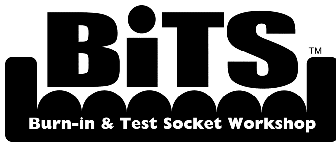


2008 Invited Speaker

ARCHIVE 2008

“Catching the Mobile Wave: Packaging is Going 3D”

Dr. Belgacem Haba
Fellow and CTO of Advanced Packaging and Interconnect
Tessera Inc.

Hand-held communication and entertainment products will continue to dominate the consumer markets worldwide, and with each generation offering more and more features and/or capability, system level integration and miniaturization becomes more of a priority. And even though the actual applications and functionality of the new product offering expands, the customer is expecting each generation to be smaller and lighter that its predecessor.

The cell phone is a great example of how new technologies and techniques can be applied to maintain performance improvements over time. The explosion of the cell phone market over the last few years is a testament to the increase of functionality and complexity of miniaturization. However, this has led to some serious issues, especially mechanical, thermal and shielding problems. Less than one part in 1,000 of the volume of an electronic product is occupied by transistors. The remaining volume consists of mechanical structure, air, passive elements, cables and connectors. 3D stacking is a natural way to reduce the system volume. Die fabricated at different process geometries can be brought together in a 3D stack, thus avoiding some of the cost issues associated with system-on-chip (SoC) designs. This presentation focuses on the different alternatives available for 3D packaging as well as new ideas that people are planning for the mobile phone revolution to continue.

Dr Haba is responsible for overseeing next-generation research and development activities for Tessera, Inc. Dr. Haba was a founder of SiliconPipe Inc. His previous positions include managing the packaging research and development division at Rambus, managing advanced research and development projects at the NEC Central Research Laboratories in Japan and, before that, he worked for IBM at its T.J. Watson Research Center in New York. He holds 93 U.S. patents, and over 150 worldwide patents and patent applications. Dr. Haba was awarded the Most Inspirational Paper award at the 2006 BiTS Workshop.

COPYRIGHT NOTICE

The papers in this publication comprise the proceedings of the 2008 BiTS Workshop. They reflect the authors’ opinions and are reproduced as presented , without change. Their inclusion in this publication does not constitute an endorsement by the BiTS Workshop, the sponsors, BiTS Workshop LLC, or the authors.

There is NO copyright protection claimed by this publication or the authors. However, each presentation is the work of the authors and their respective companies: as such, it is strongly suggested that any use reflect proper acknowledgement to the appropriate source. Any questions regarding the use of any materials presented should be directed to the author/s or their companies.

All photographs in this archive are copyrighted by BiTS Workshop LLC. The BiTS logo and ‘Burn-in & Test Socket Workshop’ are trademarks of BiTS Workshop LLC.

Catching the Mobile Wave: Packaging is Going 3D

2008 Burn-in and Test Socket Workshop
March 9 - 12, 2008

Belgacem Haba, Ph.D.
Tessera

Outline

- Introduction
- Driving forces and limitations
- 3-D package stacking
- 3-D wafer-level stacking
- 3-D by embedding technologies
- 3-D in optics
- Conclusion

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 2

Packaging is the key

- About 1cm cube of silicon
- The rest is Packaging

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 3

Mobile Phone Evolution

1970s	1980s	1990s	Today
~$5000	~$4000	~$300	Free Voice,
Voice	Voice	Voice	Data

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 4

Evolution of Memory

- 5MB IBM hard drive, 1956

Jan 7th PR: SanDisk Announces the 12-Gigabyte microSDHC Card – the World's Largest Capacity Card for Mobile Phones

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 5

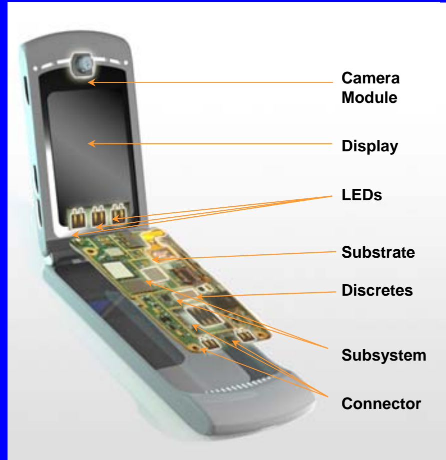
Outline

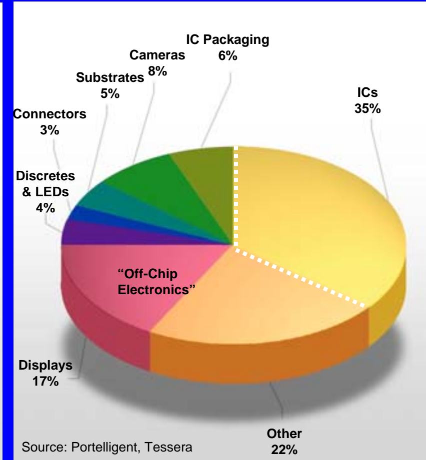
- Introduction
- Driving forces and limitations
- 3-D package stacking
- 3-D wafer-level stacking
- 3-D by embedding technologies
- 3-D in optics
- Conclusion

