

Thermal Management Challenges for 3D Packaging

Thomas S. Tarter
Package Science Services LLC
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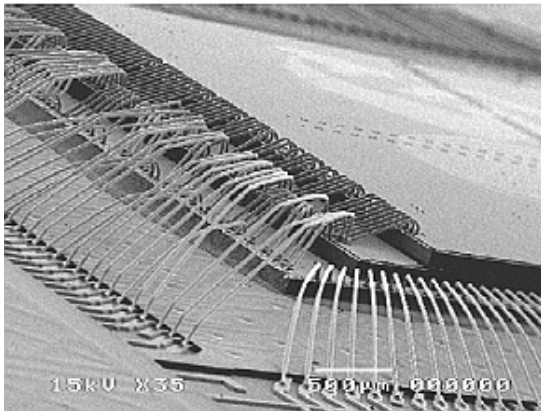


Outline

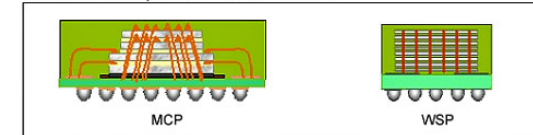
- ▶ Need, Evolution and Proliferation of 3D packaging
 - Moore's Law and Packaging
 - Density and Power
 - Miniaturization and Performance
 - Cost
- ▶ Thermal Management of 3D Packaging
 - Stacked Chip Package
 - Traditional interconnect (WB, FC)
 - Through silicon via
- ▶ Summary and Conclusion



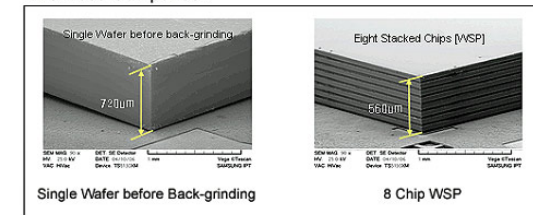
Density and Power



Structural Comparison - Cross Section



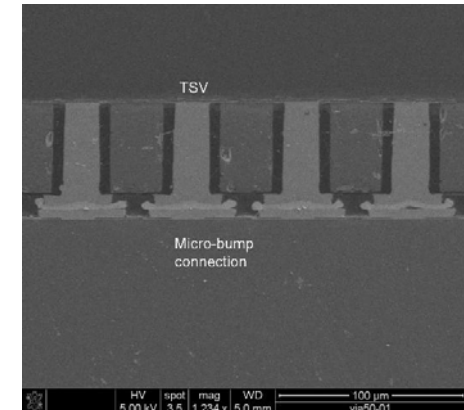
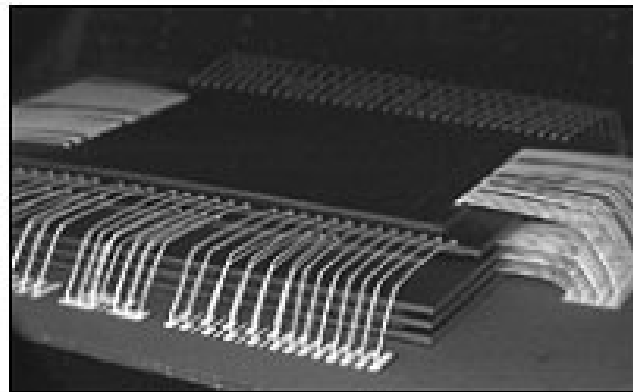
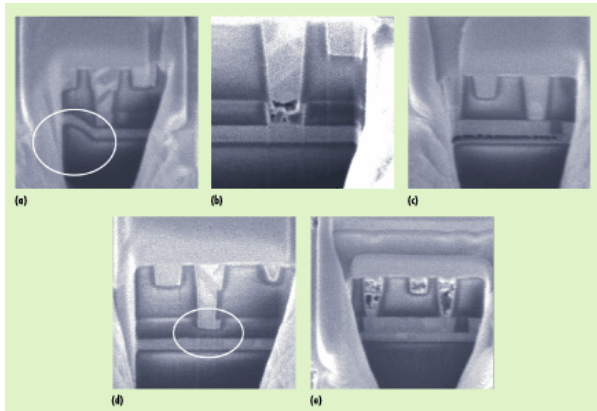
Thickness Comparison



- ▶ In the last decade chip stacking has been used as a way to increase density using like and mixed die sets
- ▶ The proliferation of powerful mobile devices has continued to test the limits of density and performance in compact systems
- ▶ More power in smaller spaces
- ▶ Consumer demand for higher performance and smaller form factor continues
- ▶ Stacked chip packaging is a primary enabler for these devices
- ▶ Thermal management issues are core to the success of a given multi-chip design



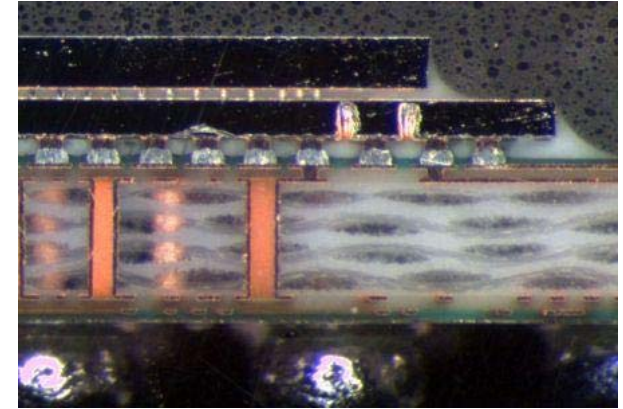
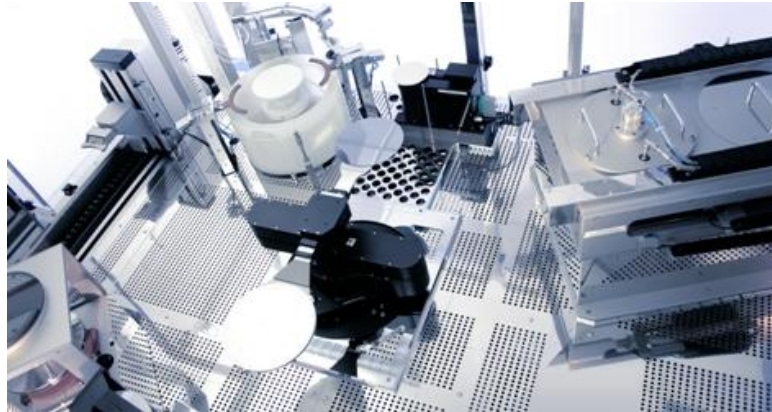
Miniaturization and Performance



