ASE GROUP

Technology Diversity Rules the MEMS Packaging Landscape

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ASEEU TECHNOLOGY

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Outline

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1. Overview of ASE Group
2. Overview of MEMS/Sensor Market
3. ASE MEMS/Sensor Packaging
4. Evolution of Wafer Level Packaging (WLP)
5. ASE MEMS WLP Toolbox
6. Summary

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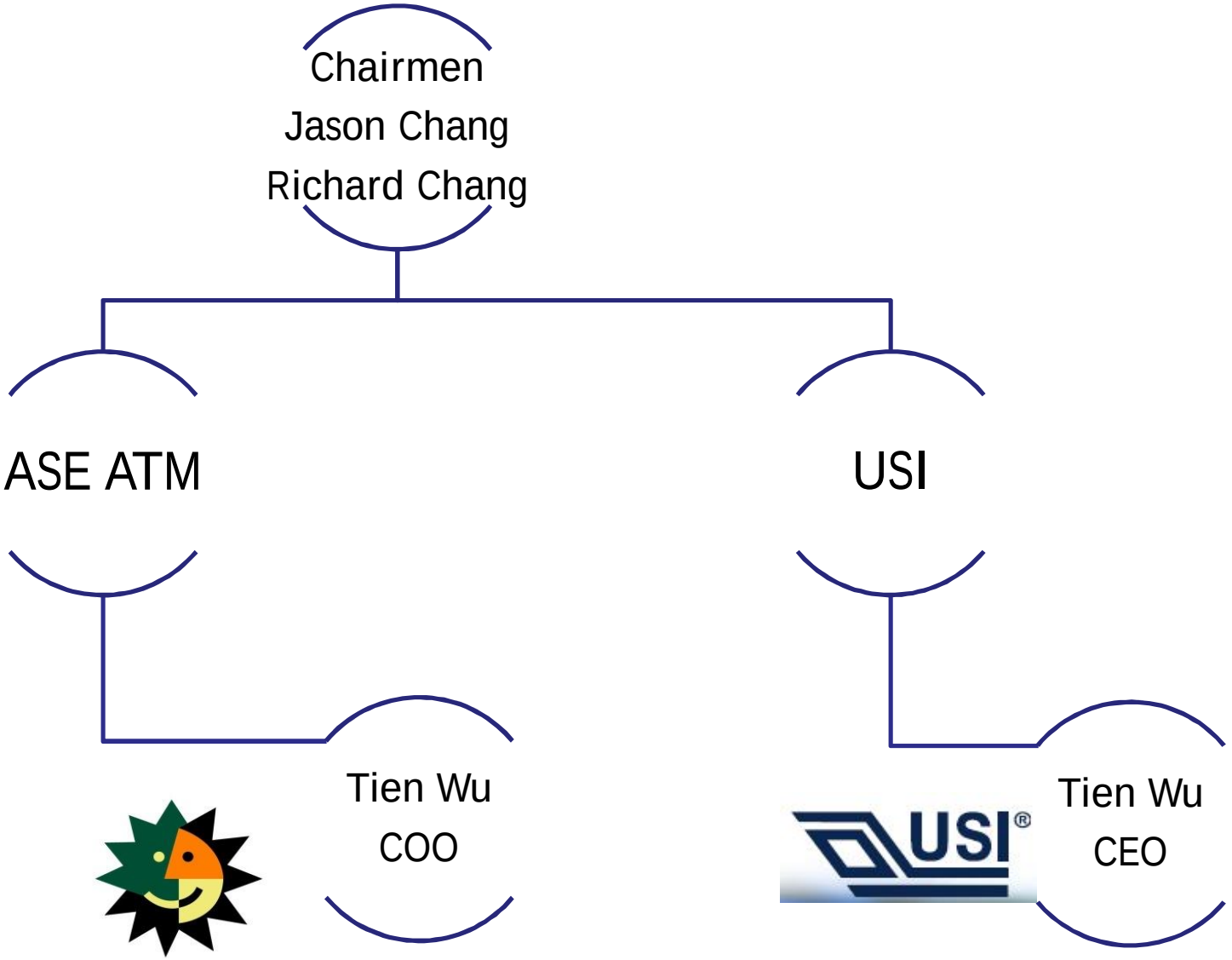
ASE Group: Business Units



2012 revenues:	**$4.4B**	**$2.1B**
2013 revenues:	**$4.84B (10%)**	**$2.7B**

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ASE Group: MEMS & Sensor Packaging


Suzhou, China (ASEN)