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 6

The Inside of Mobile Phones

Mobile Phone Components | **Mobile Phone Distribution of BOM**





03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 7

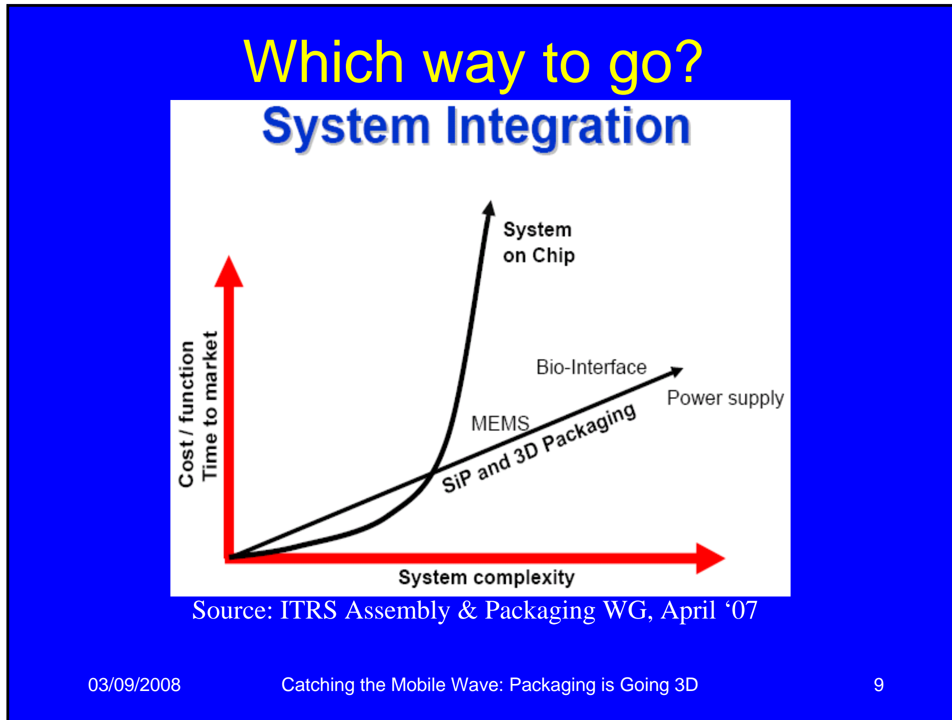
2007 ITRS & iNEMI Updates

Packaging is now a limiting factor but it is enabling for More than Moore

- Packaging has become the limiting element in system cost and performance
- The Assembly and packaging role is expanding to include system level integration functions.
- As traditional Moore's law scaling become more difficult innovation in assembly and packaging can take up the slack.

Source: ITRS & iNEMI 2007 updates

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 8


Which way to go?
System Integration
System on Chip
Bio-Interface
Power supply
MEMS
SiP and 3D Packaging
Cost / function
Time to market
System complexity
Source: ITRS Assembly & Packaging WG, April '07
03/09/2008
Catching the Mobile Wave: Packaging is Going 3D
9

Mobile Phone
Camera Bezel
Rear Bezel
Daughter PCB
Camera Module
Display
Front Enclosure
Display Bezel
Battery Cover
Battery
Rear Enclosure
Main PCB
Keypad PCB
Keypad
Source: Portelligent
03/09/2008
Catching the Mobile Wave: Packaging is Going 3D
10

Phone Thickness Drivers

- Voltage control inductors
- High-value Capacitors
- Filters
- Oscillators
- Camera
- Connectors
- Battery
- Package stacking

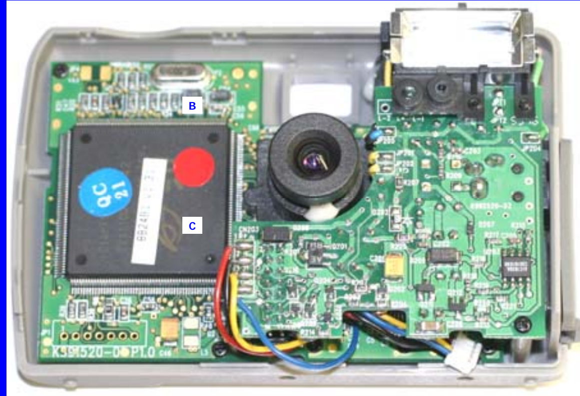
03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 11