- ▶ High performance computing is limited by interconnect losses
- ▶ Interconnect scalability cannot keep pace with gate length
- ▶ Interconnect switching power can be 50% of overall dynamic power
- ▶ Stacking chips can reduce chip-to-chip interconnect length but does not address on-chip interconnect length
- ▶ Through-silicon vias help to reduce interconnect losses on-chip and chip-to-chip



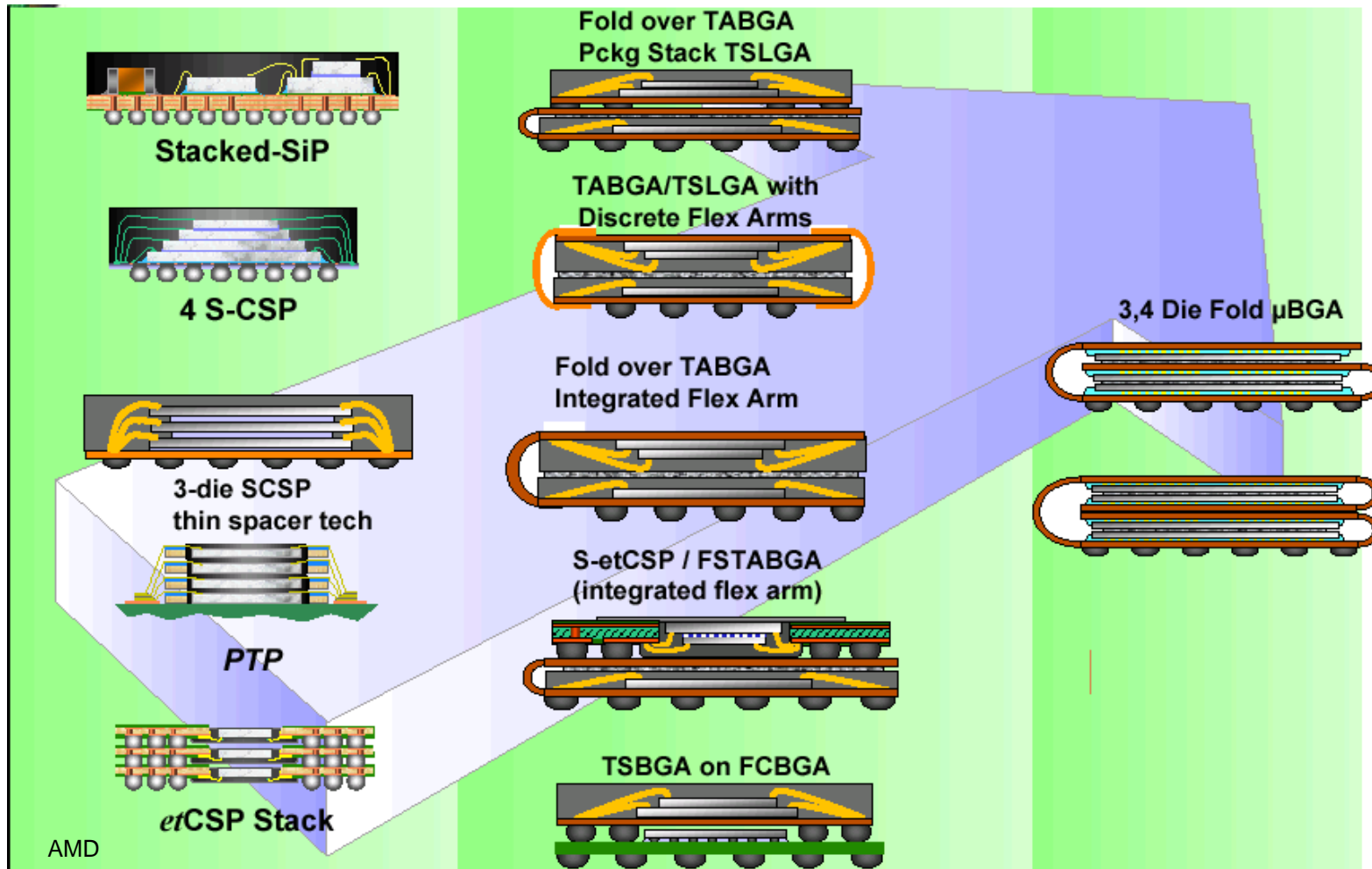
Cost



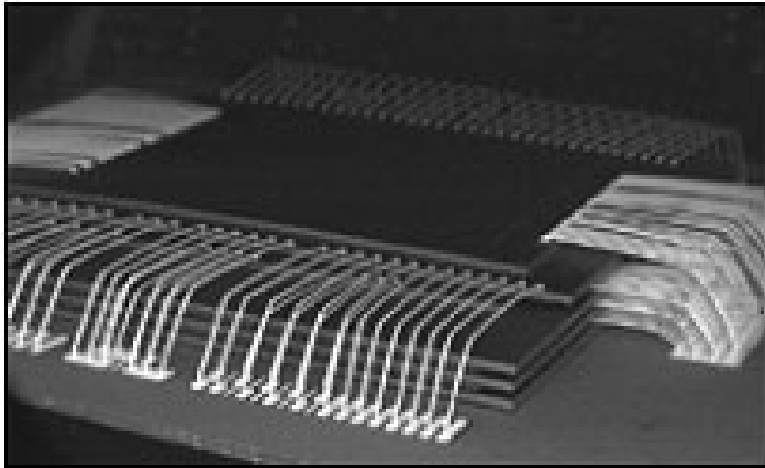
- ▶ Reducing cost or maintaining cost with more functionality is the number one priority
- ▶ Stacking packages and chips may be less costly than advancing lithography
- ▶ TSV and other 3D packaging technologies reduce real estate, material usage and back-end process costs



