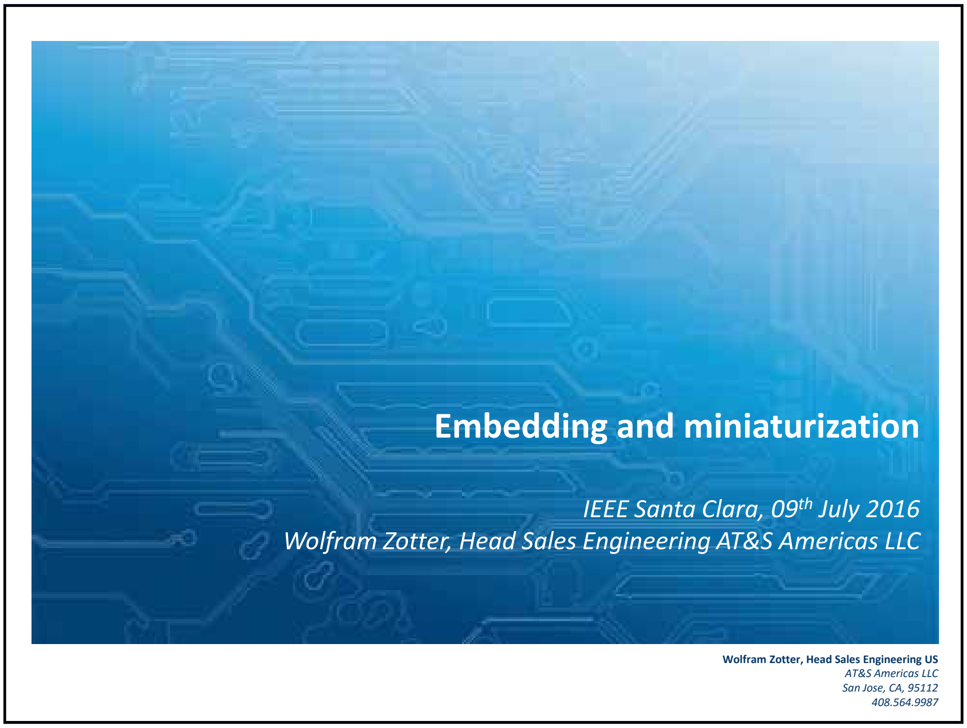
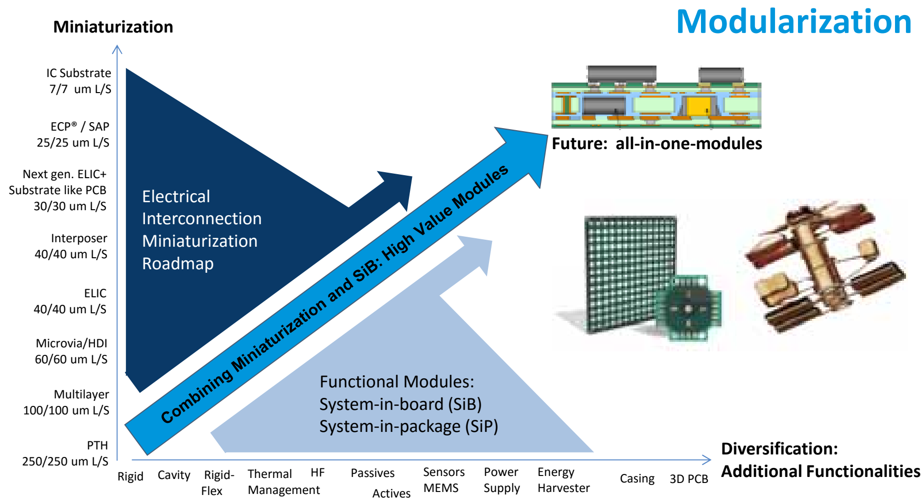

Embedding and miniaturization
IEEE Santa Clara, 09th July 2016
Wolfram Zotter, Head Sales Engineering AT&S Americas LLC
Wolfram Zotter, Head Sales Engineering US
AT&S Americas LLC
San Jose, CA, 95112
408.564.9987


AT&S
Megatrends
till 2030
2030: 59% of global
population will live in cities
Healthy living: Health is not
only contrast of sickness
INDIVIDUALISATION
SILVER SOCIETY
2020: 50 Billion things
connected to the internet
2030: Population 8,3 Billion
INTERNET of
THINGS
HEALTH
Autonomous Driving
Energy Efficiency

Interconnection technology trends



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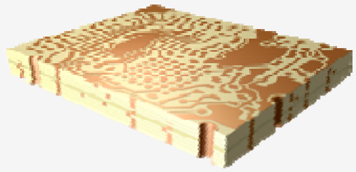
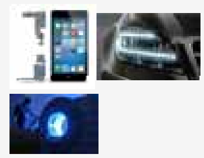
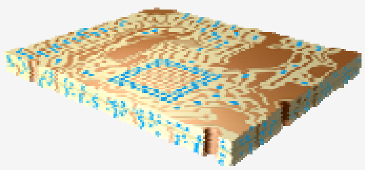
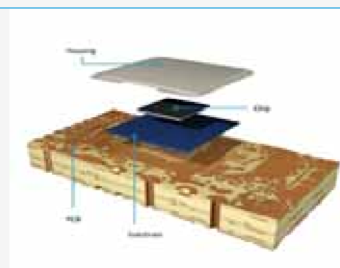
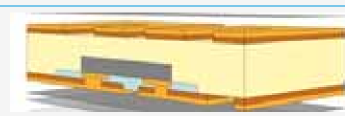
- Embedding future

