All-Polyimide Thermal Interface Products

SMTA
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Why polyimide?

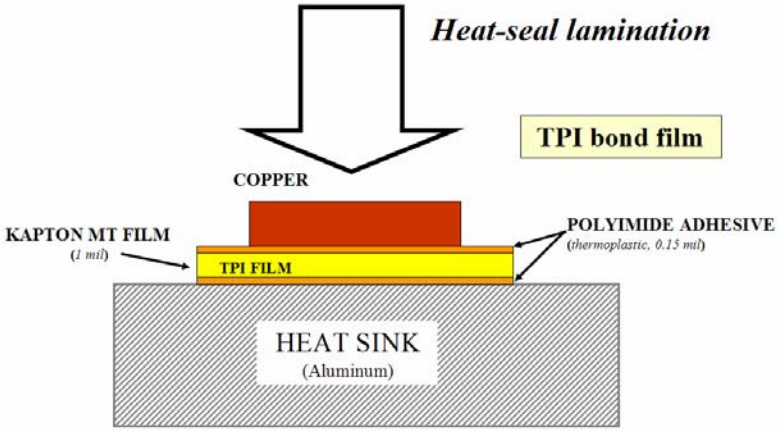
HARSH ENVIRONMENT ELECTRONICS

- Thermal resistance
- Electrical properties
- Chemical resistance
- Low CTE
- 'Filled' polymer retains properties (*solvent-cast*)
- Non-flammable (UL V-0)

"All-Polyimide" = Both dielectric and adhesive are polyimide chemistry

All-polyimide systems enable….

- **Excellent thermal durability**:
  - Operation at 200°C+
  - Exposure to 300°C+



- **High thermal transfer to heat sink**:
  - 0.1 °C-sqin/W
  - With >4000V dielectric

- **Hardware-free**:
  - Less interfaces
  - No pressure dependency
  - Design flexibility

Brief history of polyimides

DIELECTRIC FILM:

- Chemistry invented in early ’60s (DuPont)
- Kapton ‘H’ film patented in 1964
- Filmed films introduced in mid ’80s (DuPont MT)

FRAIVILLIG TECHNOLOGIES:

- TPI bond film (1995) – *basis for application-specific products*:
- PowerSite patches (1999)
- PowerFlex circuits (2001)
- PowerVia columns (2001)
- CuprImide substrates (*under dev.*)

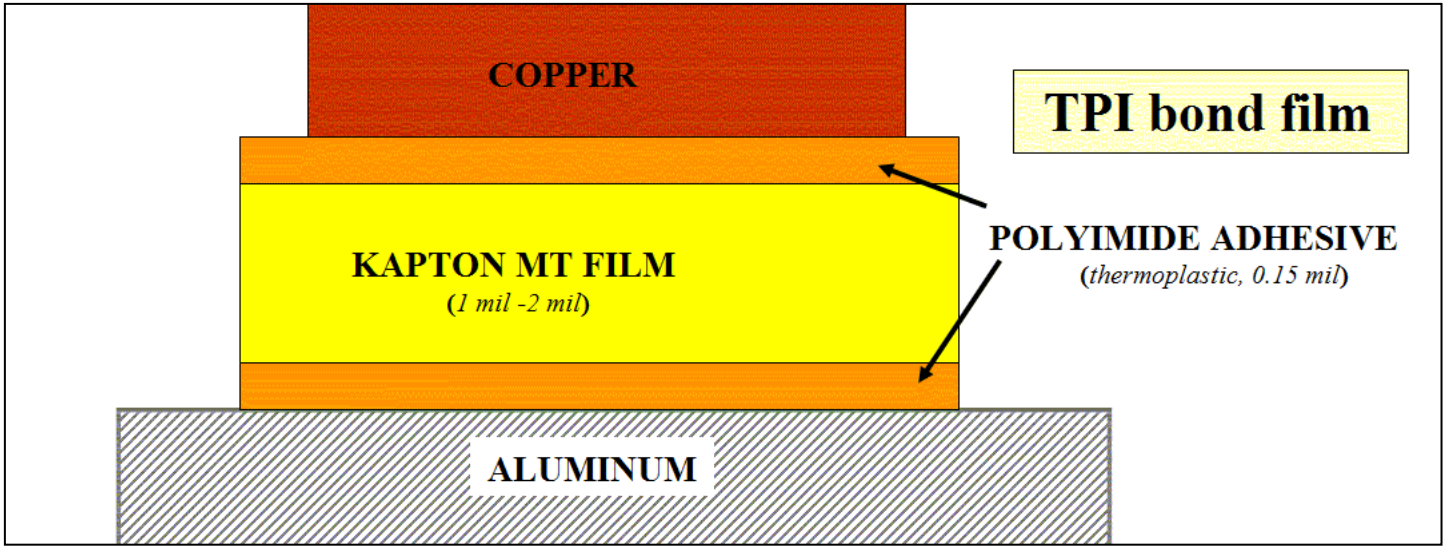
ADHESIVE (thermoplastic):

