Invited Speaker

Wednesday 3/12/14 11:30am
Kiva Ballroom

TRENDS IN WAFER LEVEL PACKAGING: THIN IS IN!

by

E. Jan Vardaman
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***Jan Vardaman, President and Founder of TechSearch International**, is the author of numerous publications on emerging trends in semiconductor packaging and assembly. She is a member of IEEE CPMT, SMTA, MEPTEC, IPC, IMAPS and SEMI. She was elected to two terms on the IEEE CPMT Board of Governors. Before founding TechSearch International, she served on the corporate staff of Microelectronics and Computer Technology Corporation (MCC), the electronics industry's first pre-competitive research consortium. She has made numerous presentations on developments in advanced packaging.*

ABSTRACT

WIreless products continue to drive the unit volume growth in semiconductor packaging today. Growth in wafer level packages (WLPs) continues to be driven by the strong preference for small form factor, low profile packages for use in mobile phones. WLPs with a variety of pin counts and die sizes are also found in watches, MP3 players, digital cameras, laptops and tablets. Pin counts are increasing and ball pitch is decreasing. New WLP formats are emerging. Fan-out WLPs (FO-WLPs) are receiving increased interest for more than just single die package and are emerging as a new potential format for SiP. This presentation examines application trends for WLPs, trends in pin count, die size, and ball pitch, as well as new package formats.

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Trends in Wafer Level Packaging: Thin is In!

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TechSearch International, Inc.

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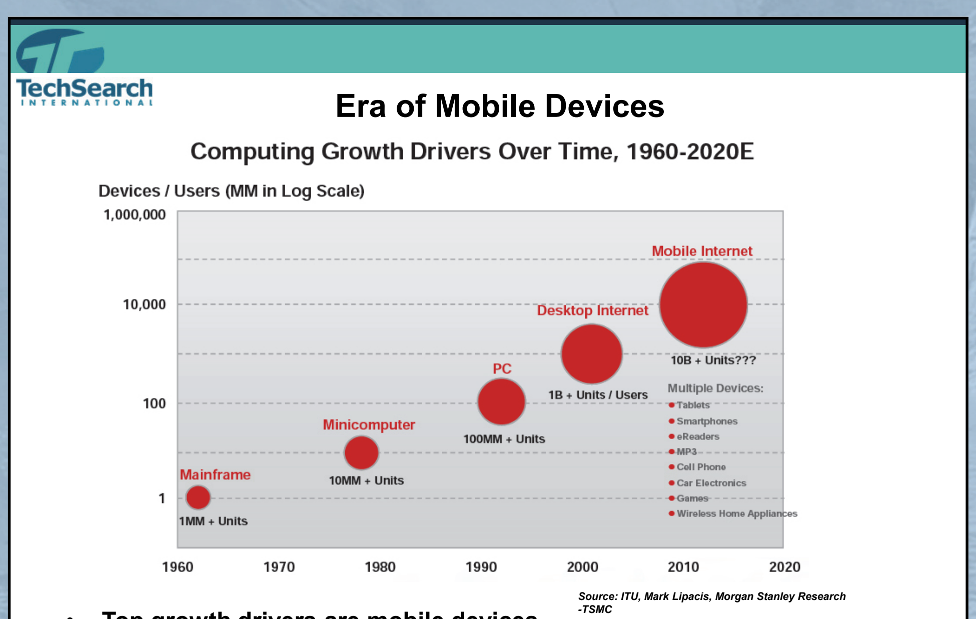

- Top growth drivers are mobile devices
- Consumers want smaller and thinner products
- Driving growth of thin package solutions

Mobile Devices

- Mobile Devices
  - Laptops
  - Smartphones
  - Tablets
  - Feature phones
  - Wearable electronics
- Attributes
  - Typically shorter lifetimes (2 years)
  - Performance varies
  - Require high reliability in focused on drop test for high-end smartphones and tablets, some manufacturers not as concerned with drop or reliability because customer does not expect it
- System packaging needs
  - Small form factor
  - High performance, high bandwidth
  - Lower power consumption (consumers want longer battery life)
  - Thermal issues (air flow difficult)
  - Lower cost
- Packaging options
  - BGA, FBGA, LGA, (including MCM), PoP, stacked die CSP, QFN, SON, CLGA, WLP
- Cost/Performance Trade-off Determines Adoption, but Form Factor is Key

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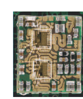
Packages for Mobile Devices