Shanghai, China (Material)


Shanghai, China (A&T)


Kunshan, China


Penang, Malaysia

ASE Worldwide Locations

Kummersbruck, Germany
Wateloo, Belgium
Vienna, Austria
Yokohama, Japan
Shanghai, China
Hsinchu, Taiwan
San Jose / Santa Clara, CA
Irvine, CA
San Diego, CA
Tempe, Arizona
Austin, Texas
Boston, Massachusetts
Hillsboroug, NC


ChungLi, Taiwan


Kaohsiung, Taiwan


ASE Weihai, China


Paju, Korea


Takahata, Japan

ISE Labs
Fremont, California
Austin, Texas


Singapore

Sites with MEMS & Sensor packaging capabilities

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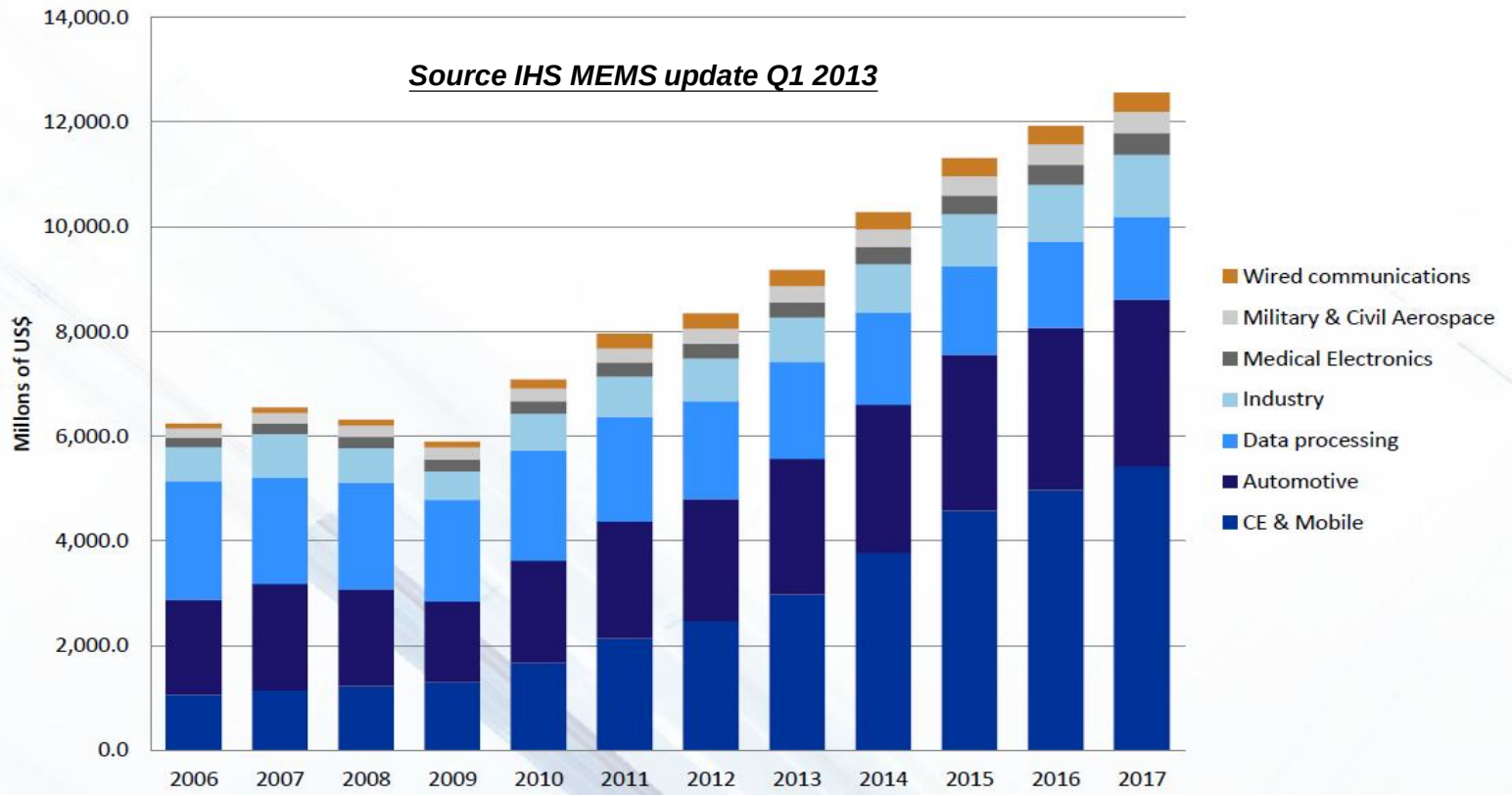
MEMS Market: The Big Picture