Integrated Hermetic Packaging

- SAWs, crystal oscillators and many MEMS oscillators require hermetic packaging
- Hermetic packaging is difficult to integrate into typical low-cost electronic assemblies

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 12

Main Board of Camera



Cameras are too thick

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 13

Outline

- Introduction
- Driving forces and limitations
- 3-D package stacking
- 3-D wafer-level stacking
- 3-D by embedding technologies
- 3-D in optics
- Conclusion

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 14

Interconnect Pitch Limitations

die
150 um
size
Die size
Die pitch
time

Package
500 um
size
pkg size
pkg pitch
time

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 15

SFT Silicon Interposer

Flip mount
64Mb SiS-DRAM Area
64Mb SiS-DRAM Area
DRAM I/O
SiS-DRAM Chip
Interface Macro
Interface Macro
ASIC Area
SiIP Die
Flip mount
ASIC Chip

60 um Pitch Flipchip

Silicon on Silicon Interposer

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 16

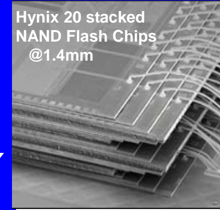
3D Electronics (like Human Evolution)

2D development

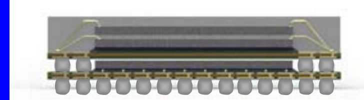
3D improves density and efficiency

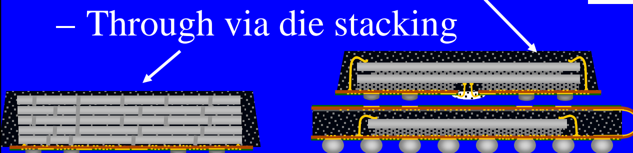
03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 17

Third direction: Z direction



- As many die as possible in z-direction
- 3 solutions:
  - Wire bondable die stacking in single package
  - Package stacking (POP: package on package)
    - Ball-Stack
    - Fold over
  - Through via die stacking





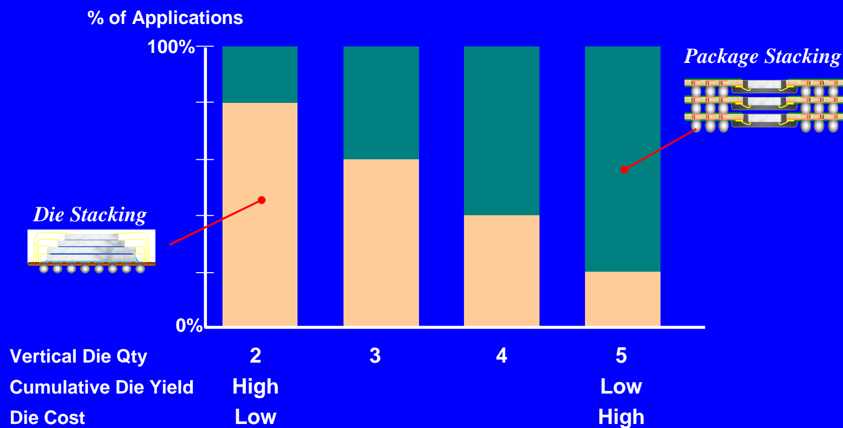
03/09/2008

Different Stacking Technologies

- Package stacking technologies
  - Solder ball
  - Cu pin
- Die stacking technologies
  - Wire bond stacking
  - Through Silicon Via stacking
  - Edge bond stacking

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 19

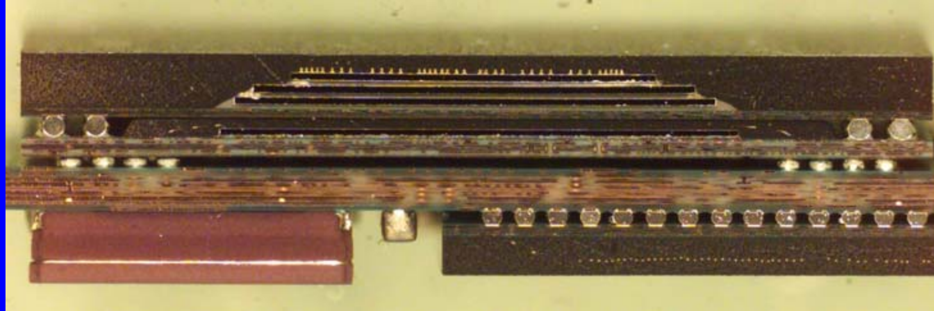
3-D: When to Die Stack vs. Package Stack