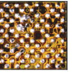
- Touch screen controllers: quad flat no-lead (QFN), fine pitch ball grid arrays (FBGA)
- Antenna: ceramic land grid array (CLGA), QFN
- Power amplifiers: LGA (with laminate substrate), typically wire bond moving to flip chip
- RFIC: FBGA, flip chip BGA (FC-BGA), wafer level package (WLP), Fan-out WLP (FO-WLP)
- Modem IC: FC-BGA, stacked die package (FC and WB), package-on-package (PoP)
- Application processor: FC-BGA, bottom package of PoP
- NAND flash: FBGA
- Power management IC (PMIC): FC-BGA, WLP
- WiFi/Bluetooth: CLGA, LGA (with laminate substrate), WLP
- Near Field Communications (NFC): FBGA
- Sensors: LGA

QFN

PoP

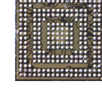


LGA module

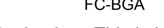


WLP

FO-WLP



FC-BGA



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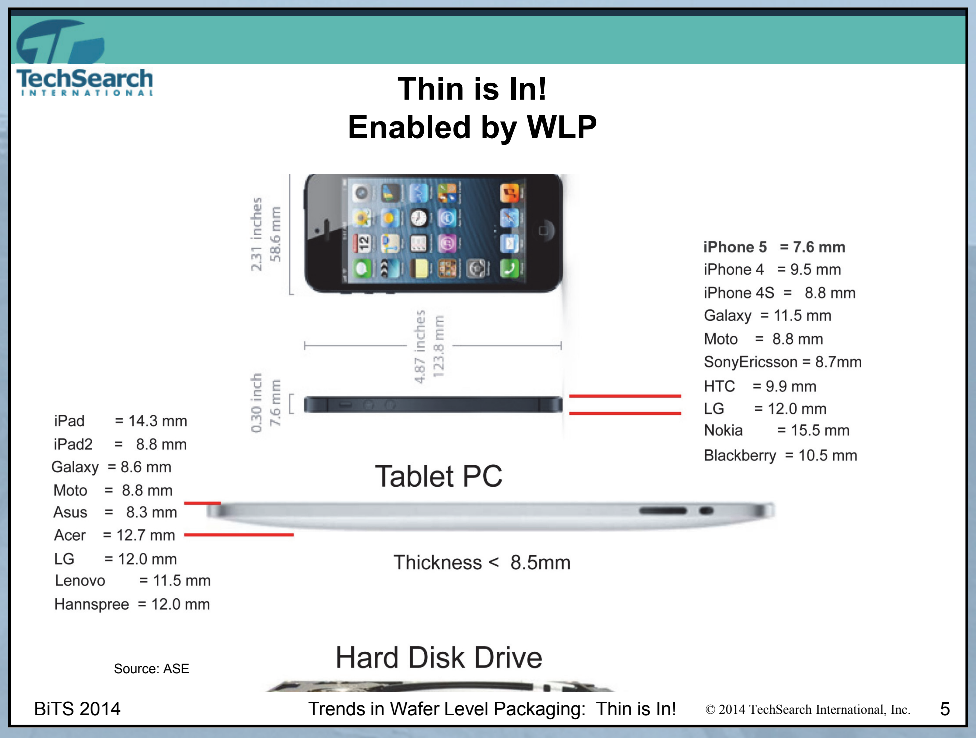
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Thin is In!
Enabled by WLP
2.31 inches 58.6 mm
4.87 inches 123.8 mm
0.30 inch 7.6 mm