- Developed in late ’70s by NASA
- System developed for “atom smashers” in late ’80s
- All-polyimide systems developed for flexible laminates in early ’90s

PI ADHESIVE FEATURES:

- *Comparable properties to PI films => adhesive no longer the “weak link”*
- *Strong bond even when thin (0.1-0.2 mil) – maximize thermal transfer, while minimizing cost*
- *Heat-sealable – fast, single-unit production*

TPI bond film



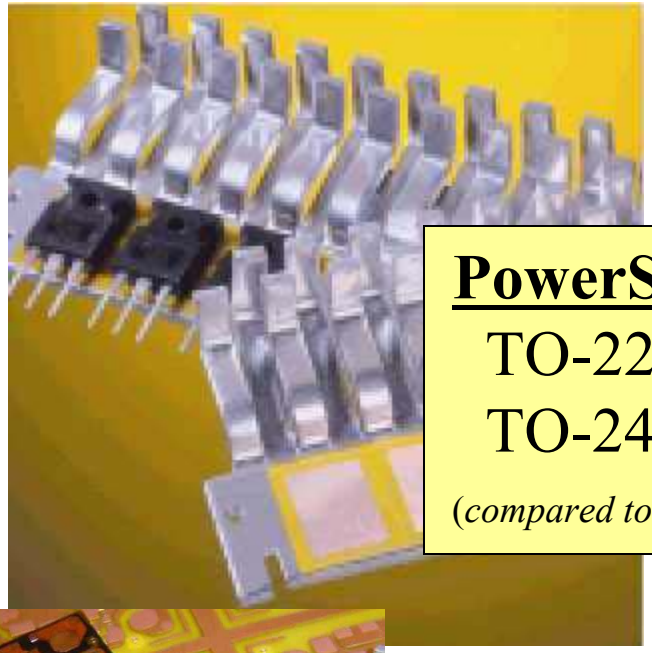
Not to scale

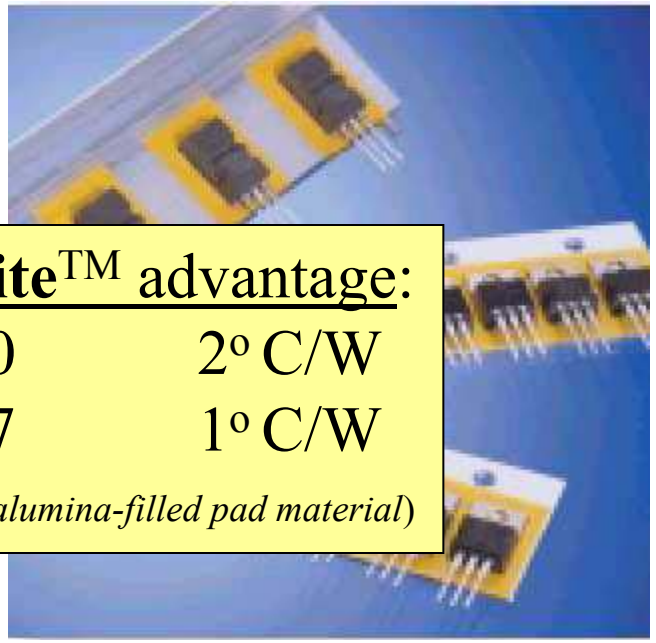
TPI BONDING:

'Heat-sealing' a solderable surface
(*copper foil or PCB)*
to an aluminum heat sink

BONDING CONDITIONS:

