High Power Packaging: Materials, Design and Analysis Considerations

By Jesse E. Galloway, Ph.D.
MCM Packaging

PBGA

FCBGA

Flip-Stack CSP

PS-fcCSP with Interposer

RF Modules

SCSP

Cell Phone SiP
MCM Benefits

- Memory proximity
- Higher Speed
- Integration of components
- Flexible packaging
- Modular / Scalable
- Multi-function package integration at the Subcon
MCM Challenges

- Non-symmetric layout
- Disparity in IC peak temperature limits
- Choosing optimal material sets for all components
- Minimizing package level stress
- Minimizing 2\textsuperscript{nd} level interconnect stresses
- Maintaining low thermal resistances
Packaging Thermal Design Space

No Heat Sink

Heat Sink

© 2007 Amkor Technology, Inc.
Without Heat Sink

Thermal performance primarily function of design:

- Ground vias
- Ground balls
- Size of heat spreader
- Flow velocity
Thermal performance primarily function of design:
- Heat sink size
- Bond line thicknesses
- Thermal interface resistance
- Flow velocity

With Heat Sink
TIM I Material
(Conductivity)

© 2007 Amkor Technology, Inc.
TIM I Material
(Parameters)

• Dispensability
• Stability over time at elevated temperature
• Adhesive strength
• Bulk thermal conductivity
• Contact resistance
• Maximum filler size
TIM I Material
(Voiding)

• Dispense uniformity
• Flow uniformity
• Volatiles
Polyimide Standoff

Bulk conductivity and contact resistance affect Theta jc

© 2007 Amkor Technology, Inc. Mar-07,
TIM I Material (Aging)

(Temperature Cycling)

% Increase in Theta jc

- Material E
- Material F

Temp Cycles (0 - 100C)

(High Temperature Storage)

% Increase in Theta jc

- Material G

Hours at 150C
# Design Feature
(Bare Die Vs. Lid)

<table>
<thead>
<tr>
<th>q</th>
<th>Bare Die FCBGA</th>
<th>Lidded FCBGA</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_{\text{die}}$</td>
<td>$\frac{L_{\text{die}}}{k_{\text{die}}A_{\text{die}}}$</td>
<td>$\frac{L_{\text{die}}}{k_{\text{die}}A_{\text{die}}}$</td>
<td>Same</td>
</tr>
<tr>
<td>$\theta_{\text{TIM I}}$</td>
<td>NA</td>
<td>$\frac{L_{\text{TIM I}}}{k_{\text{TIM I}}A_{\text{die}}}$</td>
<td>Lidded higher</td>
</tr>
<tr>
<td>$\theta_{\text{Lid}}$</td>
<td>NA</td>
<td>$\frac{1}{2\pi k_{\text{Lid}}L_{\text{Lid}}} \ln \left( \frac{R_{\text{Lid}}}{R_{\text{Die}}} \right)$</td>
<td>Lidded higher</td>
</tr>
<tr>
<td>$\theta_{\text{TIM II}}$</td>
<td>$\frac{L_{\text{TIM II}}}{k_{\text{TIM II}}A_{\text{die}}}$</td>
<td>$\frac{L_{\text{TIM II}}}{k_{\text{TIM II}}A_{\text{Lid}}}$</td>
<td>Bare die higher</td>
</tr>
<tr>
<td>$\theta_{\text{HTSNK}}$</td>
<td>$\frac{1}{2\pi k_{\text{HTSNK}}L_{\text{HTSNK}}} \ln \left( \frac{R_{\text{HTSNK}}}{R_{\text{Die}}} \right)$</td>
<td>$\frac{1}{2\pi k_{\text{HTSNK}}L_{\text{HTSNK}}} \ln \left( \frac{R_{\text{HTSNK}}}{R_{\text{Lid}}} \right)$</td>
<td>Bare die higher</td>
</tr>
<tr>
<td>$\theta_{\text{Fin}}$</td>
<td>$\frac{1}{h_{\text{FSN}}A_{\text{Fin}}}$</td>
<td>$\frac{1}{h_{\text{FSN}}A_{\text{Fin}}}$</td>
<td>Same</td>
</tr>
</tbody>
</table>
Design Feature
(Impact of Including Lid)

Cross Over Point depends on:
• Resistance of TIM
• Conductivity and thickness of Lid
• Planarity of interfaces
Design Feature
(Lid Thickness)

\[ \theta_{jc} = \theta_{jc}(\delta_1, k_1, \delta_2, k_2) \]

![Diagram showing lid warpage and maximum TIM I BLT as a function of lid thickness.](image)
Design Feature
(Proximity of die)

$T_{o=0} \ (110 - 150^\circ C) \rightarrow 25^\circ C$
Design Feature
(Proximity of die)

NODAL SOLUTION
STEP=1
SUB =3
TIME=1
/EXPANDED
U2 (AVG)
RAY=0
DMIN = .637E-15
SMIN = -.266E-18
SMAX = .637E-15
Design Feature (Proximity of die)
Design Feature
(Proximity of die)

Lateral Heating affected by die spacing
Performance Feature
(Impact of TIM I Delamination On Hot Spot)

2mm x 2mm hot spot with 10x heat flux

Relative Theta JC

Hot Spot Location

adhered

delaminated
Materials – Design - Analysis

Materials
- TIM I
- Flash diffusivity
- Adhesion
- Thermal resistance
- Aging
- Warpage

Design
- Solder join reliability
- Warpage control
- Layout
- Lid

Analysis
- Hot Spot
- Warpage
- Solder joint reliability
- Die interaction
Conclusions

• High power MCMs require low resistance TIMs

• Materials must be stable over time

• Delamination becomes critical issue when hot spots are located near die edge

• Design trade-offs must be analyzed to specify optimal lid design

• Location of MCM die affect maximum junction temperature and BLT