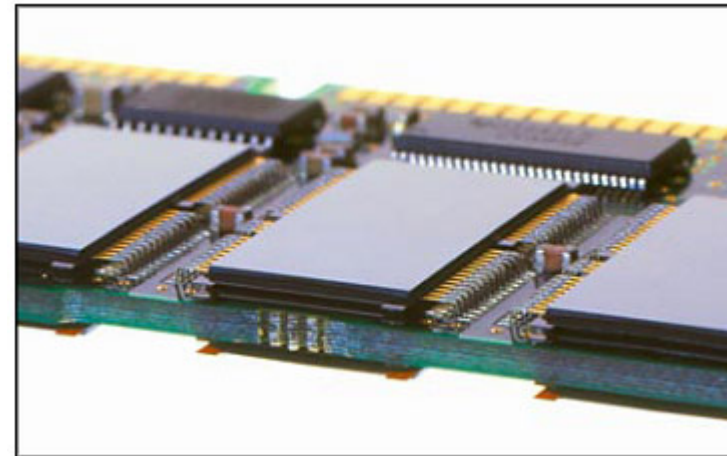
Stacked Package Examples



3D Packaging



Toshiba MCP



Elpida Memory Tape Carrier Package

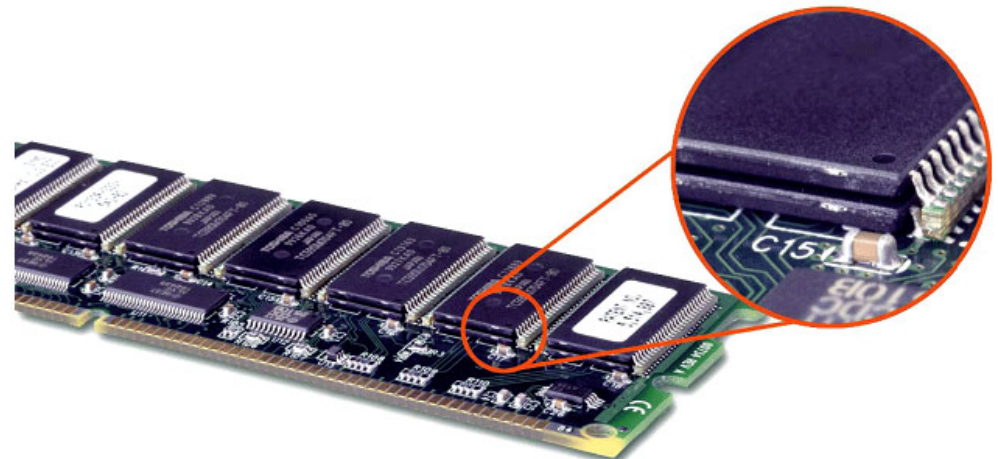


4 Die μ Z[®] Ball Stack



8 Die μ Z[®] Ball Stack

Tessera uZ Ball Stack Package

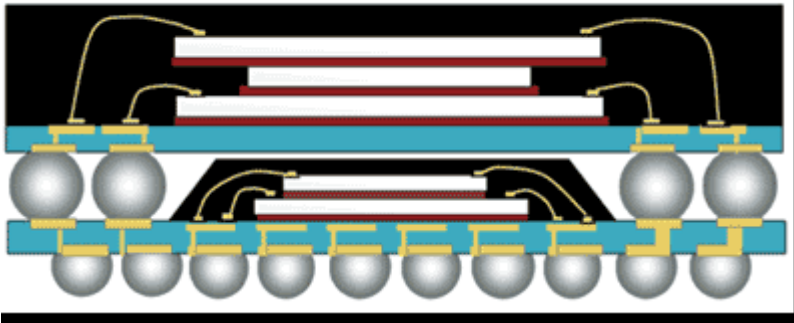


STEC TSOP Stacking

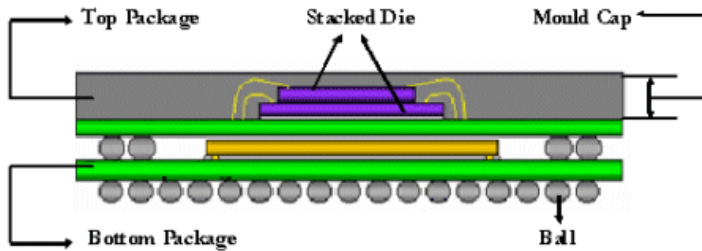


3D Packaging

Assembled Package-on-Package



Package-on-Package (PoP)

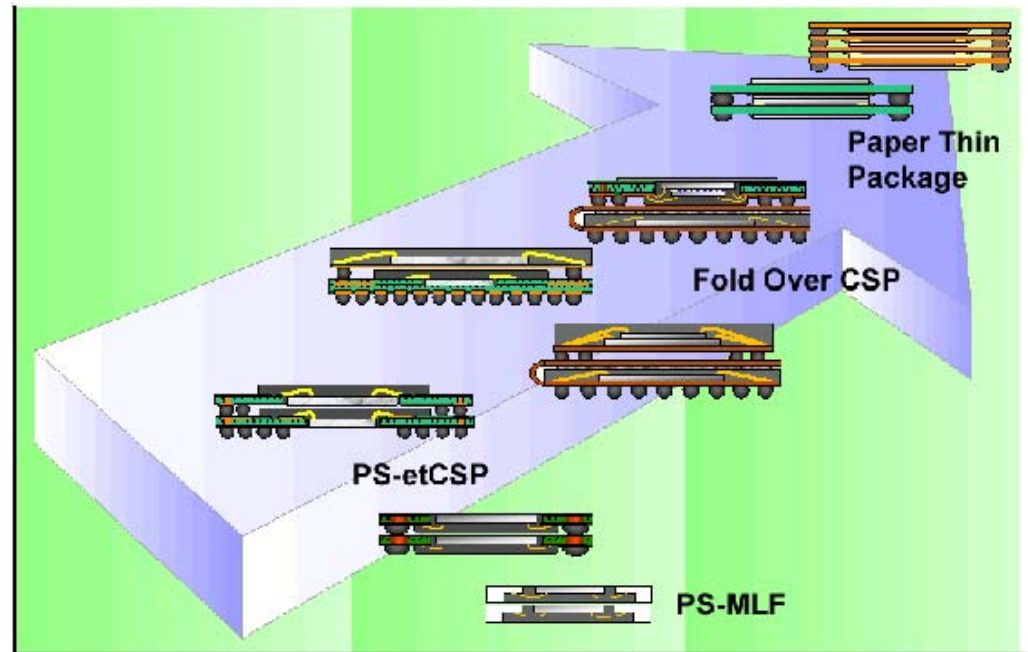


Top package - Integrates high-capacity memory device by die-stacking

Bottom package - Integrates high-density digital logic devices (processors)