- 250-320°C
- 200-600+ psi
- 10-30 seconds





PowerSite™ advantage:

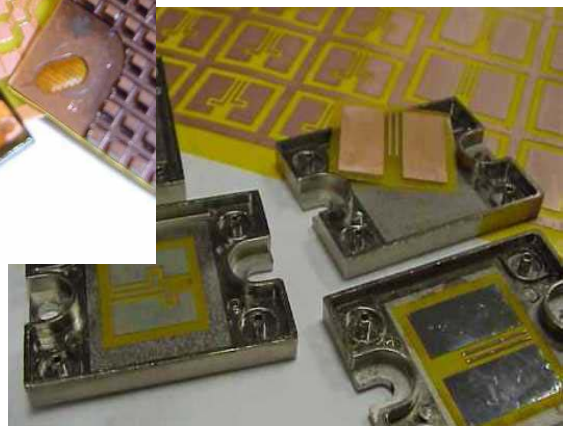
TO-220	2° C/W
TO-247	1° C/W

(*compared to alumina-filled pad material*)

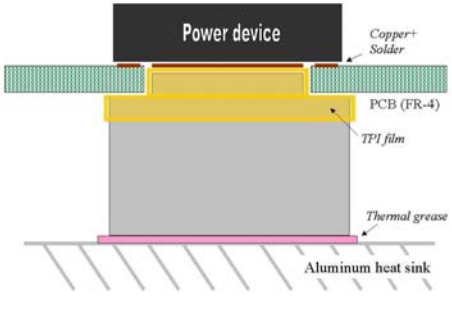
Fraivillig Technologies

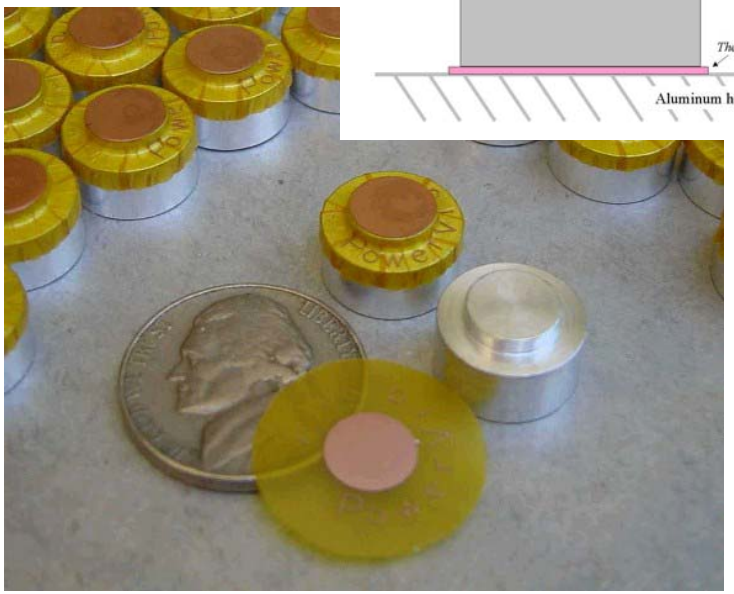
- *Next-gen thermal management*
- *Heat-sealed -- No attachment hardware*
- *All-polyimide construction*
- *Thermal impedance = 0.1° C-sqin/W*