Source: Amkor / Sharp

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 20

Package on Package

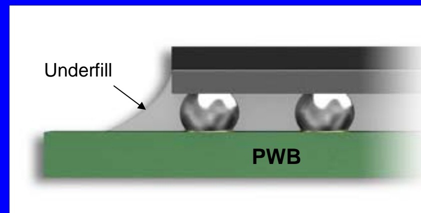


Photos source: Prismark/Binghamton University

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 21

Addressing the Challenges – Reliability

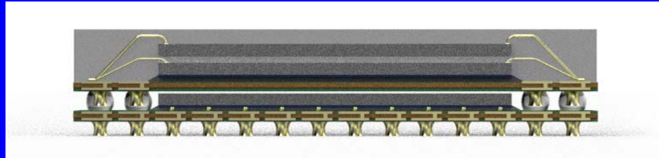
the Need for Underfilling

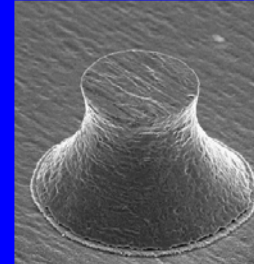


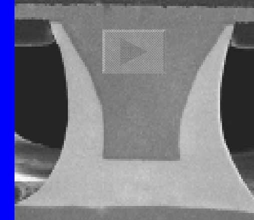
- Mobile phones drop tests increasingly difficult to pass
- Underfill is a necessity – increases cost and effective size

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 22

Typical Pin after SMT







Improvement in drop test

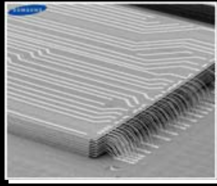
03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 23

Outline

- Introduction
- Driving forces and limitations
- 3-D package stacking
- 3-D wafer-level stacking
- 3-D by embedding technologies
- 3-D in optics
- Conclusion

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 24

Latest High Die Stacking Press Releases



Samsung

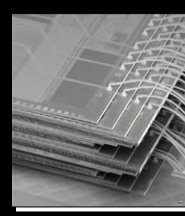
- 16 die stacked
- 8Gb NAND flash chips, can enable up to a 16 gigabyte (GB) MCP solution
- Wafer-thinning technology to only 30-micrometers (µm) (65% thickness of 10 chips)

November 01, 2006

Akida Elpida

- 20 stacked NAND Flash Chips @1.4mm thickness
- Die Thickness: 30µm

April 23, 2007



Hynix

- 20 stacked NAND Flash Chips @1.4mm thickness
- Die Thickness: 25µm

May 06, 2007

High die stacking (beyond 4-6) has substantial manufacturing challenges:

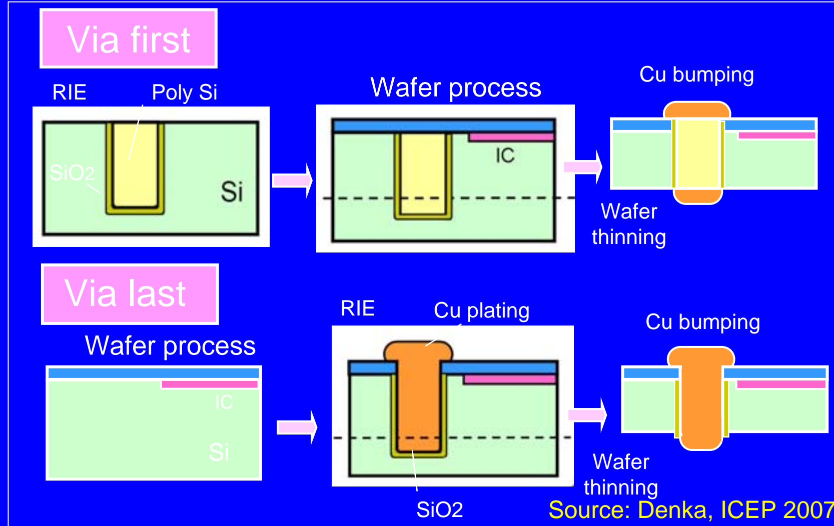
- High cost
- Compound yield
- Complex assembly process
- Questionable reliability performance