Source: Frost & Sullivan

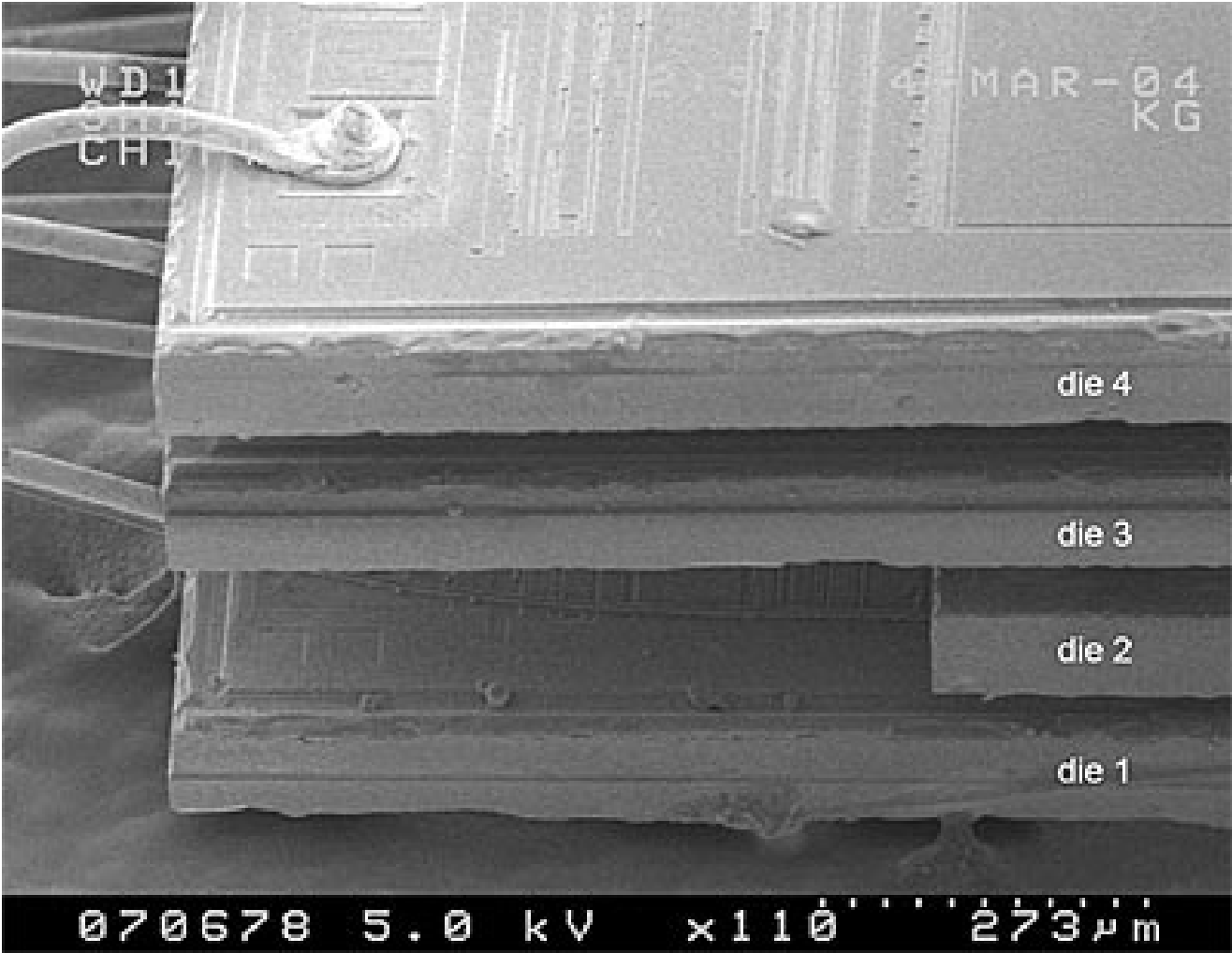
Frost and Sullivan



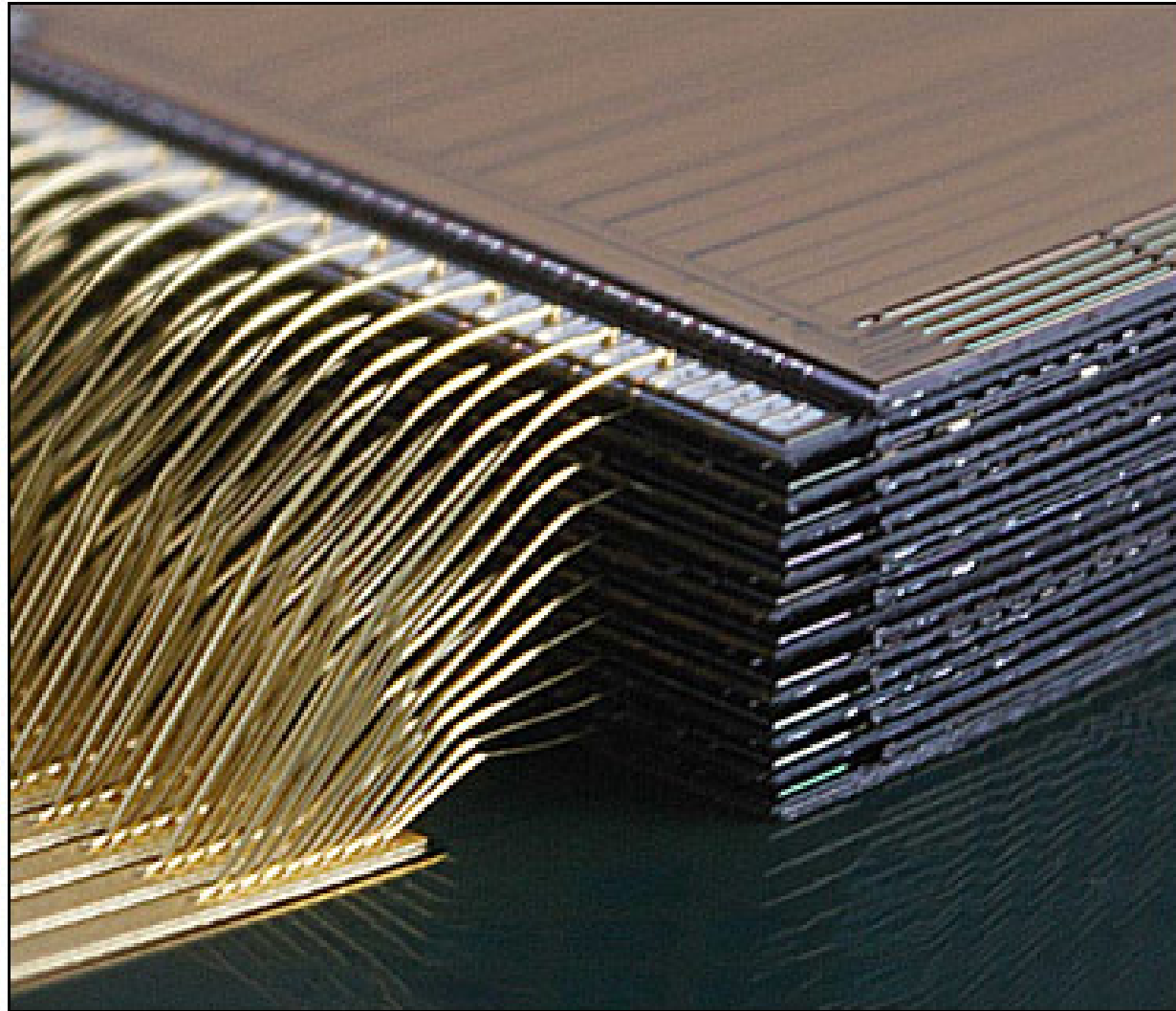
AMD



Chip Stacking



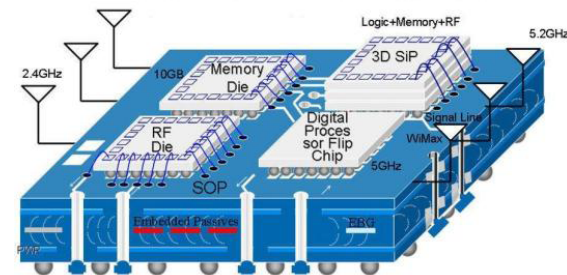
Extreme Chip Stacking



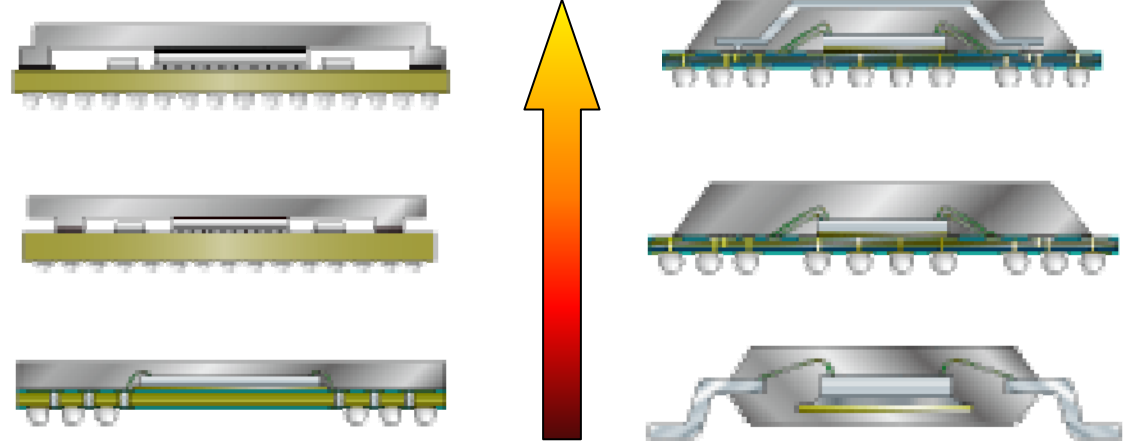
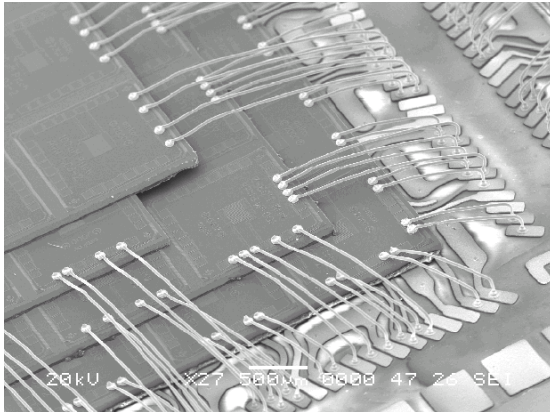
Elpida Memory 1.4mm MCP with 20 Stacked Dies



Thermal Management of Stacked-Chip Packaging



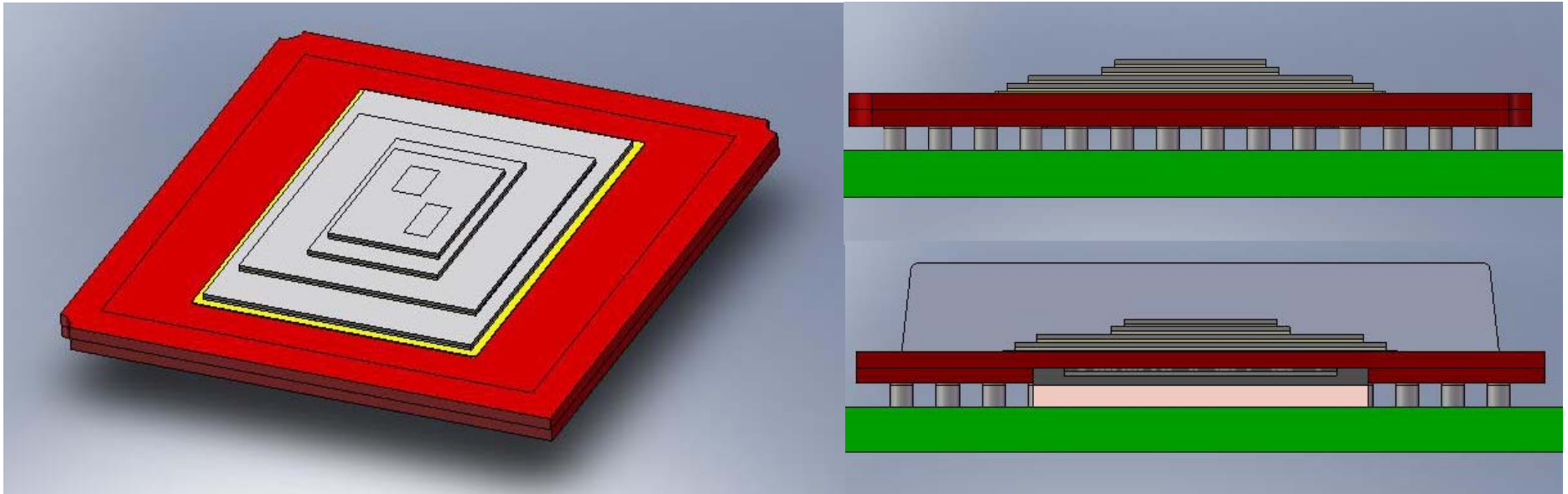
3D Thermal Management



- ▶ It is easy to see that in 3D designs, thermal management can be a challenge
- ▶ Chips can't always be placed a particular order without the use of spacers
- ▶ Spacers increase thermal resistance and add low-k adhesive layers
- ▶ Care must be taken not to align hot spots
- ▶ Heat removal in traditional packages is provided by external heat sinking, either through the top or the bottom or both



Stacked Chip Package Thermal



- Plastic overmolded package with 5 chips
 - Logic, memory, special function
 - Varied die size dictates stacking order
 - Chip on bottom of package (cavity)
 - 1.2W total power dissipation
 - $T_A = 22^\circ\text{C}$