iPhone 5 = 7.6 mm
iPhone 4 = 9.5 mm
iPhone 4S = 8.8 mm
Galaxy = 11.5 mm
Moto = 8.8 mm
SonyEricsson = 8.7mm
HTC = 9.9 mm
LG = 12.0 mm
Nokia = 15.5 mm
Blackberry = 10.5 mm
iPad = 14.3 mm
iPad2 = 8.8 mm
Galaxy = 8.6 mm
Moto = 8.8 mm
Asus = 8.3 mm
Acer = 12.7 mm
LG = 12.0 mm
Lenovo = 11.5 mm
Hannspree = 12.0 mm
Tablet PC
Thickness < 8.5mm
Hard Disk Drive
Source: ASE
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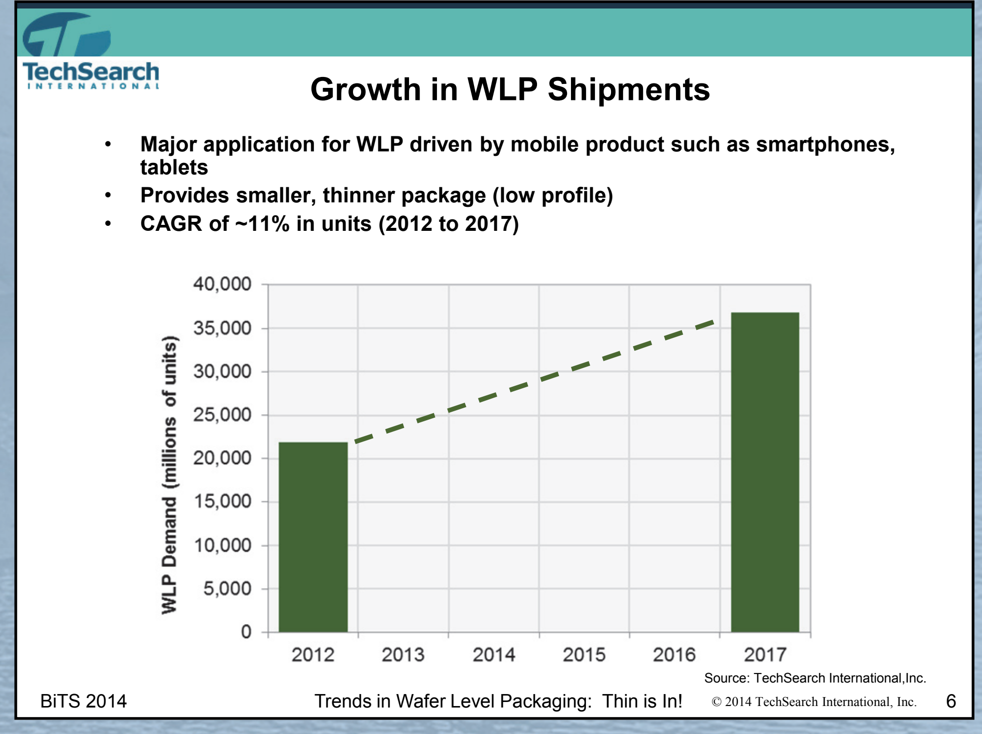
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Growth in WLP Shipments
• Major application for WLP driven by mobile product such as smartphones, tablets
• Provides smaller, thinner package (low profile)
• CAGR of ~11% in units (2012 to 2017)
WLP Demand (millions of units)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
2012
2013
2014
2015
2016
2017
Source: TechSearch International,Inc.
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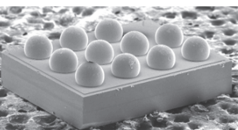
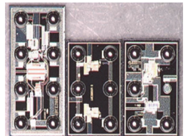
Typical Wafer Level Packages