Challenges With Wire Bond Stack

- Grinding very thin die
- Handling of very thin die
- Wire bonding of thin die overhang
- Compound yield
- Testing and burn-in

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 26

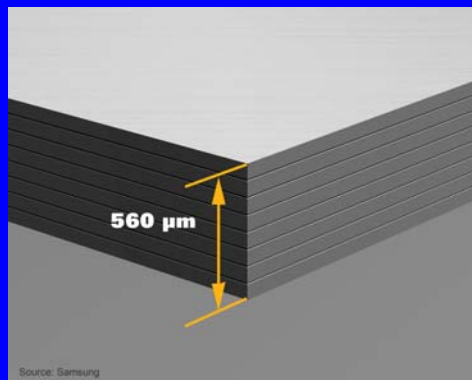
"Via first" and "Via last" process flow



03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 27

Through Silicon Vias

Eight Stacked Chips (WSP)



8-die Stack

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 28

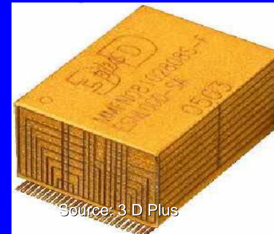
Challenges with Through Silicon Vias

- Grinding very thin die especially at 12 inch wafers
- Handling of very thin die
- Rigidity in via design and via real estate
- Testing and burn-in
- Availability of infrastructure

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 29

Stacking By Edge Connect

16-die Flash Stack

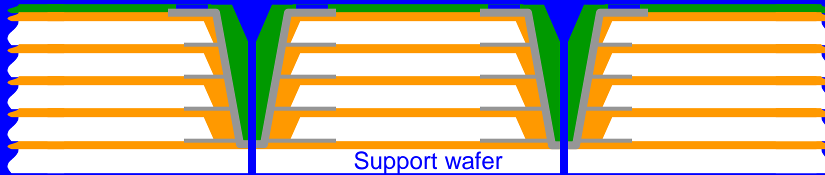


8-die Flash Stack

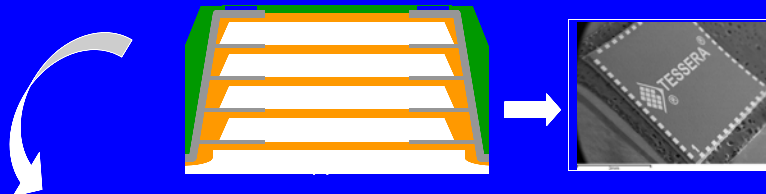
16-die Flash Stack

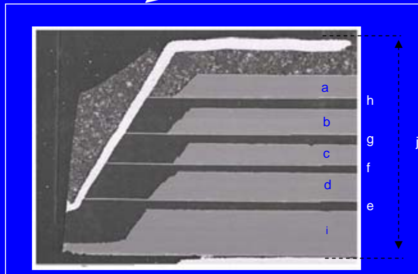
03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 30

Wafer Level Edge Contact From Tessera



Final Product (Ready For Wire Bond)





Item	Thickness	Comments
Die	**~25 µm**	a, b, c, d, e
Adhesive	~3 µm	e, f, g, h
Carrier	30 µm	i

Total Package Thickness ~ 155 µm

Final Product (Ready For Surface Mount)

Ultra thin 4 x Die stack

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 33

Six, 4-Die Stacks Within a Pkg (24 die < 1 mm)

3D schematic

Wire bond to 6 WLSP

SD Card Footprint

Cross Sectional SEM

950 um

Toward 32 die in < 1 mm

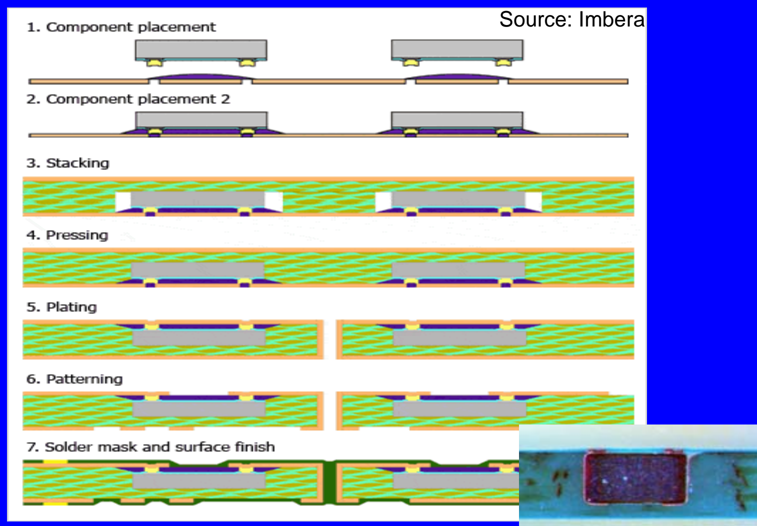
03/09/2008 34

Outline

- Introduction
- Driving forces and limitations
- 3-D package stacking
- 3-D wafer-level stacking
- 3-D by embedding technologies
- 3-D in optics
- Conclusion