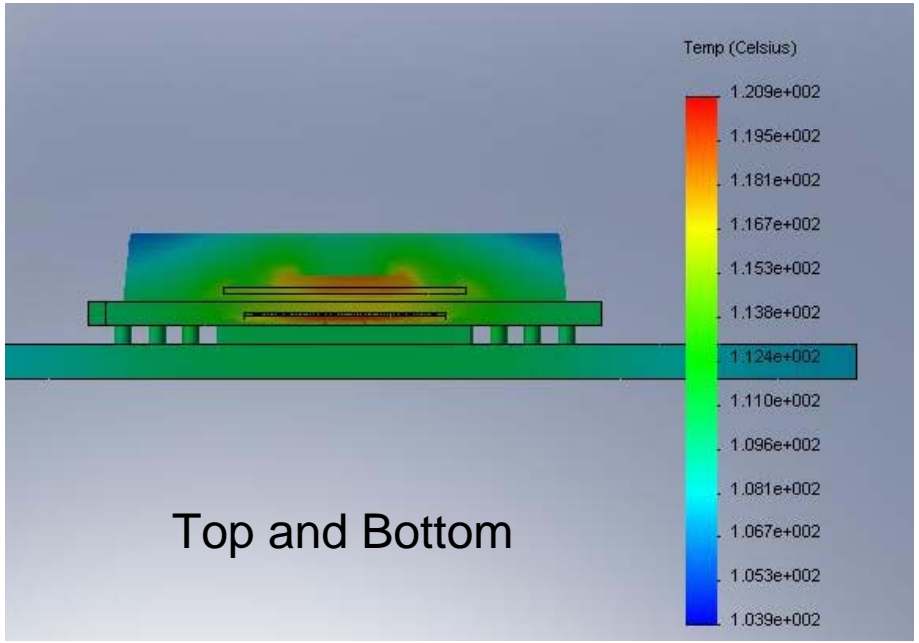
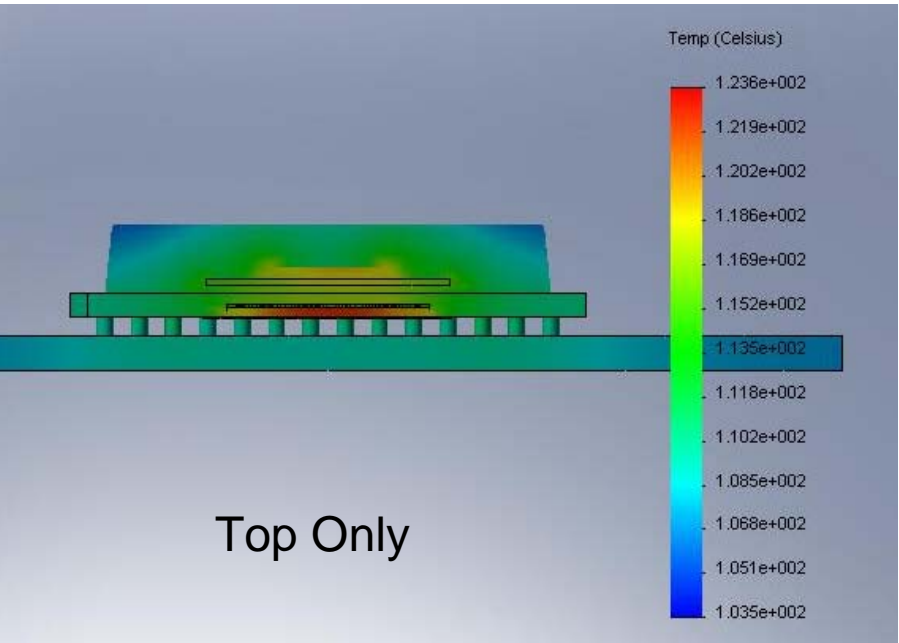
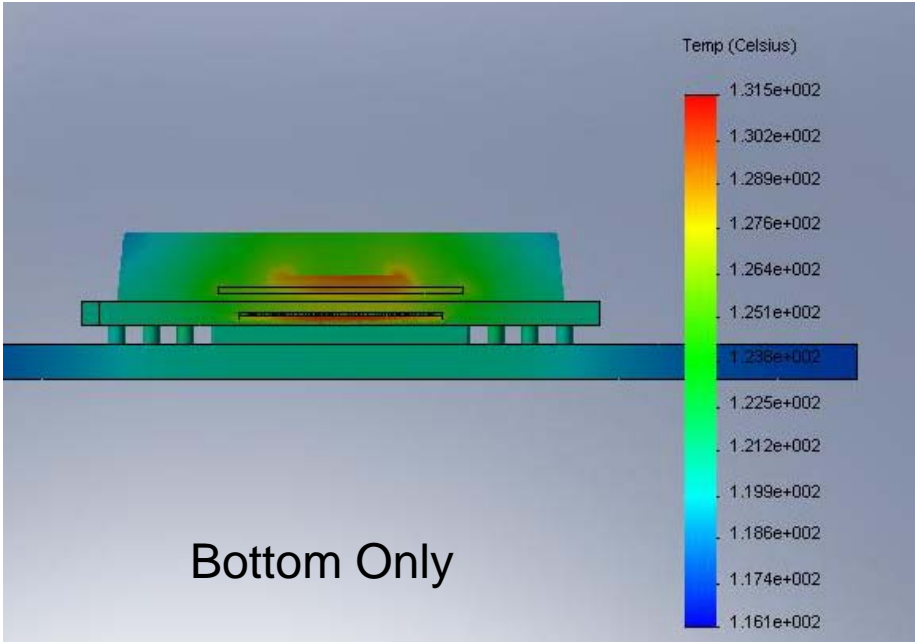
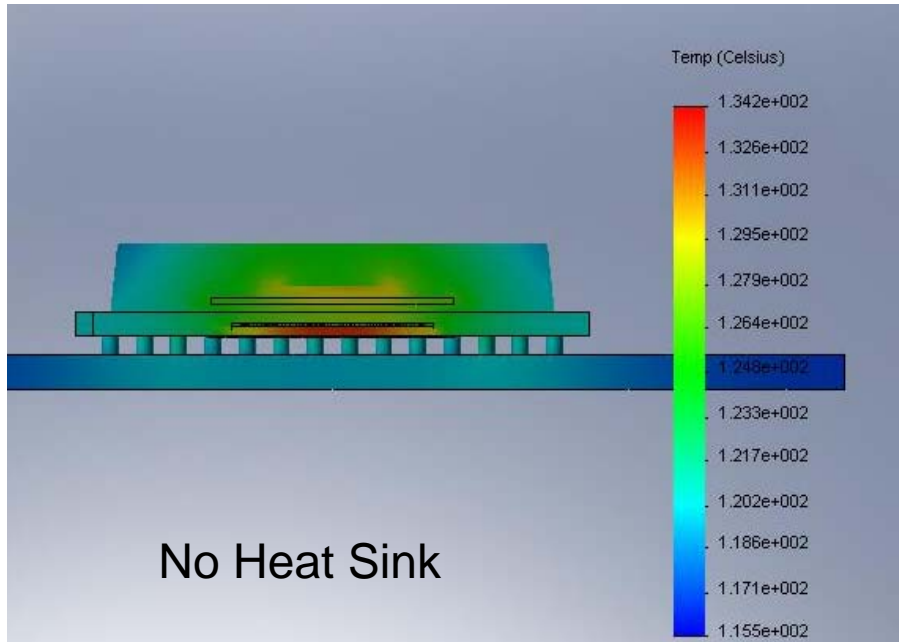