PowerFlex™



PowerVia™



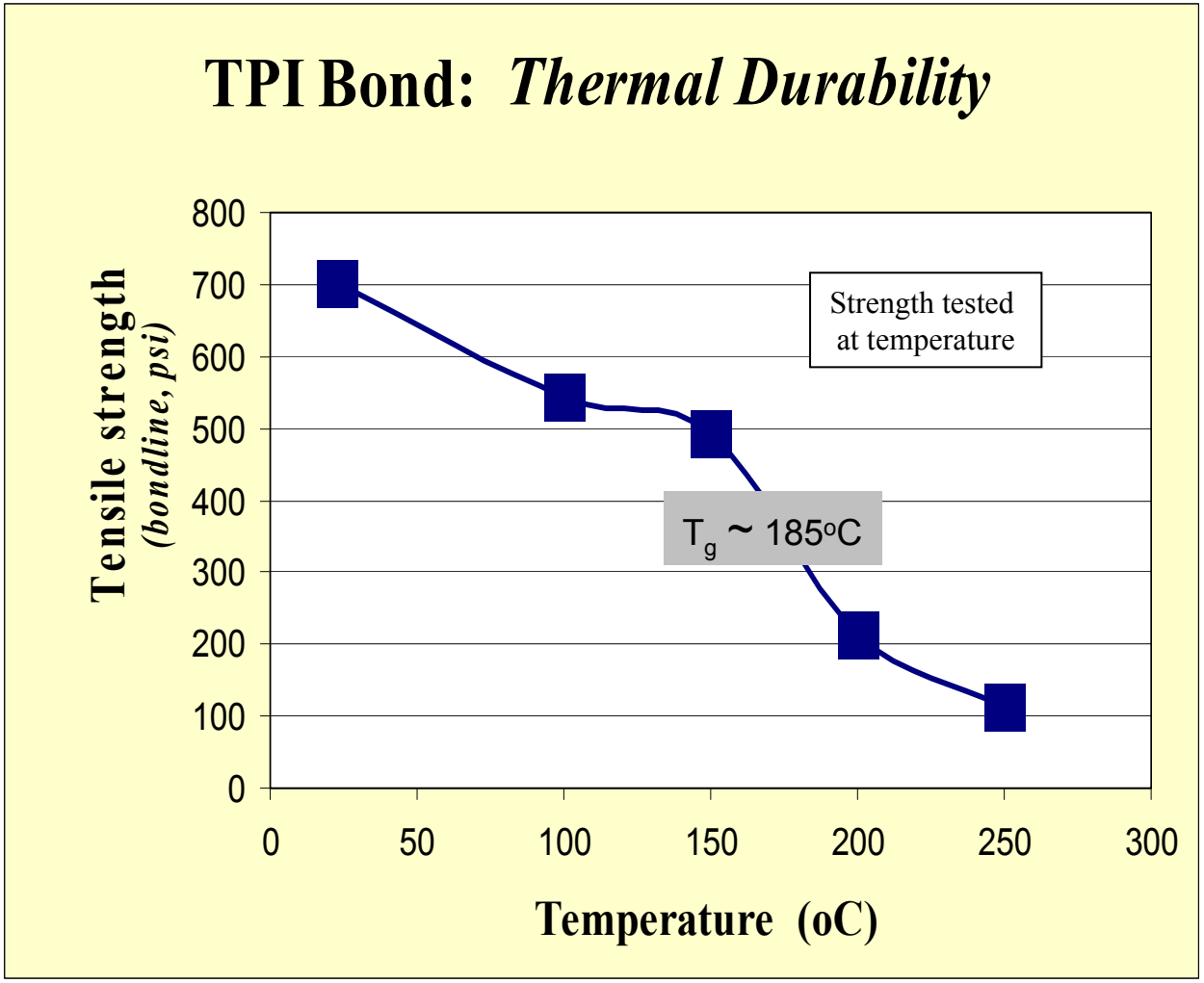


TPI bond durability

TENSILE STRENGTH
- High and consistent to 150°C+ *(see chart opposite)*
- No/little degradation with thermal aging to 150°C+

SHEAR STRENGTH
- Room temp = 4000 psi
- 150°C = 2000 psi

THERMAL TRANSFER
Unchanged with:
- Thermal shock
- Thermal cycling
- Thermal aging
- 85/85 aging



TPI products for thermal management

TPI bond film allows heat-sealing of solderable surfaces to aluminum heat sinks for power device attachment

Fraivillig Technologies and EIS Fabrico offer a range of high-performance power electronic packaging options:

- **TPI** bond film – *all-polyimide performance*
- **PowerSites**™ – soldering discrete power devices to baseplates
- **PowerFlex**™ – flexible printed circuits bonded to baseplates
- **PowerVia**™ – solid-metal, electrically-isolated thermal vias for PCBs
- **CuprImide**™ coated copper – high thermal transfer, low-cost substrate
- Contract assembly

