Advanced Thermal and Embedded Solutions for Laminate Substrate Designs

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Abstract

As demand for high-powered solutions and smaller package footprints continues to grow, it drives the need for continued advancement of laminate based substrate technologies. Besides shrinking the conventional SMT component and utilizing high thermally conductive epoxies, advancing the laminate substrate is the next step to increase functional integration and reduce package footprint. By embedding active and passive components as well as utilizing alternative fabrication methods we can balance increasing functional density while mitigating thermal challenges. This poster will review and compare various thermal solutions including standard vias, slot vias, and embedded heat slugs from both a fabrication and thermal modeling point of view.

Packaging Solutions

The demand for higher power multi-chip modules in smaller laminate package footprints has necessitated the development of alternative thermal solutions from conventional standard via construction. There are now options available to incorporate slot vias, embedded thermal slugs and cavities to facilitate improved heat transfer. Additionally, there are solutions for packaging embedded active and passive components to further reduce laminate package footprints.

Thermal

- *Standard Vias (conventional)*
  - *Various diameters and pitch/array sizes*
  - *Conductive, non-conductive, or solid copper depending on aspect ratio*
  - *Lowest cost for fabrication*

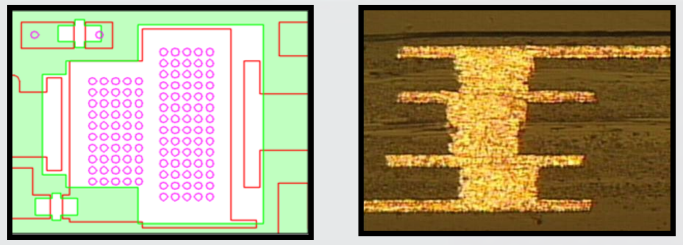


Fig.1: Standard Vias

- *Slot Vias*
  - *Solid copper elongated vias*
  - *Increased surface area for thermal dissipation*
  - *Potential for RF shielding*
  - *Low - Medium cost for fabrication*

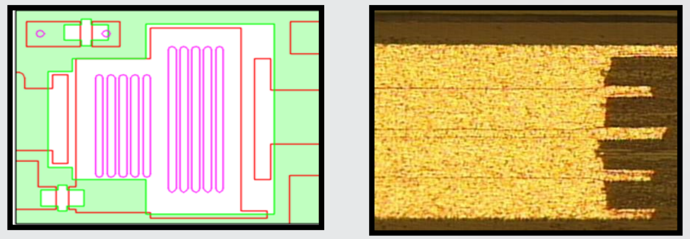


Fig.2: Slot Vias

- *Thermal Slugs*
  - *Embedded*
  - *Material options include Cu, AIN, CuW, CuMo, and CuMoCu*
  - *Slug needs to be matched in terms of CTE to laminate*
  - *Higher cost for fabrication (Improved thermal performance)*

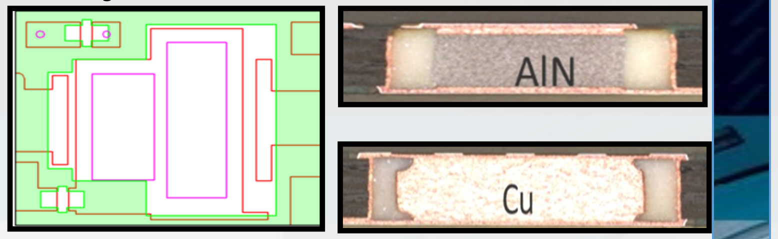


Fig.3: Thermal Slugs

- *Cavity Laminate*
  - *Die mounted directly to cavity base*
  - *Cavity is typically lasered or mechanically routed*
  - *Shorter RF bond wires*
  - *Higher cost for fabrication*
  - *Improved thermal and RF performance*

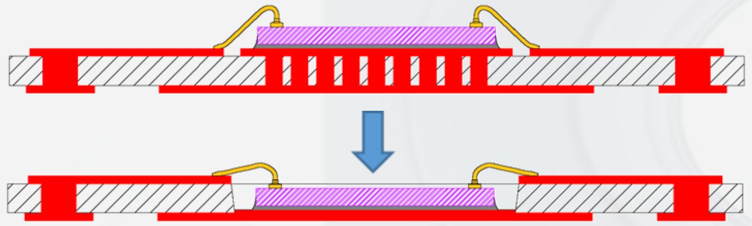


Fig.4: Die in Cavity

Embedded Components

- *Passive and Active*
  - *Die or component placed into internal layers*
  - *Reduced package footprint*
  - *Improved signal performance*
  - *Higher cost for fabrication/ Lower cost assembly*