What the organic world has to offer (1/2)…

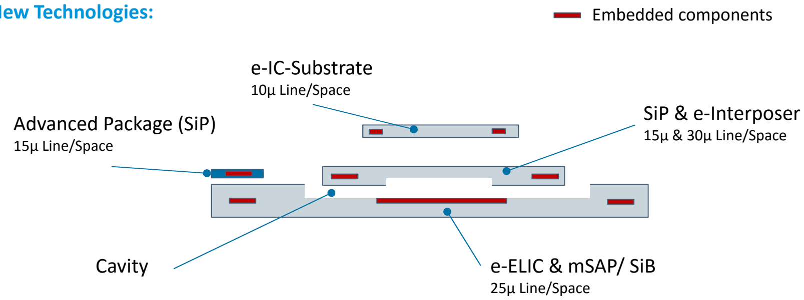
	General Description & Technology	Application Areas	Markets
Standard & HDI PCBs	 PCBs are the interconnection platform for electric, electronic & mechanical components (such as resistors , capacitors, IC's, connectors; etc.) Density: Line/ Space > 35 micron	 Computer, Consumer, Communication, Automotive Industrial, Medical	OEM´s Tier 1 Tier 2
SiP / modules	 Substrate-like PCBs are the next evolution of high-end HDI PCBs with higher density: Line/Space 20-30micron	 Wearables and applications of the "Internet of Things"	OEM's Tier 1 Tier 2

What the organic world has to offer (2/2)…

	General Description & Technology	Application Areas	Markets
IC substrates	 IC substrates serve as interconnection platform with higher density (Line/Space < 15 micron) between semiconductors (Chips) & PCBs	 High-end processors for Computer, Communication, Automotive, Industrial	OEM's Semiconductor Industry
Embedding	 Embedded Component Packaging allows to embed active/passive components (e.g. wafer level dies) within the layers of a PCB – contributes to miniaturization	Power Electronics, e.g. for Automotive, Industrial	OEM's Semiconductor Industry

Various possibilities

New Technologies:

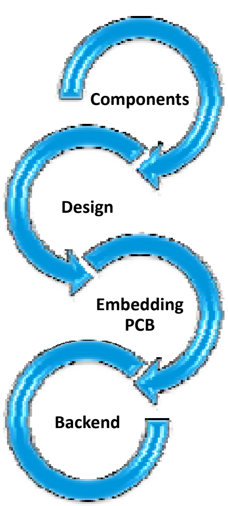


Existing technologies:

PTH / Multilayer / HDI / ELIC / FPC

The combination of new and existing technologies will offer new solutions
Embedding is one of the key enabler
Clear interfaces to the existing supply chain is a prerequisite

Embedding environment

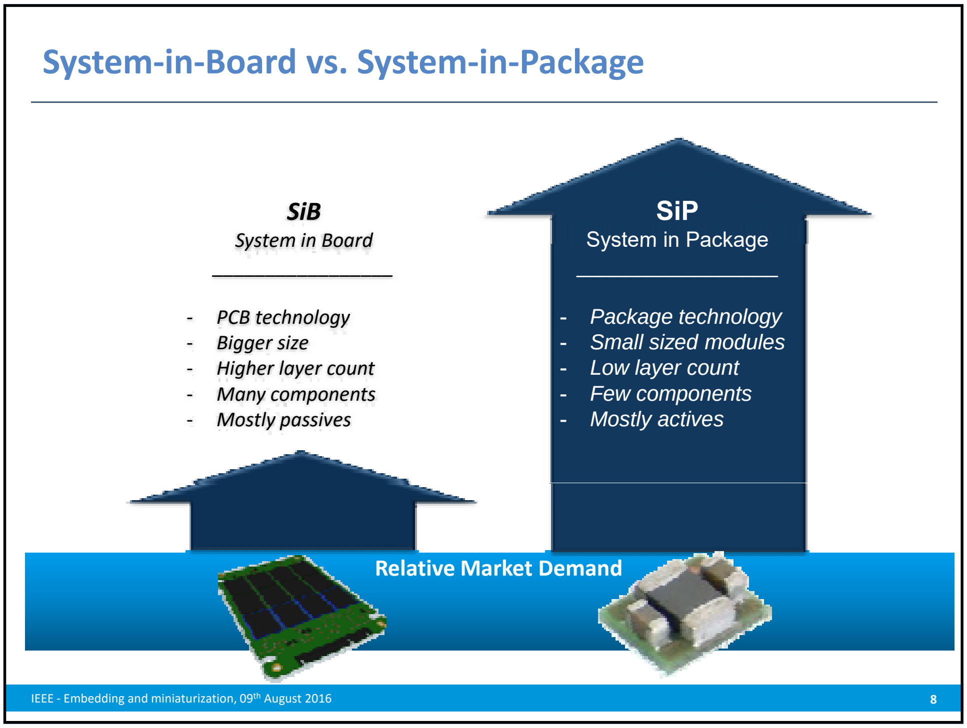


passive component suppliers as well as semiconductor companies do already offer support for embedding-friendly components

Main design platforms already support embedding components as existing features...
- Mentor Graphics Expedition 7.9.x
- Cadence Allegro 16.6
- Zuken CR 5000

Established vendor base to embed components into Organic substrates / materials.