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 35

IMBERA Embedded Process



03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 36

FREESCALE RADIO-IN-PACKAGE USING RCP

General Process flow

Flash Mem PSRAM

Fabricate Memory Base with embedded components

RF Radio Module Atlas UL Flash PSRAM

Add Stacked Pkgs

RF Radio Module Atlas UL Flash PSRAM

Attach solder balls, Singulate, final test

64Mb PSRAM Micron 4.81x5.65mm

256Mb Flash Intel 5.48x 8.64mm

20x20mm area

Atlas U-lite 8x8mm LGA 185 I/O, 0.5mm

Ratptor 7x7mm 34 I/O LGA

TransAAM with SAWs 8x9mm XX I/O LGA

LTE SiP 289 I/O 9x9mm 0.5mm pitch

20x20mm area

Source: Freescale.

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 37

FREESCALE RCP RADIO IN PACKAGE

Memory Base

Transceiver & PA

Baseband Processor

Power Management

All 'sub-assemblies' are fully tested using traditional 'non-integrated' test methodologies AND using conventional lowest test cost (ATE) platforms

NOW READY FOR SYSTEM INTEGRATION

1.4mm

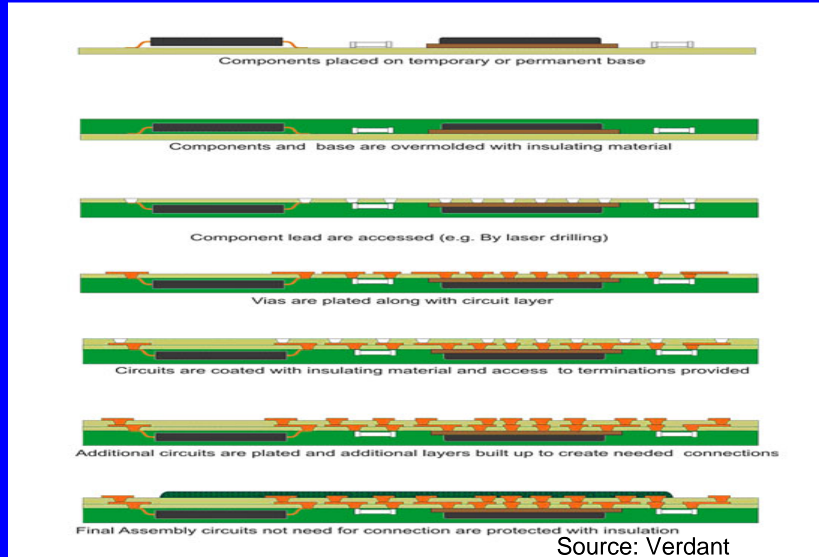
profile view

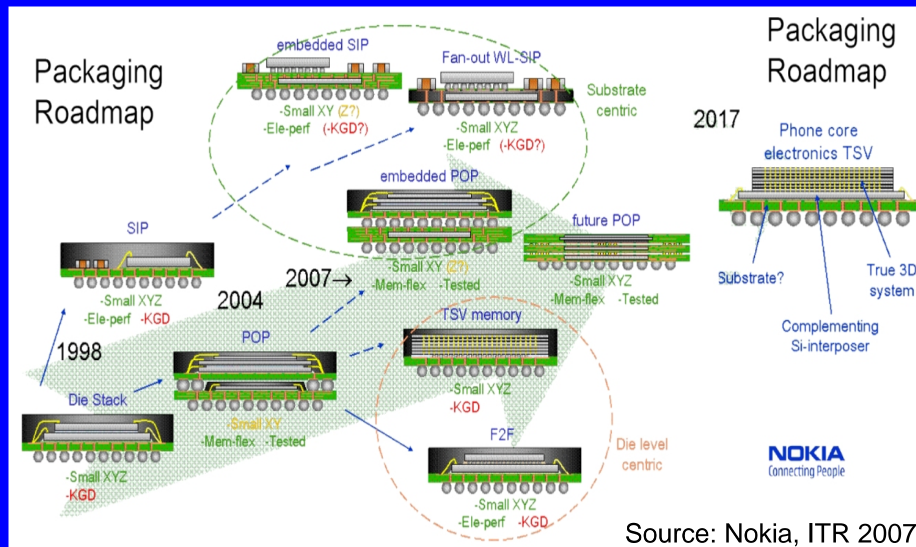
20mm

18mm

top view

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 38


OCCAM Process
Components placed on temporary or permanent base