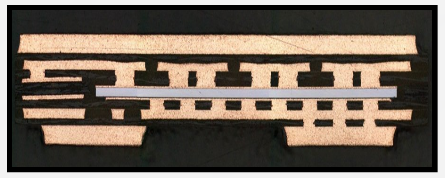


Fig.5: Embedded Active Component

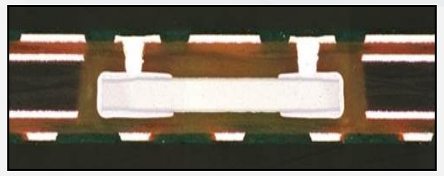
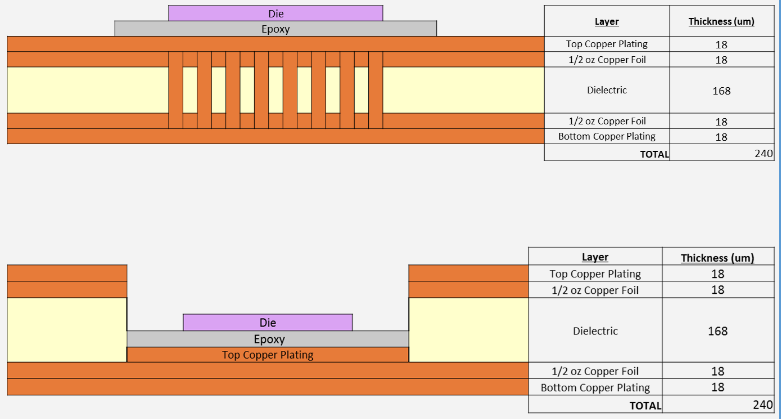


Fig.6: Embedded Passive Component

Package Level Thermal Modeling

Model Parameters

- *Package*
  - *5 x 5 mm LGA*
  - *1/2 oz starting copper weight top and bottom*
  - *Die attached to laminate surface or cavity using silver epoxy*
    - *Thermal Conductivity: 24 W/(m-K)*
  - *80um outer diameter Vias: Cu filled (conventional & slot vias)*
  - *Via array size 12 x 8, 180um pitch (conventional vias)*
  - *Via array size 12 x 1, 180um pitch (slot vias)*
  - *Cu coin is the same length and width as the die*
  - *Cavity had die mounted on bottom metal with extra plating*
- *Device Performance*
  - *1 Watt power dissipation*
  - *Running at CW*



Layer	Thickness (um)
Top Copper Plating	18
1/2 oz Copper Foil	18
Dielectric	168
1/2 oz Copper Foil	18
Bottom Copper Plating	18
TOTAL	240

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Fig. 7: Package Configurations Examples

Package Thermal Modeling: Thermal Cut Planes

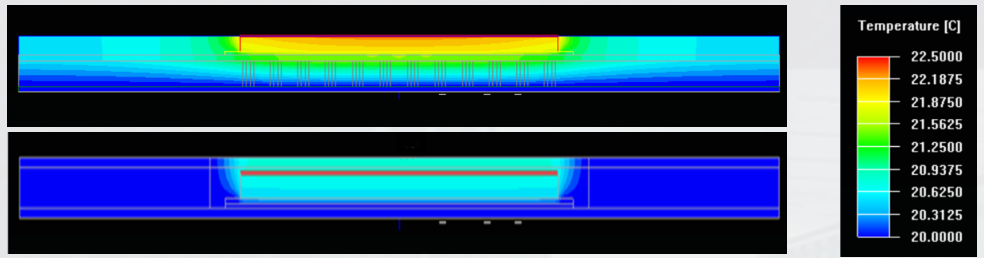

Fig. 8: Thermal Cut Plane Examples

Thermal Package Model Results

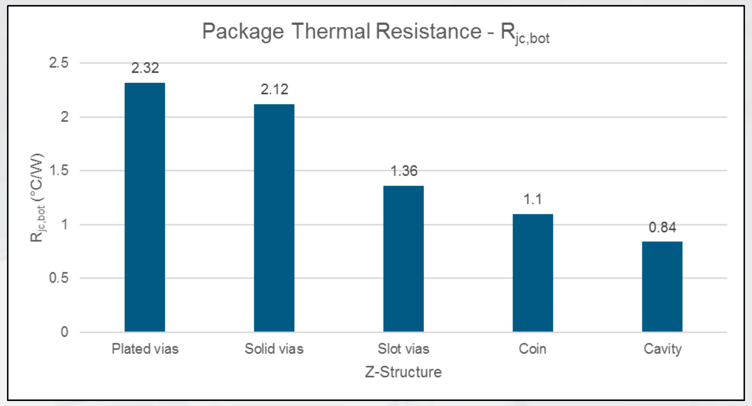

Fig. 9: Package Configuration Thermal Results

Z-Structure	$R_{jc.bottom}$ (°C/W)	($R_{structure}$) / (R_{cavity})
Plated vias	2.32	276%
Solid vias	2.12	252%
Slot vias	1.36	162%
Coin	1.10	131%
Cavity	0.84	100%

Table 1: Package Configuration Thermal Results (1W)

Summary

- *Advanced thermal packaging solutions can provide significant thermal performance improvements over conventional package construction methods.*
- *Slot Vias can be utilized in applications where there is a necessity for additional power dissipation (from conventional vias) allowing an increase in surface area for heat transfer with variable size, pitch, and pattern flexibility.*
- *Embedded Thermal slugs increase the surface area greater than conventional and slot vias and maximizes heat transfer. Various thermal slug material options are available but CTE match to the laminate also needs to be considered.*
- *Cavity laminates maximize surface area for heat transfer and minimize the thermal length (medium) for improved heat transfer rate.*