OSATs and others to finalize and finish modules incl. embedded components


System-in-Board vs. System-in-Package
SiB
System in Board
- PCB technology
- Bigger size
- Higher layer count
- Many components
- Mostly passives
SiP
System in Package
- Package technology
- Small sized modules
- Low layer count
- Few components
- Mostly actives
Relative Market Demand
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Reasons for embedding…

Trends and challenges in electronics

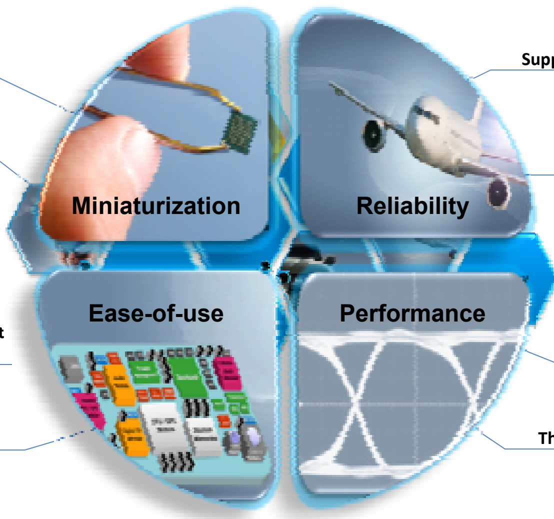
More functions

Smaller devices

Short cycles design-to-market

Increased component population

Fragile components



Supply chain complexity

Increased cost of high-end IC design

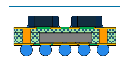
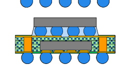
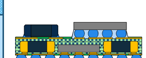
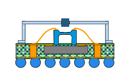
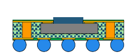
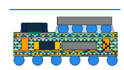
Less power

Intelligent mechanical devices

Thermal management

Miniaturization broken down…

Feature	Application	X,Y Reduction	Embedded Component advantage
Power	Voltage Convertor	40%	Smallest footprint – integrated module – fully tested solution
	Charge Management	40%	Stacked package for advanced Li-ion battery charge management
Media & Wireless	Media Codec	30%	Integrated module – discrete passives stacked on eWLP
	Mobile TV	50%	Single device solution for mobile TV tuner
	NFC module	40%	Stacked package for smallest footprint solution
MEMS & Sensor	MEMS µphone	50%	Superior performance MEMS µphone / pressure sensor with smallest form factor
	Identification	New feature	Integrated biometric sensing
	Position sensor	50%	High accuracy Hall effect sensor – advanced micro joystick application
Shielding	Sensitive devices	50%	Implementation of shielding using the laminate package instead of metal can

Wearable miniaturization vs. technology

Based on a standard wrist-band wearable product a breakdown on possible miniaturization technologies comparing the PROs/CONs against each other

		HDI standard technology	HDI + SemiFlex (1 bend region)	HDI + SemiFlex (2 bend regions)	HDI Rigid-Flex	HDI + Embedding
PCB Dimensions [mm]		100%	110%	116%	110%	about 55 – 75%
No. PCB's per Prod. Panel		100%	90%	90%	86%	153%
Cost Reduction	Assembly	No	No	No	No	Yes
Form Factor Improvement	Curved Display	No	Yes	Yes	Yes	Yes
	Wrist Band	No	No	No	No	Yes
Supply Chain Reduction		No	No	No	No	Yes
Design complexity		Low	Med	Med	Med	High
Option to add functionality		Med	Med	Med	Med	High

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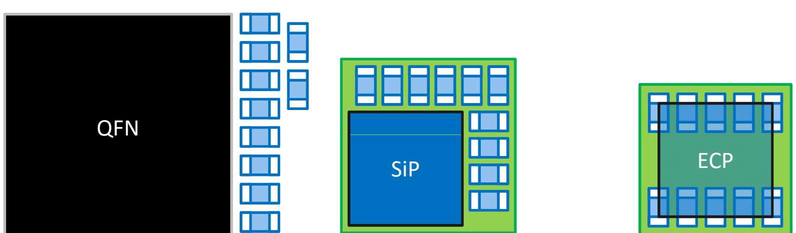
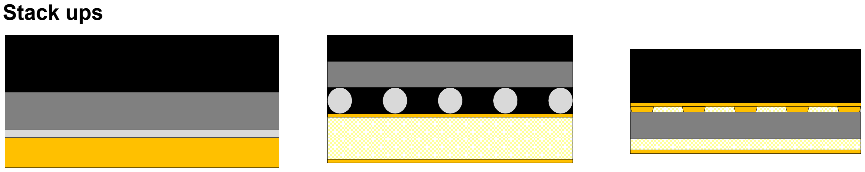
Architecture comparison



QFN	SiP	ECP
Die @ 3*3 mm Passives @ 0402 Component distance @ 250 µm	Die @ 3*3 mm Passives @ 0402 Component distance @ 200 µm	Die @ 3*3 mm Passives @ 0402 Component distance @ 250 µm
Surface @ 45 mm²	**Surface @ 21 mm²**	**Surface @ 16 mm²**

Stack ups



T-resistance: 0,35 K/W | **T-resistance: 21,81 K/W** | **T-resistance: 7,61 K/W**