Components and base are overmolded with insulating material
Component lead are accessed (e.g. By laser drilling)
Vias are plated along with circuit layer
Circuits are coated with insulating material and access to terminations provided
Additional circuits are plated and additional layers built up to create needed connections
Final Assembly circuits not need for connection are protected with insulation
Source: Verdant
03/09/2008
Catching the Mobile Wave: Packaging is Going 3D
39


Nokia Miniaturization Roadmap
Packaging Roadmap
embedded SIP
Fan-out WL-SIP
Substrate centric
-Small XY (Z?)
-Ele-perf (-KGD?)
-Small XYZ
-Ele-perf (-KGD?)
embedded POP
future POP
SIP
-Small XYZ
-Ele-perf -KGD
2004
2007→
-Small XY (Z?)
-Mem-flex -Tested
-Small XYZ
-Mem-flex -Tested
1998
POP
TSV memory
Die Stack
-Small XY
-Mem-flex -Tested
-Small XYZ
-KGD
-Small XYZ
-KGD
F2F
Die level centric
-Small XYZ
-Ele-perf -KGD
Packaging Roadmap
2017
Phone core electronics TSV
Substrate?
True 3D system
Complementing Si-interposer
NOKIA
Connecting People
Source: Nokia, ITR 2007
03/09/2008
Catching the Mobile Wave: Packaging is Going 3D
40

Embedded DRAM

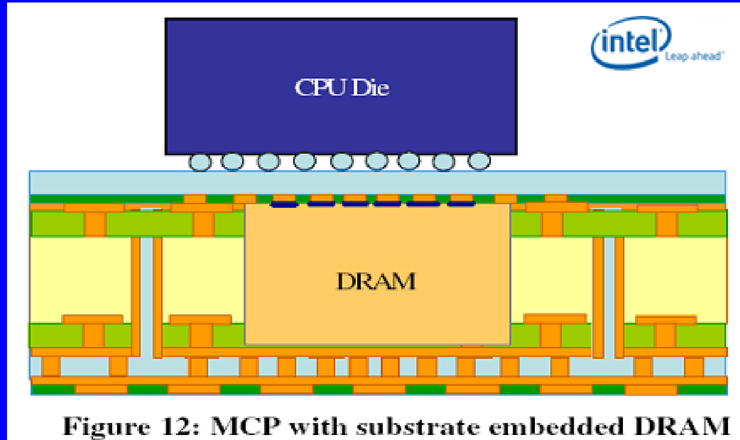
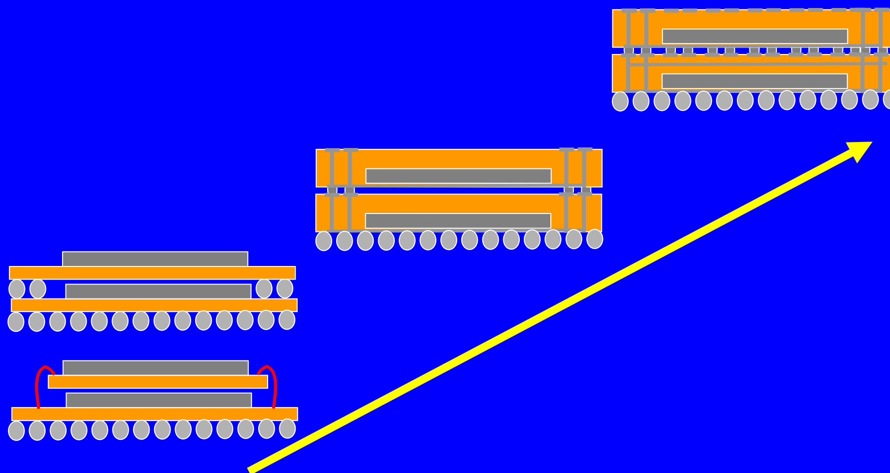