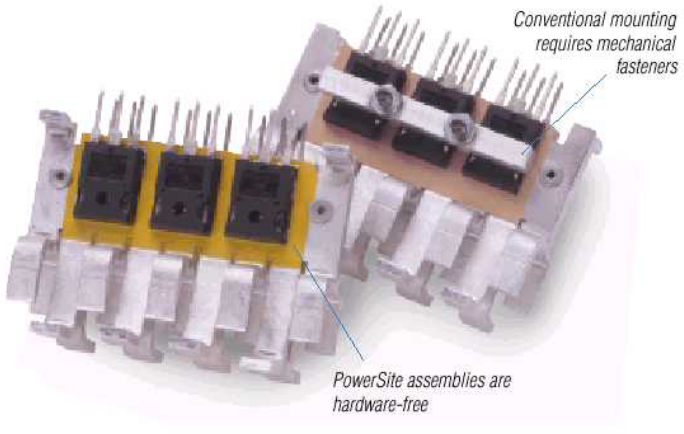
We work with OEMs on optimizing both present and future designs.

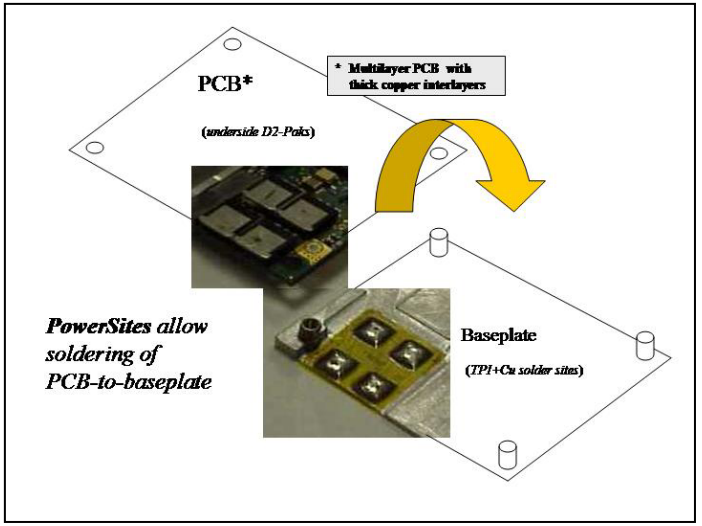
(*NOTE: Patents awarded and pending*)

PowerSite solderable pads

PowerSites allow the mounting of discrete power semiconductors directly to aluminum baseplates without attachment hardware. The TPI bond film provides over 4000 volts dielectric strength. (Patented)

- **Placed and bonded with automation onto a wide variety of baseplates** – with pits, walls, fins, any thickness…
- **Only used where a device is placed –** cost-efficient use of material
- **Can solder fully-assembled PCBs to baseplates** – with "inverted" power devices





PowerSite thermal comparisons

Versus insulator pads

Table 3B
Maximum power dissipation to reach a junction temperature of 150°C

THERMAL PERFORMANCE: Maximum Power Dissipation to reach Tj = 150 °C				
Interface Material (Air Flow, lfm =>)	**TO-220 (watt)** 0	100	**TO-247 (watt)** 0	100
Mica / grease	14.6	18.8	22.7	32.9
BN-filled silicone sheet	13.7	17.6	22.0	31.6
Kapton MT / phase change	14.1	17.9	22.9	33.1
Kapton MT / BN-filled silicone	13.3	16.9	21.8	30.5
Alumina-filled silicone sheet	12.5	15.8	20.4	28.4
Laminated copper	15.9	21.3	24.6	36.4

"Laminated copper" = PowerSite technology

Table 5
Maximum power dissipation to reach a junction temperature of 150°C

Versus IMS

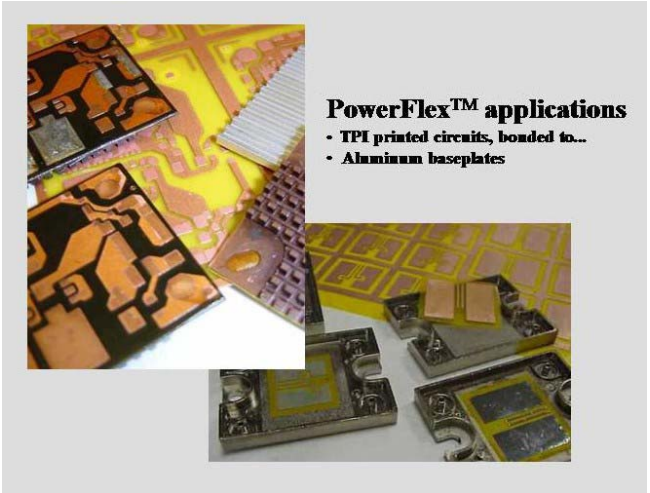
THERMAL PERFORMANCE: Maximum Power Dissipation to reach Tj = 150 °C				
Interface Material (Air Flow, lfm =>)	**TO-220 (watt)** 0	100	**TO-247 (watt)** 0	100
Insulated metal substrate	16.6	23.1	25.4	40.1
Laminated copper	16.8	23.7	24.2	38.0