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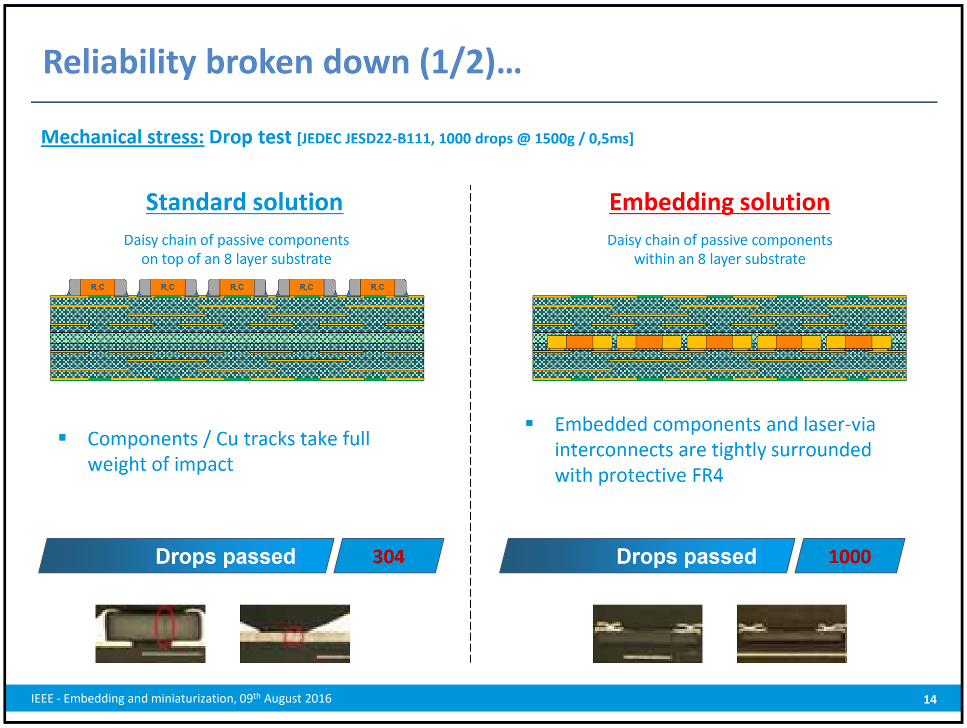
Reliability broken down (1/2)…
Mechanical stress: Drop test [JEDEC JESD22-B111, 1000 drops @ 1500g / 0,5ms]
Standard solution
Daisy chain of passive components
on top of an 8 layer substrate
R,C
Components / Cu tracks take full weight of impact
Drops passed
304
Embedding solution
Daisy chain of passive components
within an 8 layer substrate
Embedded components and laser-via interconnects are tightly surrounded with protective FR4
Drops passed
1000
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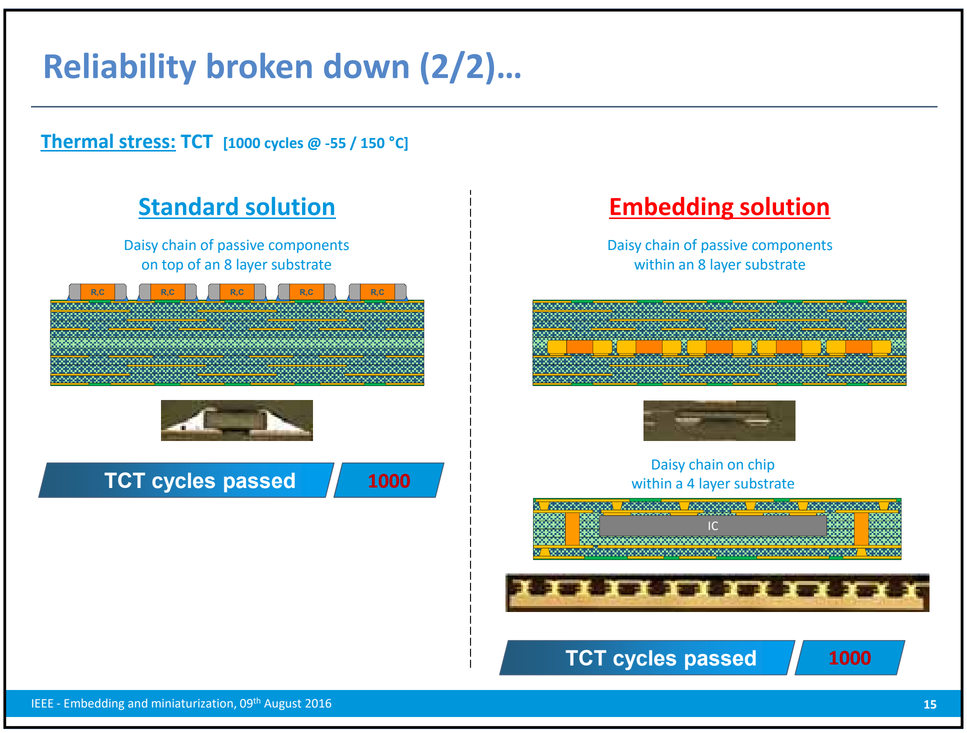
Reliability broken down (2/2)…
Thermal stress: TCT [1000 cycles @ -55 / 150 °C]
Standard solution
Daisy chain of passive components
on top of an 8 layer substrate
R,C
TCT cycles passed
1000
Embedding solution
Daisy chain of passive components
within an 8 layer substrate
Daisy chain on chip
within a 4 layer substrate
IC
TCT cycles passed
1000
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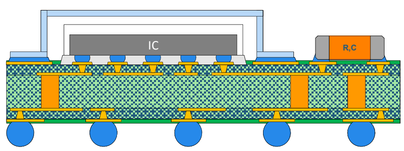
Performance broken down…

Example: EMI-shielded module

Standard solution

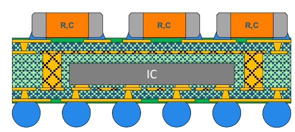
- Solder joints
  (less conductivity & more parasitic)
- Long path to other components
  (side-by-side components)
- No shielding
  (external shielding necessary increase of cost and z-dimension)



Embedding solution

- Cu-plated microvias
  (better conductivity & less parasitic)
- Short path to other components
  (stacked components)
- Intrinsic shielding
  (shielding by ground layers and edge plating / via stitching)