Figure 12: MCP with substrate embedded DRAM

Source: Intel

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 41

Likelihood of Evolution of POP



03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 42

Outline

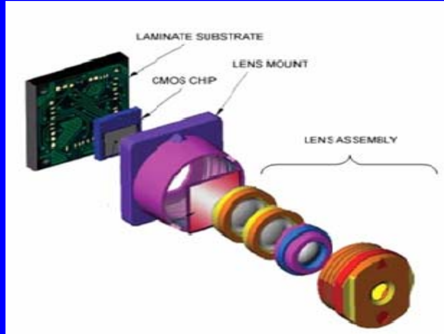
- Introduction
- Driving forces and limitations
- 3-D package stacking
- 3-D wafer level stacking
- 3-D by embedding technologies
- 3-D in optics
- Conclusion

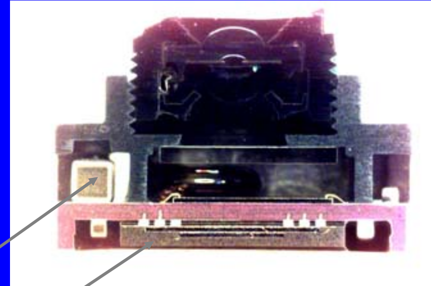
03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 43

Main Board of Camera

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 44

Cell Phone Camera Module





Passives

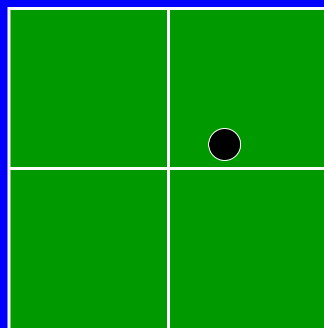
Image processor and memory

Source: Prismark

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 45

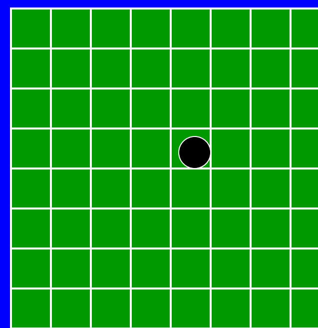
COB Assembly
Smaller pixels - More particle problems

Lower Resolution
Larger Pixels



Particle has small effect on pixel

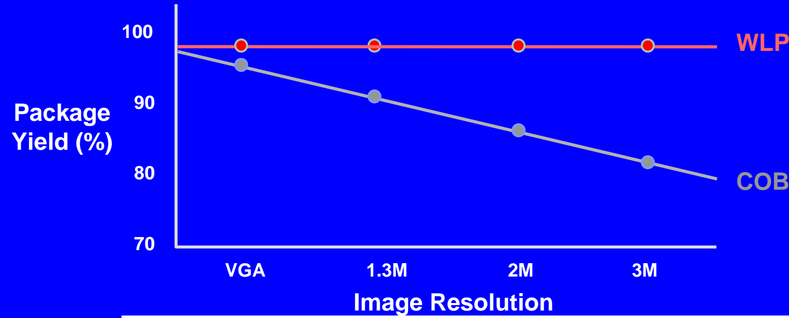
Higher Resolution
Smaller Pixels



Particle has large effect on pixel

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 46

COB vs WLP Module Yield

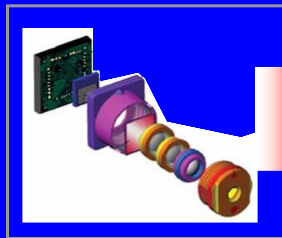


Particle Contamination During COB Manufacturing Decreases Yield at Higher Resolution

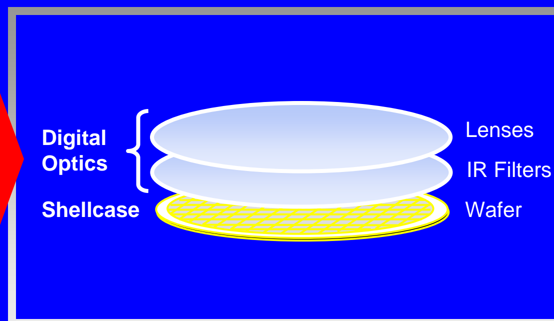
03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 47

Wafer Level Camera Modules

From This…



To This…



03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 48

Revolutionizing the Camera Module

Conventional camera phone

OptiML™ wafer level technology

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 49

Image Without EDOF

1 Meter Away

Infinity

10 Centimeters Away

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 50

Image With EDOF

1 Meter Away

Infinity

10 Centimeters Away

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 51

Conclusion

- Packages are getting thinner and thinner
- Contact pitch are getting smaller and smaller
- Multiple die packages will become the norm
- See more and more embedded passives and some actives
- Packages would have contacts from top and bottom
- Expect complex testing schemes

03/09/2008 Catching the Mobile Wave: Packaging is Going 3D 52

End of Slide Show, Click to Exit.