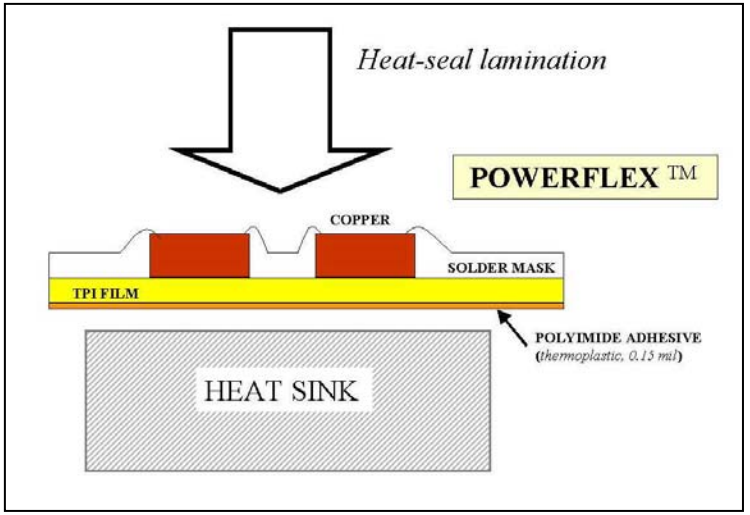
SOURCE: Parker Chomerics Technical study, 2000

PowerFlex flexible printed circuits

PowerFlex circuits --based on TPI bond film-- are made with conventional printing-and-etching processes, and are then heat-sealed to aluminum baseplates. The TPI bond film provides over 4000 volts dielectric strength. (Patents pending)

- **Placed and bonded with automation onto a wide variety of baseplates** – with pits, walls, fins, any thickness…
- **Only used where a device-mounting and circuit pattern are needed** – cost-efficient use of material
- **Available in single- and multi-layer constructions**
- **Can extend beyond the plane of the baseplate** – interconnections to other subassemblies possible
- **Lower cost and more design flexibility than IMS** (*Insulated Metal Substrate*) **or DBC ceramic**





PowerVia thermal columns

PowerVias are solid aluminum columns that are inserted into a conventional rigid PCB. The copper foil bonded to the PowerVia 'top' with TPI bond film allows the soldering of the SMT power device. The fully-assembled PCB is then attached to the heat sink. The TPI bond film provides over 4000 volts dielectric strength. (Patented)

FIGURE 1: **PowerVia cross-section.**
Note that electronic components (not shown) can be mounted to the bottom-side of the PCB.

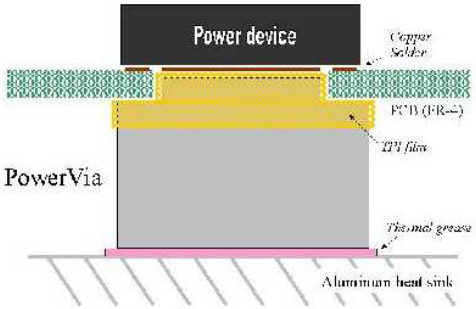
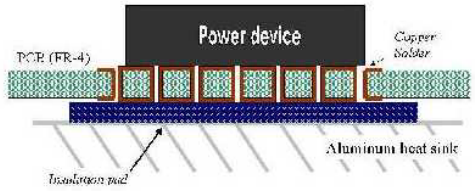


FIGURE 2: **Thermal via, with the dielectric insulation pad.**
Note that the PCB must be secured, with high-pressure, flush against the aluminum heat sink to ensure thermal transfer.