EMI with ECP® | **- 20dB**

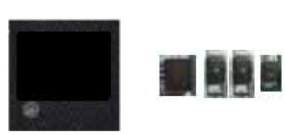


"Ease-of-use" broken down…

Example: Mobile TV tuner

Standard solution

- Components on PCB: **5**
- Solder pads on PCB: **44**
- Footprint on PCB: **29 mm²**



Embedding solution

- Components on PCB: **1**
- Solder pads on PCB: **28**
- Footprint on PCB: **16 mm²**

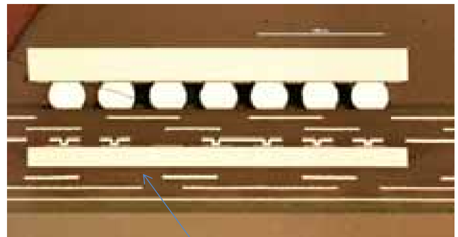
Components in BOM	**- 80%**
Solder pads	**- 36%**
Footprint	**- 45%**

Embedding visuals…

X-section of embedded devices

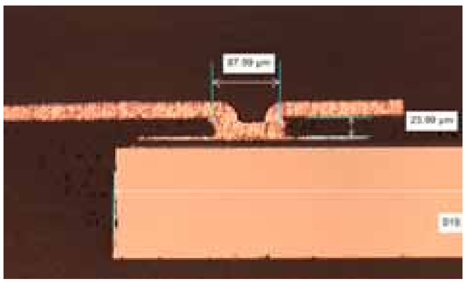
Surface mount CSP

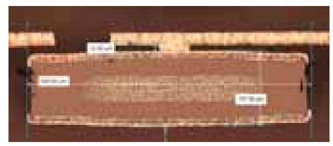
PCB with embedded IC



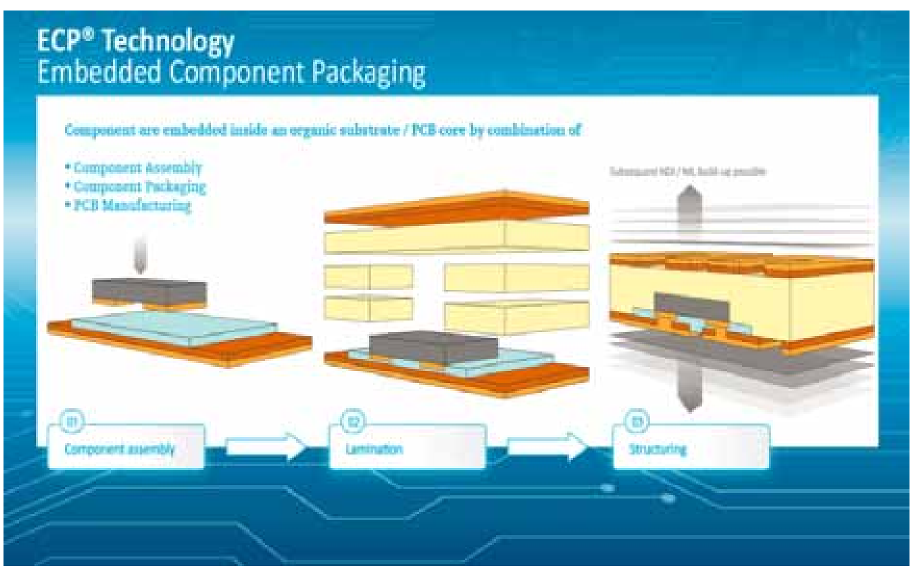
Embedded IC

For interconnection, same technology and processes as for HDI/microvia PCBs!

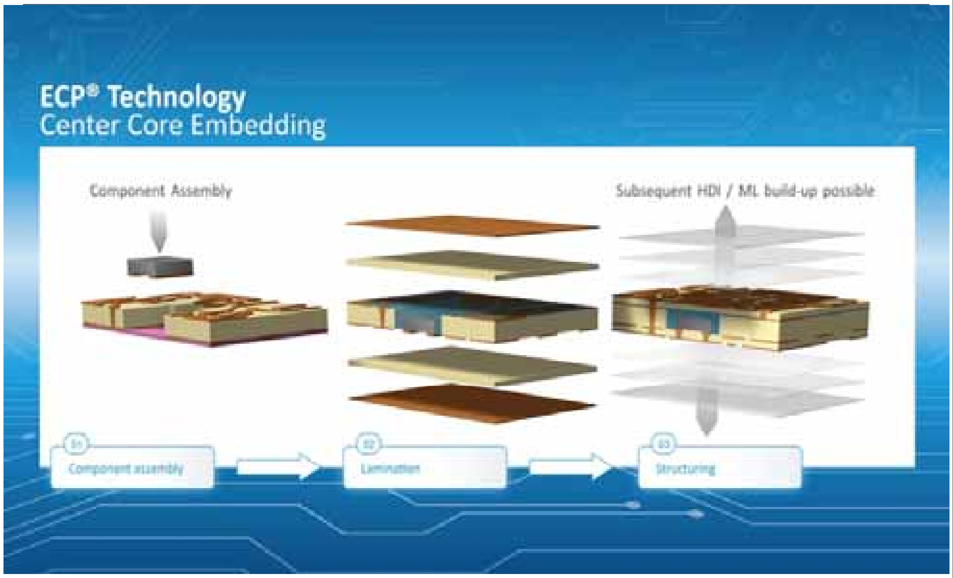




Fundamental embedding approach #1



Fundamental embedding approach #2



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Standard embedding components

