs*	Multi-layer structure and method for forming a thermal interface with low contact resistance between a microelectronic component package and heat sink
(Pending)			
20050073816	Interface pad of copper and solder	*CPUs*	Thermal interface assembly and method for forming a thermal interface between a microelectronic component package and heat sink
20050045372	Interface pad of copper and solder (thick)	*All*	Heat spreading thermal interface structure
20030007329	Interface pad of copper (or aluminum) and nickel and solder	*CPUs*	Thermal interface structure for placement between a microelectronic component package and heat sink
20020154485	Interface pad of metal foil and solder	*CPUs*	Multi-layer structure and method for forming a thermal interface with low contact resistance between a microelectronic component package and heat sink
20020148635	Interface pad of metal foil and solder	*CPUs*	Multi-layer structure and method for forming a thermal interface with low contact resistance between a microelectronic component package and heat sink