• Die size	<8 mm x 8 mm
• I/O count	2 to 400+
• Minimum I/O pitch	200 microns
• Bump diameter	250 to 500 microns
• Bump height	100 to 400 microns
• Package height	0.33 to 1.0 mm
• Wafer diameters	150mm, 200mm, 300mm

Source: Adapted from Amkor





Source: Texas Instruments

Source: ASE

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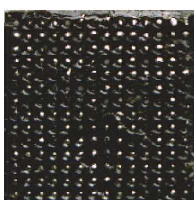
WLP Trends

- Consumer products and other applications
  - Mobile phones (highest volume application)
  - Digital cameras and camcorders
  - MP3 players (such as iPods)
  - Watch modules
  - Laptop and tablet computers
  - Medical
  - Automotive
  - Wearable electronics
- Conventional WLPs for many device types
  - WLPs for analog functions, power management, RF, wireless LAN, IPD, LED driver, sound IC, etc.
  - Highest I/O count 309 (Fujitsu power management IC)
  - Largest body size Apple/Cirrus Logic Audio CODEC 5.72 x 6.03 x 0.59 mm, 121 solder balls, 0.5mm pitch
  - Increasing number of 0.4mm pitch parts, some 0.35mm pitch



Source: TPSS

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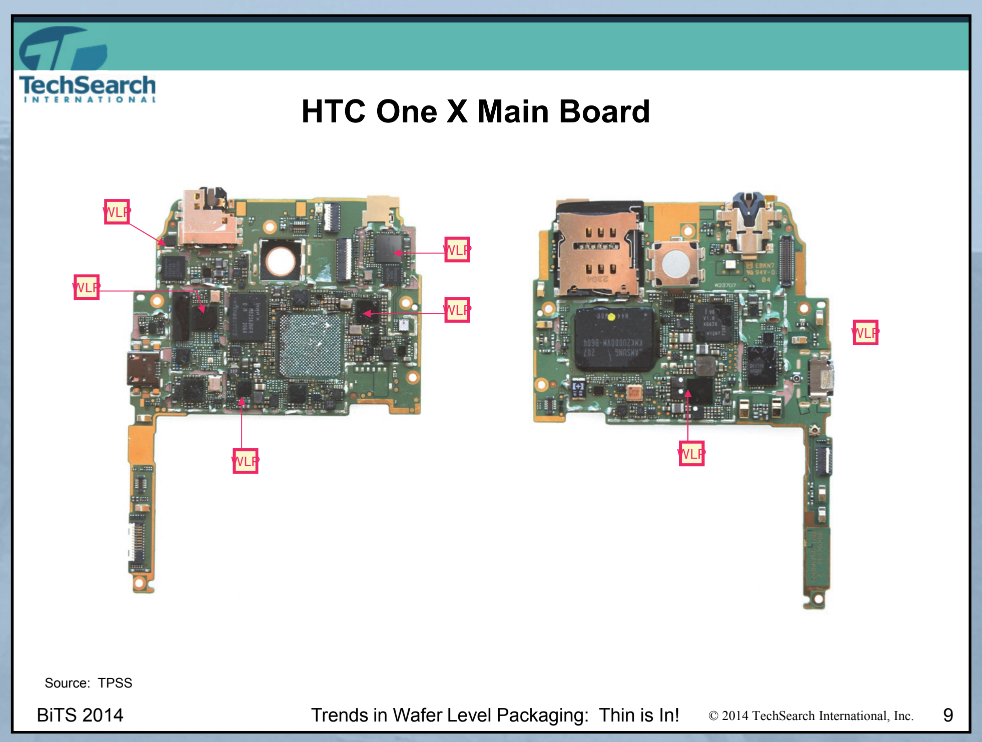

WLP Examples in Mobile Phones

Mobile Phone (number of WLPs)	Supplier (function)	Ball Count	Size (mm)	Pitch (mm)
Apple iPhone 5 (11+)	Unknown	9	1.49 x 1.43 x 0.57	0.5
	AJY	9	1.58 x 1.59 x 0.45	0.5
	Qualcomm (RF power mgt.)	105	4.63 x 3.88 x 0.57	0.4
	RFMD (antenna)	12	1.91 x 2.08 x 0.53	0.4
	Apple/Cirrus	42	2.79 x 3.53 x 0.45	0.4
	Unknown	8	1.96 x 2.74 x 0.47	0.5
	NXP (LED driver)	36	2.11 x 2.14 x 0.4	0.35
	Broadcom (controller)	72	3.31 x 4.39 x 0.54	0.4
	AKM (electronic compass)	14	1.6 x 1.6 x 0.48	0.4
	TI (touch screen controller)	99	4.64 x 3.81 x 0.64	0.4
	ShellOP (ligh sensor)	6	2.4 x 1.7 x 0.8	_
Samsung Galaxy S3 GT-10300 (6)	Asahi Kasei (compass)	14	2 x 1.98 x 0.51	0.5
	Maxim (PMIC/MU/control)	100	4.52 x 4.54 x 0.69	0.4
	Maxim (PMIC)	144	5.14 x 5.1 x 0.64	0.4
	Broadcom (receiver)	42	3.04 x 2.87 x 0.57	0.4
	Wolfson (CODEC)	90	4.18 x 3.88 x 0.45	0.4
	Intel (RFIC) eWLB	139	5 x 5.3 x 0.67	0.4
HTC One X (7)	Intel (RFIC) eWLB	148	5.39 x 5.03 x 0.67	0.4
	Asahi Kasei (compass)	14	1.98 x 1.97 x 0.48	0.5
	TI (WiFi/Bluetooth/FM tran)	174	5.7 x 5.35 x 0.64	0.4
	TI (PMIC)	81	4.82 x 4.83 x 0.52	0.5
	Unknown	36	3 x 3 0.7	0.4
	TI (PMU for Tegra 3)	154	5.38 x 5.23 x 0.54	0.4
	Unknown	20	2.09 x 1.71 x 0.5	0.4