- **Active components**
  - Discrete Semiconductors
    - Diodes
    - FETs
    - IPDs
    - …
  - Integrated circuits
    - Customized ASICs
    - Microcontrollers
    - RFID…

- **Passive components**
  - Resistors
  - Capacitors
  - Varistors
  - Thermistors
  - Inductors
  - …

Specification Outline

- CSP type with **copper** termination
- Thinned to 150µm or below
- Delivery in Tape and Reel

- Termination surface must be **copper**
- Low profile (150µm preferred)
- 0402 or 0201 (inch)
- Delivery in Tape and Reel (preferred)

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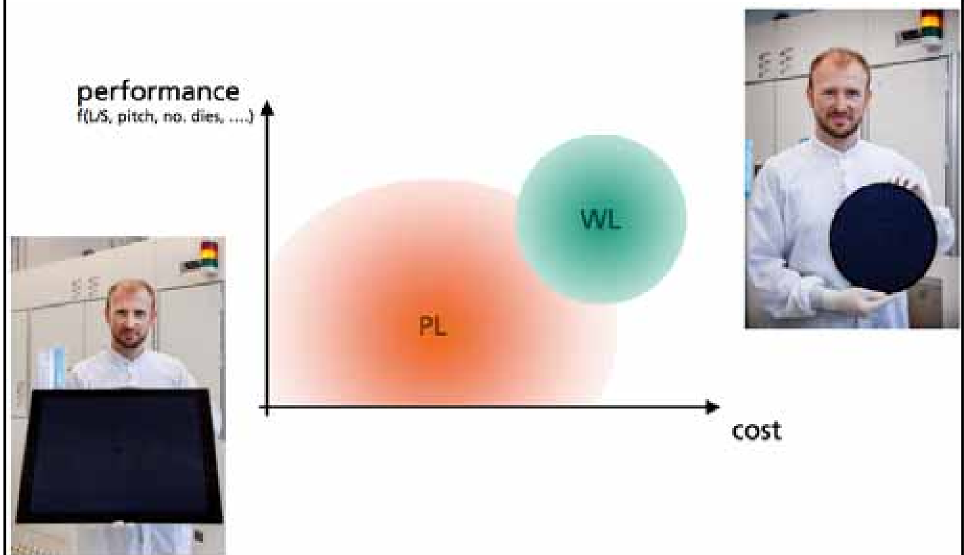
Panel-level vs. wafer-level packaging

Fraunhofer IZM



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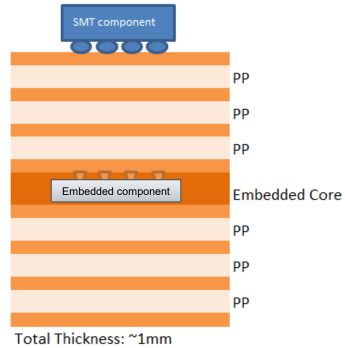
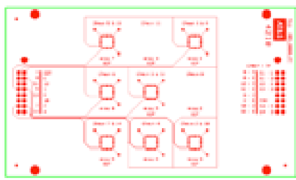
Reliability test-vehicle, details

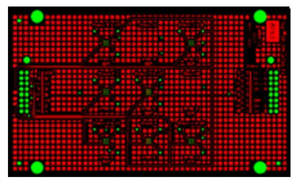
Total test vehicle configuration…

- 8 layer ELIC technology
- Total target thickness of 1.00mm
- Standard FR4 material (no specific resin type)
- Board size of 77 x 132mm
- Passive & Active test vehicle
- Grid of 3x3 test circuits (2 blank areas)
- Test circuits setup as embedding only / embedding + SMD / SMD only
- Daisy chain structures used





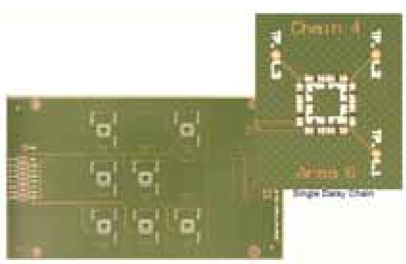
Passive test-vehicle



Active test-vehicle

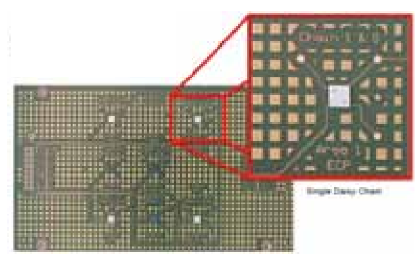
Reliability test-vehicle, details

Passive test-vehicle



- 112 components in total
- 8 components per daisy chain
- Components used:
  - 0402 (inch) 10 Ohm thick film resistor
  - Embedded version 150µm thick
  - SMD version: same supplier, standard version with tin termination and standard thickness

Active test-vehicle



- 7 components in total
- Components used:
  - 3x3 mm Si based daisy chain
  - 49 IOs
  - Embedded version 165µm thick
  - SMD version: same supplier WL – CSP, 550µm incl. solder balls