- MEMS assembly and test: 1.1B$ in 2012 ➔ 1.7B$ by 2016
- In 2012, the backend assembly & test outsource is ~35%
  ➔ Emerging fabless design houses + outsourcing by IDMs
- MEMS & sensor packaging market is highly fragmented

Growing segments:

Mobile is booming:

- more functionalities
- high volume
- lower cost
- smaller size

Automotive:

- safety and driver assistance functions are well established
- large deployment from high end to standards cars
- new needs: car infotainment/car management
- need volume & quality

Medical:

- new big opportunity
- new challenges for packaging: bio-compatibility, size, self powered devices, etc...

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MEMS Are Everywhere

Automotive:
MEMS & Sensors have drastically improved
Safety (active or passive):
- Collision avoidance
- Accident prevention
- Severity reduction

Infotainment, environment: environmental control (atmosphere, temperature, light, etc..), navigation, etc..
The intelligent vehicle is almost there!

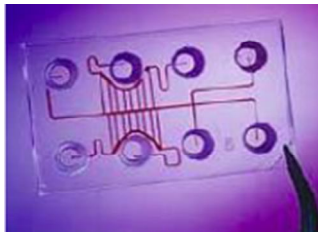
Courtesy of Electronics-lab

Next big move?
MEMS SiP modules to enable active communication between worlds...
Human machine Interface – Internet of things

Medical:
MEMS & Sensors are going to help us to stay healthy and improve treatments quality :
Need for autonomous / communicating Sensors / MEMS

Communicating Systems

NTT demo at MWC 2012
Courtesy of Analog device



Mobile / Tablet:
MEMS are everywhere in mobile: motion, environmental, light & display management
Many devices are burgeoning: gas, radiation, etc...

Courtesy of Schneider Electric

MEMS & Sensors for M2M and Home Automation:
Environment monitoring, security, active regulation, etc...
New needs for autonomous & self powered radio capable sensor/actuator

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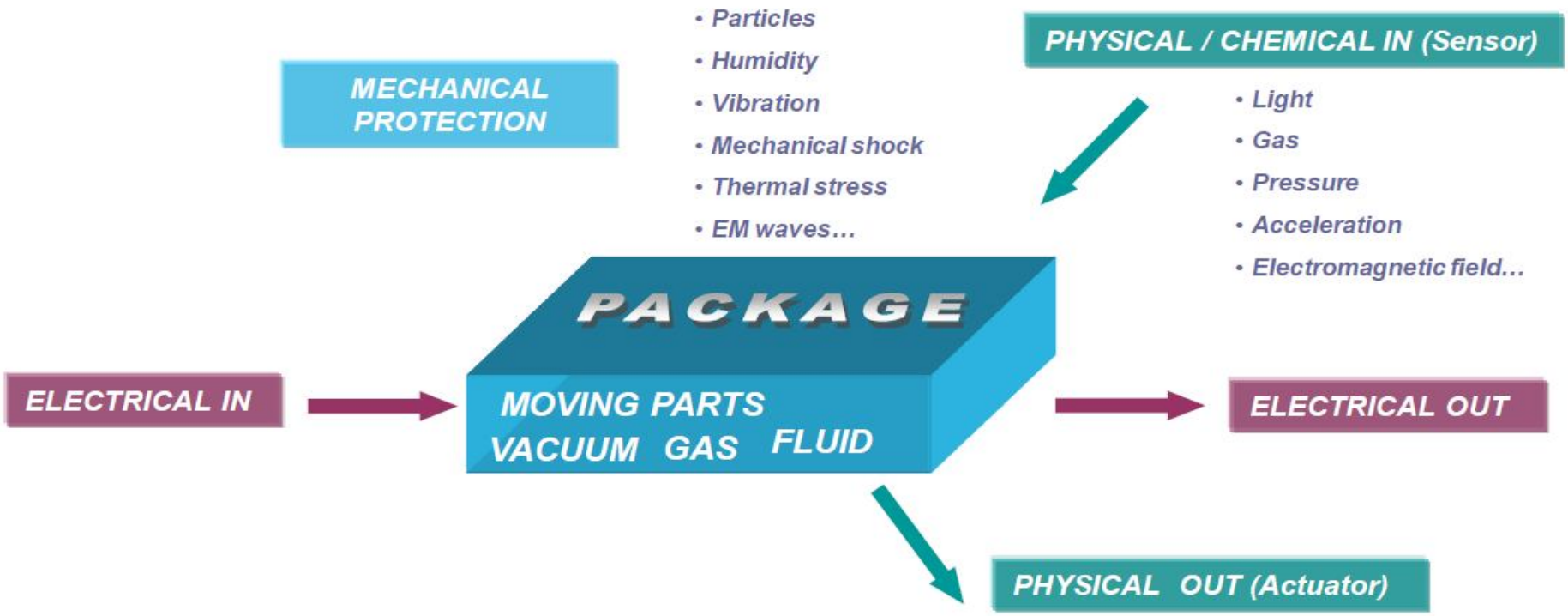
MEMS & Sensor Packaging: Challenges