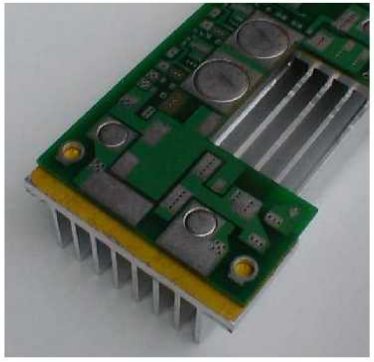


Conventional thermal via (drilled-and-plate)

- **Solid-metal construction maximizes thermal transfer** *(versus conventional plated-thru hole)*
- **No special processing required**
- **Allows double-sided SMT component mounting**
- **Can mount fully-assembled PCBs to any planar heat sink…with *no pressure dependency*** *(non-isolating thermal compound under the PowerVias)*
- **Available in standard sizes, *off-the-shelf***

FIGURE 4: **PowerVia thermal columns for D²Paks.**
TPI+copper and cylindrical aluminum slug precursors also shown. Rectangular PowerVias can also be manufactured from cut-to-length aluminum extrusion.

FIGURE 5: **Circuit board with inserted PowerVia columns.**
Various PowerVia sizes. Shown without electronic components.



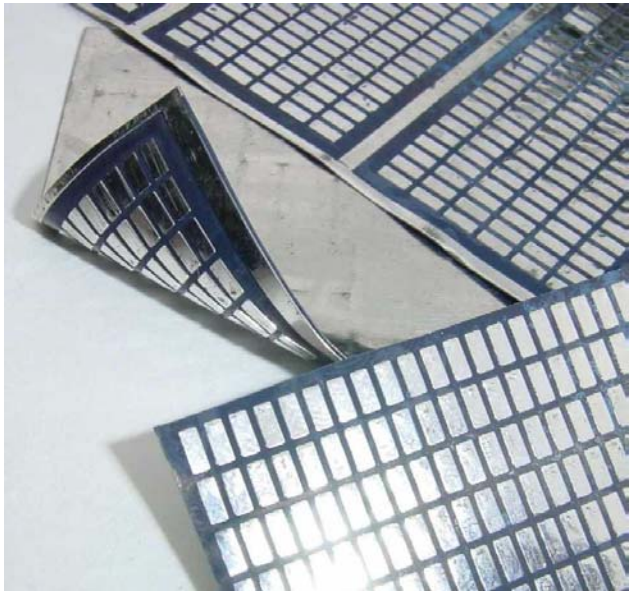
CuprImide *no-substrate* laminates

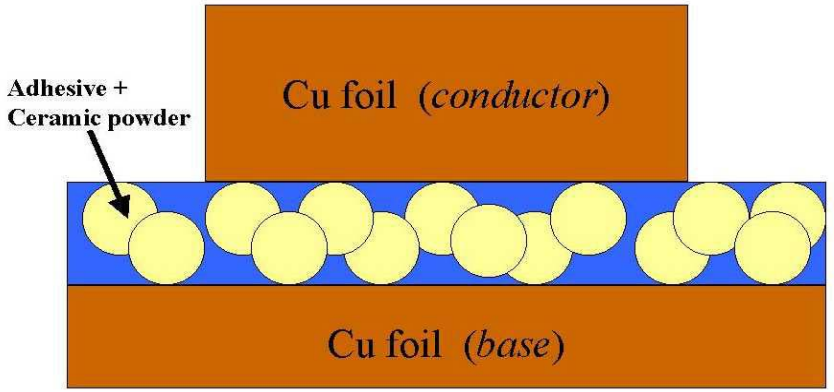
- "Substrate-less" laminates
  > No film or fabric
  > Ceramic powder + adhesive
  > Very high thermal transfer (0.5°C-sq/W)
  > Moderate-to-low dielectrics
  > Low manufactured cost

- Many applications are low voltage (12-42v)
  > *Film dielectric = overdesign*

- Technology also applies to multilayer addition in conventional PCB mfg
  > Hard board and flex
  > Fast thermoplastic bonding