Reliability test-vehicle, methods and parameters

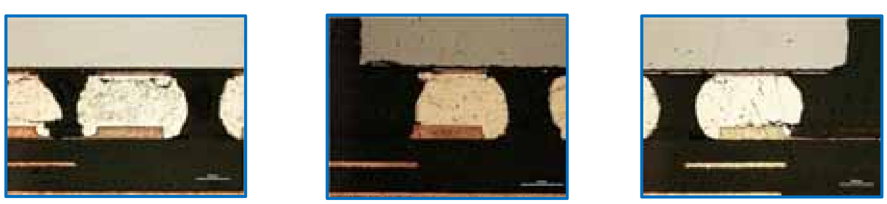
Test	Method	Analysis method	Remark	Results
Reflow Sensitivity	IPC/JEDEC J-STD-020D.1	Visual and x-section inspection for delamination	MSL 3, 3x reflow 260° Peak before assembly	Passed, w/o failures
Thermal Cycle Test (TCT)	JESD22_A104	Online resistance change	-55/+125, 500 cycles	Failures on SMD only
High Temp Storage (HTS)	JESD22_A103	Online resistance change	125° for 1000 hours	Failures on SMD only
Drop Test	JESD22_B111	Online resistance change	1500g, 1000 drops	Failures detected
Monotonic Bend Test	JEDEC 9702	Online resistance change	2mm/min	Failures on SMD only

- Boards have been tested with flying probe before and after SMT (Open/Short test)
- Samples for reflow sensitivity have gone through Open/Short test before and after the test
- Bend test only done on Active test-vehicle

Reliability test-vehicle, Thermal cycle test results

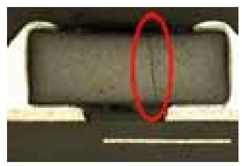
- Passive test-vehicle: - No failures detected
- Active test-vehicle: - 9 out of 70 SMD Daisy Chains failed
  - Remaining SMD passed 1000 cycles
  - First failures at 684 cycles
  - All embedded structures passed 1000 cycle

- Typical failure pictures (Corner balls)



Reliability test-vehicle, Drop test results

- Passive test-vehicle:
  - 17/18 boards showed failures on SMD structures
  - Earliest failure at 304 drops
  - 1 embedded Daisy Chain structure showed a failure at 832 drops
  - Remaining embedded structures passed 1000 drops
- Active test-vehicle:
  - 4 out of 70 SMD Daisy Chains showed failures
  - Earliest failure at 792 drops
  - All embedded structures passed 1000 drops
- Typical failure pictures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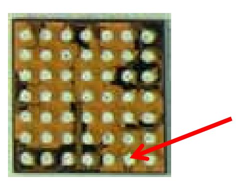
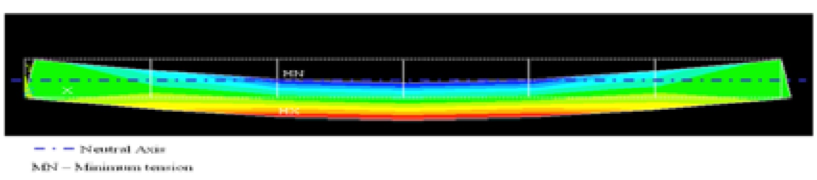
Reliability test-vehicle, Bend test results

- Active test-vehicle:
  - 1 out of 18 SMD Daisy Chains showed a failure
  - All embedded structures passed the test
- Typical failure pictures



- Blue and red represent highest rate of compression and tension respectively
- SMD components are more subject to these forces
- Green indicates where the EC's are located; i.e. along the neutral axis

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Other specific Embedding test results

Application specific test-vehicles used with variety of active components / daisy chains…

Test	Specification	Result
Thermal cycling	-55°c / +150°C	1000 cycles passed (TC Grade 1)
Temperature / Humidity	85°C / 85%RH	1000 hours passed (TH Group A)
Board bending	5 mm/s	80k bends passed
Random vibration	3 g (rms) [5-500] Hz	30 min per axis passed
Shock	10k g @ 0,2ms	3 per direction passed
Reflow sensitivity	Pb-free profile (255°C)	30 cycles passed
HAST	110°C @ 85%RH @ 5VDC	264 hours passed
Drop test	1500g @ 0,5ms	10 drops passed (MS Group F)
High temperature storage	@ 125°C	1000 hours passed (TH Grade 2)
Moisture Sensitivity Level	Peak @ 260 °C	Minimum MSL 3

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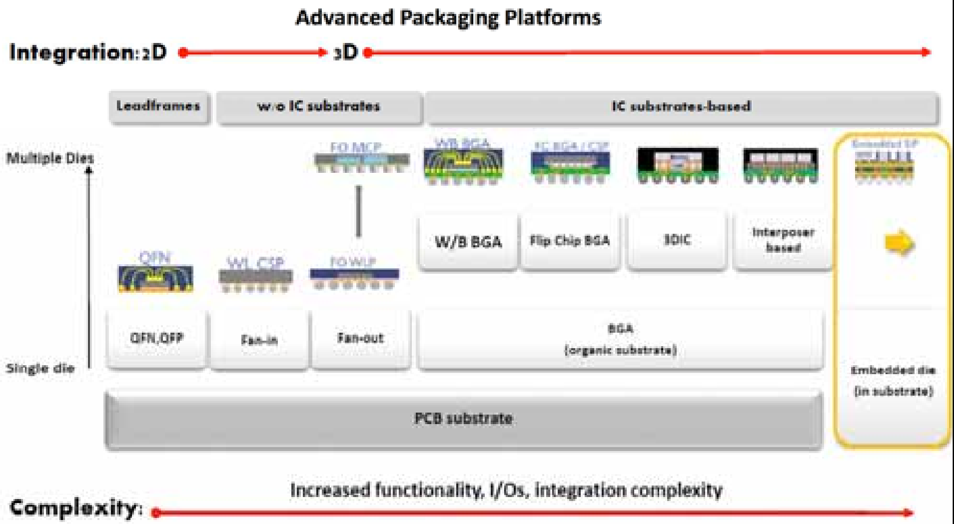
Packaging options breakdown…