- MEMS & sensor packaging requires specific and complex packages (per application) leading to increased cost
- How to reduce cost and offer standardization: manage specificity at wafer level (collective process) and offer standardized operations (Tool box)

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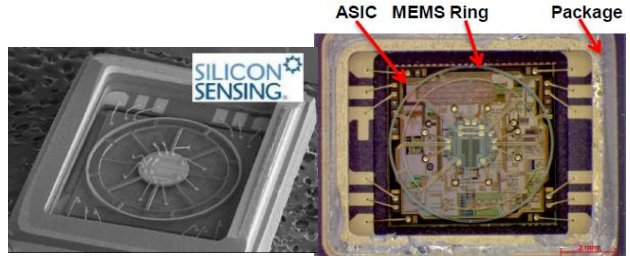
MEMS packaging requirements

High performance – key functional requirements (hermeticity, vacuum, etc…)
1 MEMS = 1 device = process = 1 package still apply



Single axis gyrometer in an hermetic cavity ceramic package (courtesy of Yole)

Market segments: cost and performance

Higher performance

Complex and custom architecture – complex stacking, multiple dice

Specific 1st level capping depending on functionality

Dedicated / customized BOM

BOM standardization – new solution for stress decoupling

New low cost solution for cavity/holed package (film assist, new lid)

Lower cost

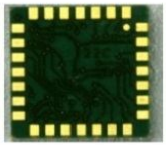
Open substrate platforms

Wafer level package – 3D integration

Price, size, low consumption pressure

Functional requirement, high quality / reliability

- ✓ Military, Aerospace
- ✓ Medical
- ✓ Industrial
- ✓ High-end custom
- ✓ Home automatio
- ✓ Automotive



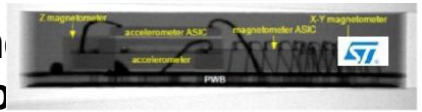
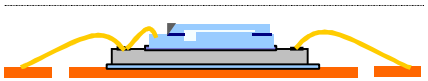
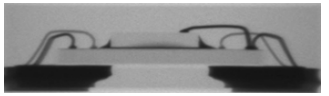


Figure 2.1.5 Bottom Edge View of Package X-Ray
LSM303DLH Package X ray. Courtesy of Chipworks

- ✓ Gaming
- ✓ Consumer



Leadframe



COL(Chip On Lead)

Laminate

Gel Coat

Low cost - Large volume enabling, dual sourcing
High need for standardization and extends to medium performance devices

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Packaging Technology: A Key Success in MEMS

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- MEMS proliferation: delicate balance between performance and cost
- New products through novel MEMS design, fab technology and innovative packaging
- Package - device interaction: packaging is even more important for MEMS
  - Impact on performance
  - Impact on product cost
- Use common semiconductor packages with some level of customization:
  - Stress decoupling
  - First level of packaging (direct contact with acting elements)
  - Assembly interconnect
- Introduce new building blocks (TSV, wafer scale processes) to enable innovative architectures and more functionalities in smaller footprint

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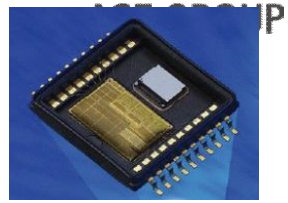
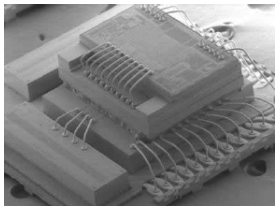
ASE – MEMS & Sensors Experience