Stacked Chip Model Results

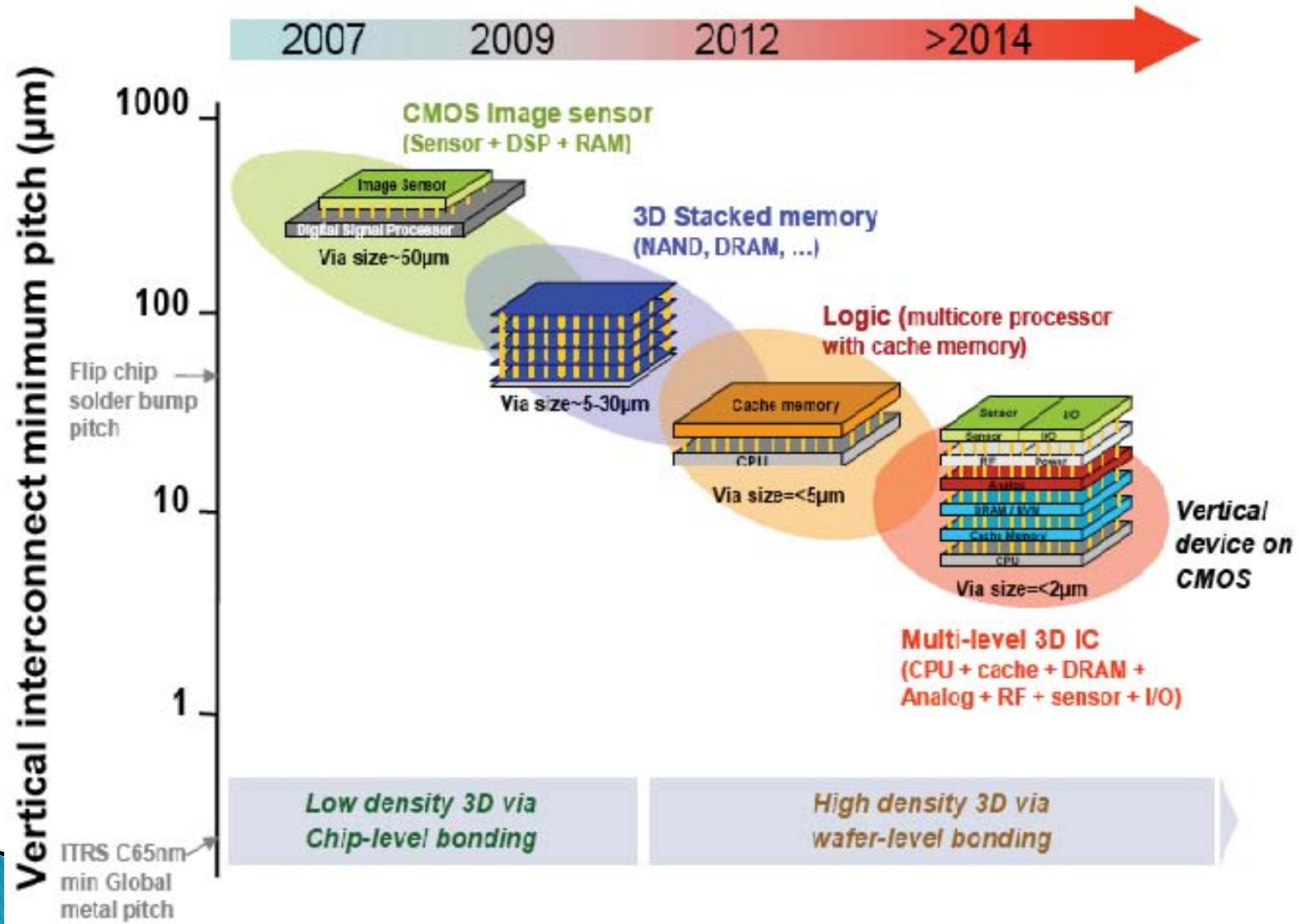
- ▶ FEM Models in SolidWorks COSMOS
- ▶ Simple block models include die-attach material thermal resistance and bulk heat transfer coefficients
- ▶ Show the effect of heat sinking

No HS	Bottom Only	Top Only	Both
134.2	131.5	123.9	120.9
ΔT	2.7	10.3	13.3

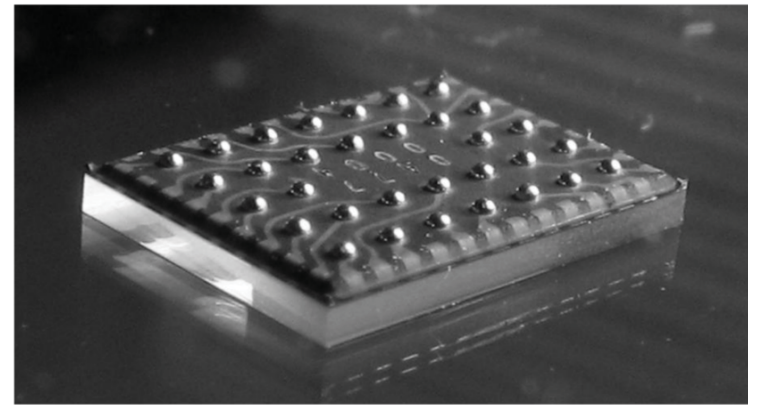
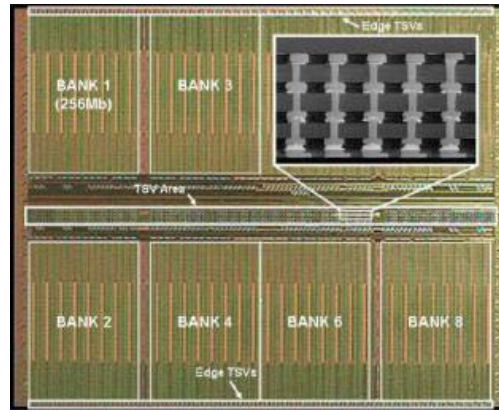
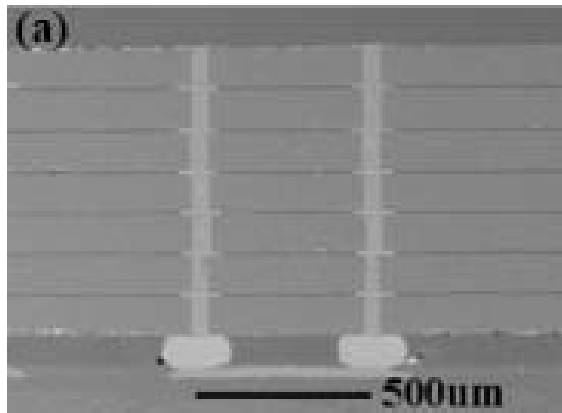