Yole Développement released 2016



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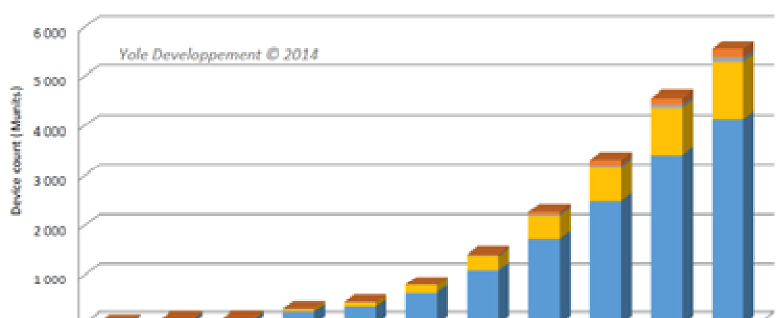
Embedding unit vs. market outlook

Embedded die unit shipment forecast

Breakdown by application area (Munits)



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Automotive	0	0	0	0	4	8	29	46	100	137	167
Medical	0	0	0	3	5	10	19	32	50	73	95
Consumer	6	17	19	57	88	158	287	457	665	938	1 140
Mobile - Wireless	25	70	77	241	352	635	1 100	1 748	2 512	3 428	4 160

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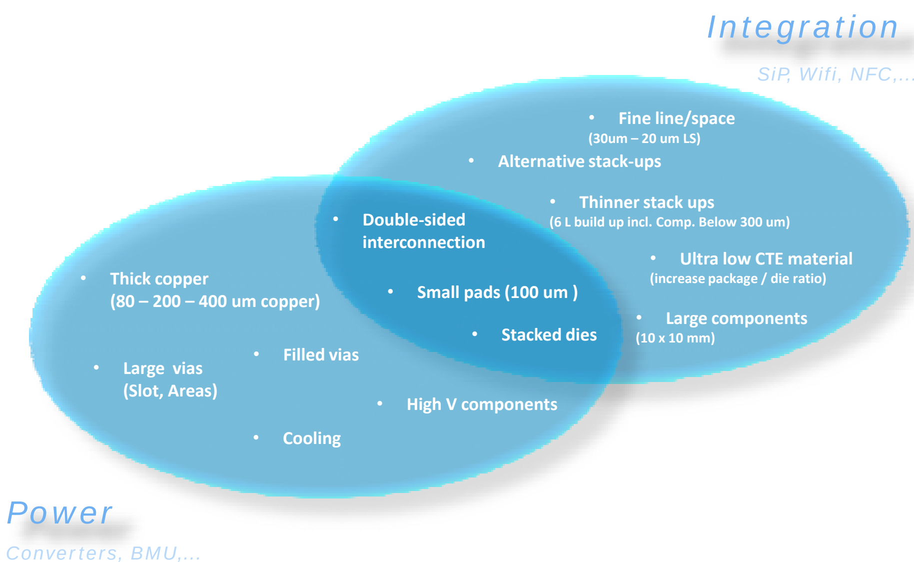
Market needs divided by applications



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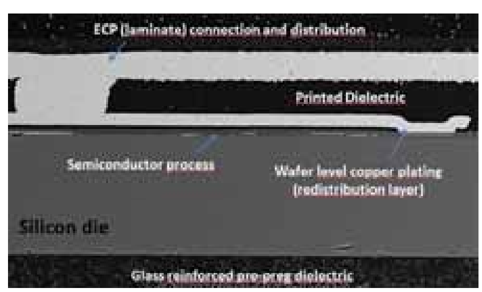
Embedding conclusions

- Technology driven by module approach
- No clear reliability specifications but PCB based tests show embedding technology supremacy
- Market needs are driving technology
- Supply chain models extremely flexible
- Resources and prerequisites setup and available
- Technology is proven
- Various markets are making a move



“Everything new seems crazy until it isn’t”

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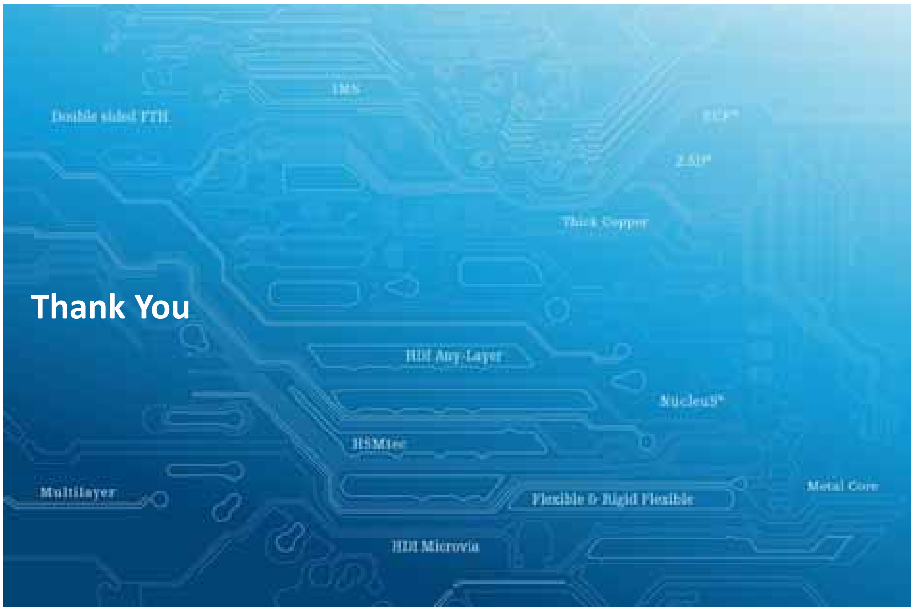
Thank You



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