- Patented

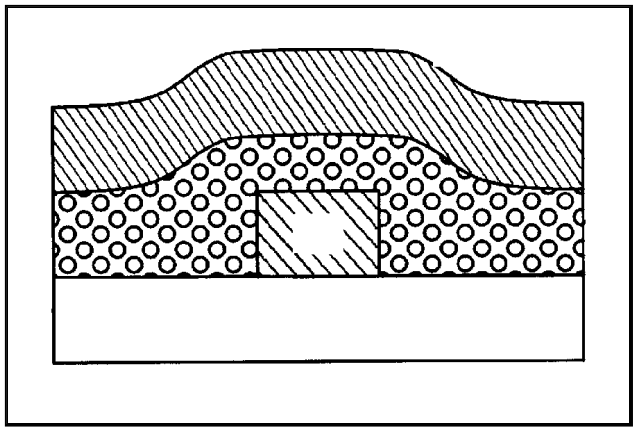




Other applications for CuprImide coated copper

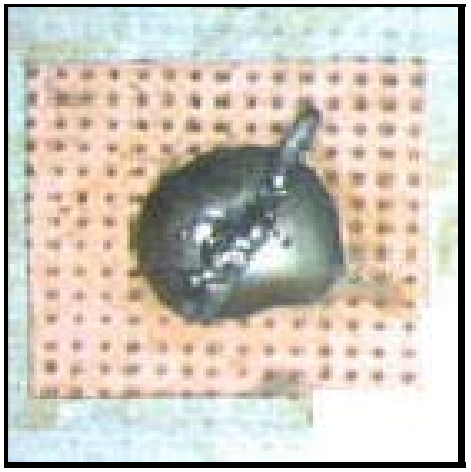
Multi-layer circuits

- Low-cost layer addition for both flex and rigid circuits (low-voltage)
- Filled adhesive-on-copper: *thermoplastic or thermoset, coated on copper in single-pass*
- Low manufactured cost



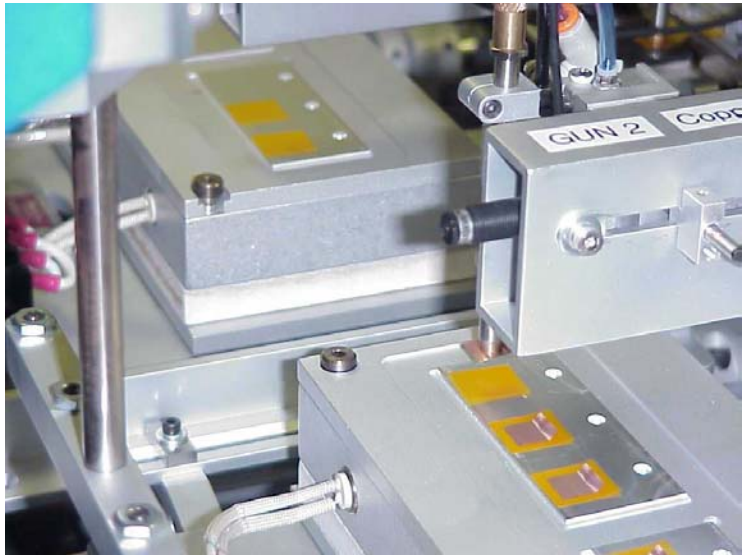
Grounding patches

- Electrical connection between PCB and aluminum heat sink => replaces hardware
- Very thin *unfilled* polyimide adhesive-on-copper *(embossing recommended)*



Contract Assembly

- EIS Fabrico's facility in Kennesaw, Georgia has installed automation equipment to manufacture PowerSite, PowerFlex, and PowerVia assemblies
- Outsourcing -- prototype and production capabilities are available.
- We are also evaluating overseas partnerships for labor-intensive assembly
- Or… OEMs can buy materials and do own processing.



All-Polyimide *potential concerns*

- **General polyimide "Achilles Heels"**
  - Hydrolysis in extreme conditions
  - Corona-resistance at high AC voltage

- **Processing temperatures of 250-320°C**
  - Specialized equipment required
  - Temperature resistance of other materials: copper oxidation, soldermask, etc.

- **Cost vs conventional** insulation and attachment systems (*lower-performance methods*)
  - Acrylic, epoxy, silicone adhesives and pads
  - Thermal grease
  - Hardware to mount to heat sinks

Target Markets

HIGH POWER ELECTRONICS

- Power supplies
- Control modules
- Motor drives
- CPU modules