TSV Roadmap



TSV Thermal

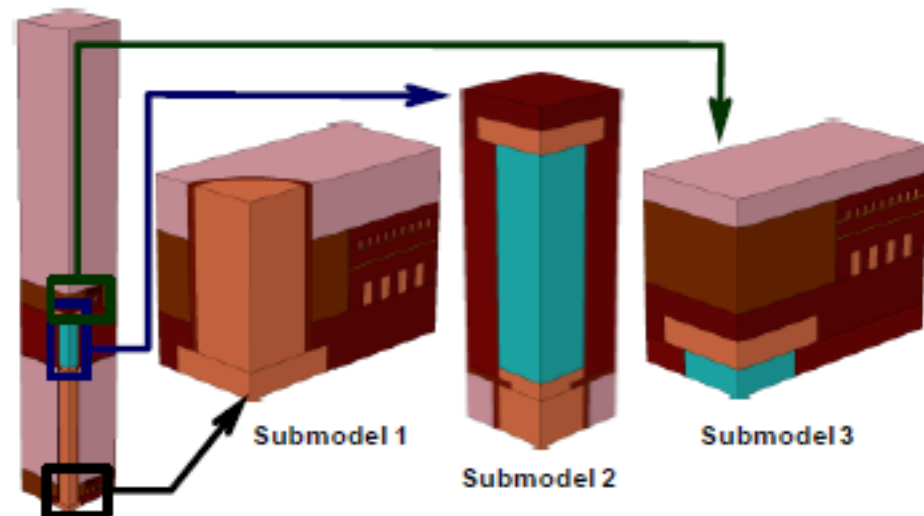
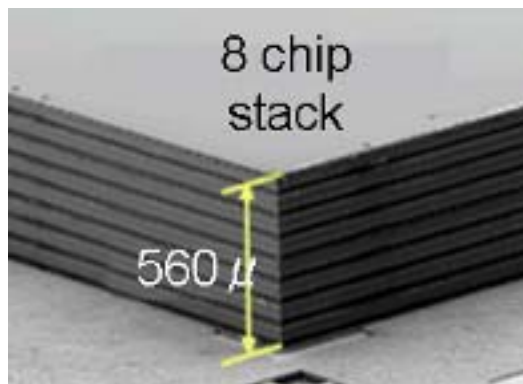


- ▶ TSV stacked chips pose a unique thermal management challenge
- ▶ The fine Cu pillars help to move heat vertically through the stack
- ▶ Gaps are introduced that must be filled
- ▶ Peripheral TSV are typical but arrays of vias are being investigated to increase heat flow
- ▶ Flexibility in placement of arrayed vias will be highly dependent on chip layout and density

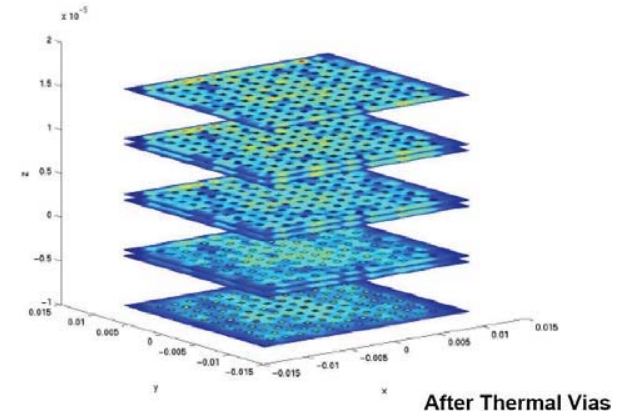
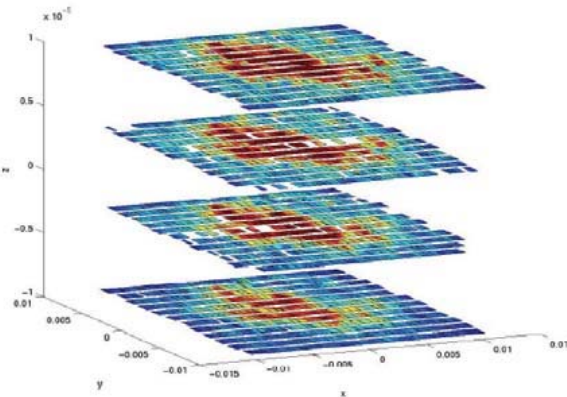
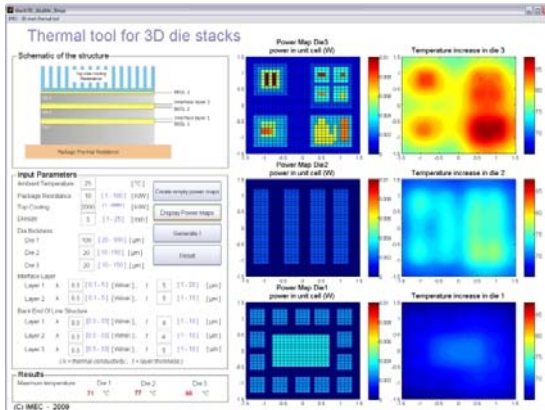


TSV Thermal

- ▶ Gaps are introduced that must be filled
- ▶ Peripheral TSV are typical but arrays of vias are being investigated to increase heat flow
- ▶ Due to the small size of TSV, computer modeling requires sub-modeling techniques



Thermal Management for TSV



- ▶ Use high-thermal conductivity interlayer adhesives / fillers
- ▶ Rotate chips such that hot spots are not spatially aligned
- ▶ Use materials that protrude from the 'stack' and provide direct attachment to heat removal structure
- ▶ Microchannel cooling
- ▶ Add multiple Cu TSV's to stack
- ▶ High thermal conductivity interposer between chips



Summary

- ▶ 3D Packaging is enabling a new generation of high density devices
- ▶ Challenges exist in design, process, materials and characterization
- ▶ Thermal Management is a primary concern
- ▶ Methods must be developed to measure and specify 3D package thermal parameters



TSV and Stacked Thermal Issues

- ▶ Thermo–electrical issues
 - Speed / propagation of chips with different temperatures
 - Change in via capacitance due to electrical field strength in Si
- ▶ Thermo–mechanical issues
 - Placement of TSV near actives can compress or expand gate
 - CTE mismatch may cause cracking or delamination



THANK YOU!

Tom Tarter
ttarter@pkgscience.com