Source: TPSS

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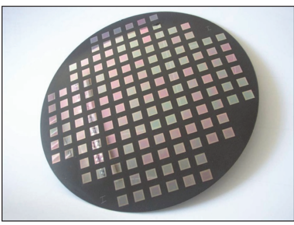
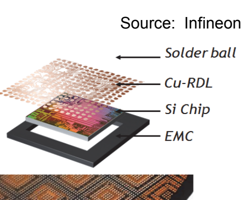
Fan-Out Wafer Level Package

- Reconstituted wafer and perimeter mold compound allows for redistribution of I/O beyond current chip footprint
  - Uses KGD
  - Number of interconnects, pitch of interconnect independent of chip size
  - Mold compound used to support the FO
  - Single, multi-die, or 3D solution
- Considered an embedded package because die is placed with interconnect on top
- Fan-out WLP (FO-WLP) from ADL Engineering, Amkor, ASE, Deca Technologies, Freescale Semiconductor, FCI/Fujikura, J-Devices, NANIUM, Nepes, SPIL, STATS ChipPAC, and TSMC
- Infineon eWLB (wireless operation acquired by Intel)
  - Technology licensed by ASE, STATS ChipPAC, NANIUM
  - Production lines at STATS ChipPAC and NANIUM today are wafers, panel in future



Source: Infineon



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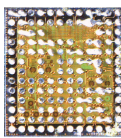
Fan-Out WLP Applications

- Applications
  - RF
  - Baseband processor
  - Potential for memory, PMIC, Application Processor, ASIC, controllers, media chips, medical devices, sensors
- FO-WLP shipments of hundreds of millions of units each year
  - Infineon (now Intel's IMC division) wireless products
  - Others

Intel Wireless Division
LTE analog baseband
5.32 x 5.04 x 0.7mm eWLB
127 balls, 0.4mm pitch



Source: TPSS

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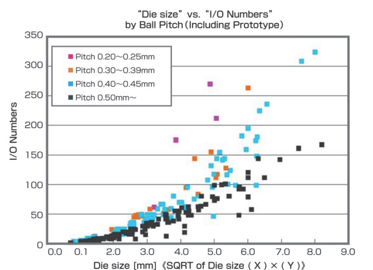
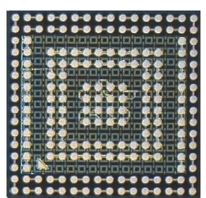
FO-WLP: Drivers

- Smaller form factor, lower profile package: similar to conventional WLP in profile
- Increased I/O density
  - Originally marketed as an alternative to fine pitch fan-in WLP
- Thinner than flip chip package (no substrate)
  - Comparing to FC-CSP
- Excellent electrical and thermal performance
- Excellent high temperature warpage performance
- Fine L/S (10/10µm)
- Can enable a low-profile PoP solution as large as 15 mm x 15 mm
- Multiple die in a low-profile package
  - Die fabricated from different technology nodes can be assembled in one a single package
- Multi layer RDL with FO-WLP
  - Higher routing level with more lines and traces
  - Shield and power dissipation needs
  - Enabler of further form factor reduction



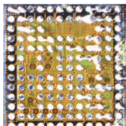
Source: Casio Micronics



Source: IMC

Fan-Out WLP

- Fan-out WLP thinner profile
- Improved performance
- Both 0.5mm pitch and 0.4mm pitch parts in production



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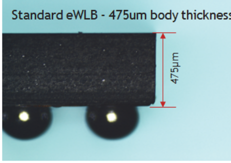

- In HVM

- Achieved by conventional back-grinding process
- Thinner profile results in more compliant structure
- Better BLR, DT & TCoB performance

Source: STATS ChipPAC

Enabling Growth of FO-WLP

- Applications
  - Wireless products today, but what about future?
  - Future automotive, medical, etc.
- FO-WLP shipments of 616 million units in 2012
  - Infineon (now IMC) wireless products
  - Spreadtrum announced adoption in Jan. 2013 for China market
  - Others
- Need plenty of suppliers with lots of capacity for large companies
- Reliability
  - Some companies have strict reliability JEDEC TCB (-55° C to 125° C) with no dielectric cracking
- Future growth requires cost reduction
  - Panel process?
  - Lower cost materials?
  - Future test?

Conclusions

- Mobile world continues to drive…
  - Volumes
  - Package trends
  - Technology development
- Thin products are driving thin package solutions
  - Must meet steep ramp with high volume
- Trend in WLP for mobile devices
  - Conventional WLP
  - FO-WLP
- Adoption of new technology
  - Cost/performance trade-off
  - Test considerations
  - Established infrastructure