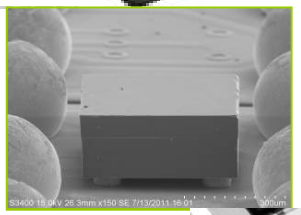
- **Established production experience:**
  - Since 1993: Pre molded open cavity packages (cavity SO, cavity LGA, custom LF) for Pressure sensor, Humidity/Temp Sensor, Gyro sensor…
  - Since 1996: Overmolded packages (QFN, LGA, BGA, SOIC, SiP) for Motion sensor (Accelerometer, Gyro, Magnetometer), FBAR, Optical Sensor, Humidity/Temp sensor, Oscillator
  - Since 2009: LGA + Lid for pressure sensor, Microphone, Humidity Sensor, Gas detection sensor, High frequency devices
  - Since 2010: Chip to Wafer WLCSP for Oscillator, Accelerometer, Magnetometer, RF tuner…
  - Since 2012: cavity molded package Suitable for Humidity/Temp sensor, Gas detection sensor, Proximity sensor, Optical sensor …
  - Since 2013: production of full WLP MEMS with TSVs in HVM

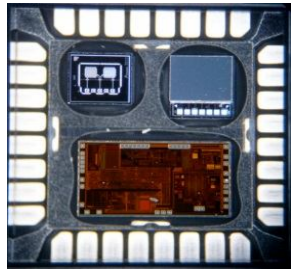
Several sites working on MEMS & sensor packaging (ASEKR, ASECL, ASEK, ASEM)



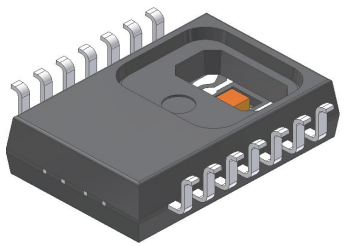


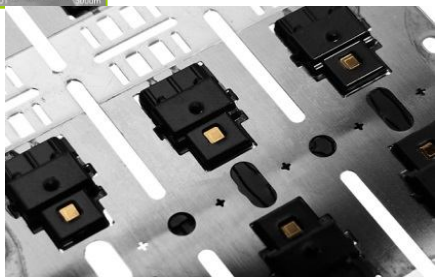
5 dies in LGA 3x3





Pre-mold QFN TPMS





Pressure sensor with FAM (courtesy of Boschman)

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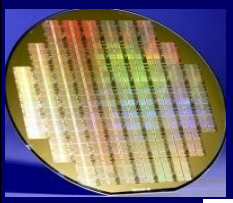
ASE MEMS & Sensor Packaging "Platform" Offering

Premold



BG & Wafer Saw

Premold

Die Attach

Wire Bond

Gel Fill

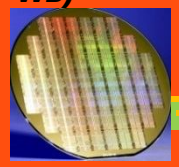
Lid Attach

Marking, T/F/S

SOIC, QFN, LGA, custom LF

OVM package

(Multi die SiP: Repeat DB & WB)



Substrate

BG & Wafer Saw

ASIC

ASIC

1st Die Attach

MEMS

ASIC

2nd Die Attach

MEMS

ASIC

Wire Bond

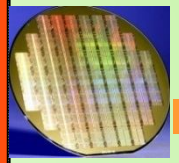
MEMS

ASIC

Mold, Marking, singulation

SOIC, QFN, LGA, BGA, SiP

Cavity mold



LF or LGA

BG & Wafer Saw

Substrate

sensor die

sensor die

LF or LGA

Die Attach

sensor die

LF or LGA

Wire Bond

sensor die

LF or LGA

Mold/PMC

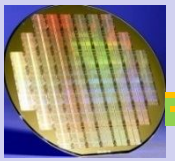
sensor die

LF or LGA

Marking, singulation

QFN, LGA, BGA

Lid package



Substrate

BG & Wafer Saw

ASIC

ASIC

1st Die Attach

MEMS

ASIC

2nd Die Attach

MEMS

ASIC

Wire Bond

MEMS

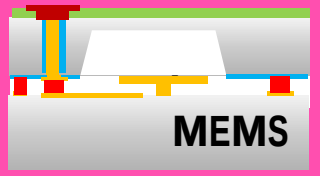
ASIC

Lid placement, attach & bake

LGA, BGA

WLP MEMS

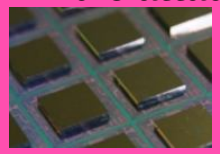
TSV last manufacturing



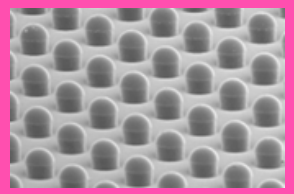
TSV middle & First process

Wafer bonding

C2W die attach



RDL and bumping



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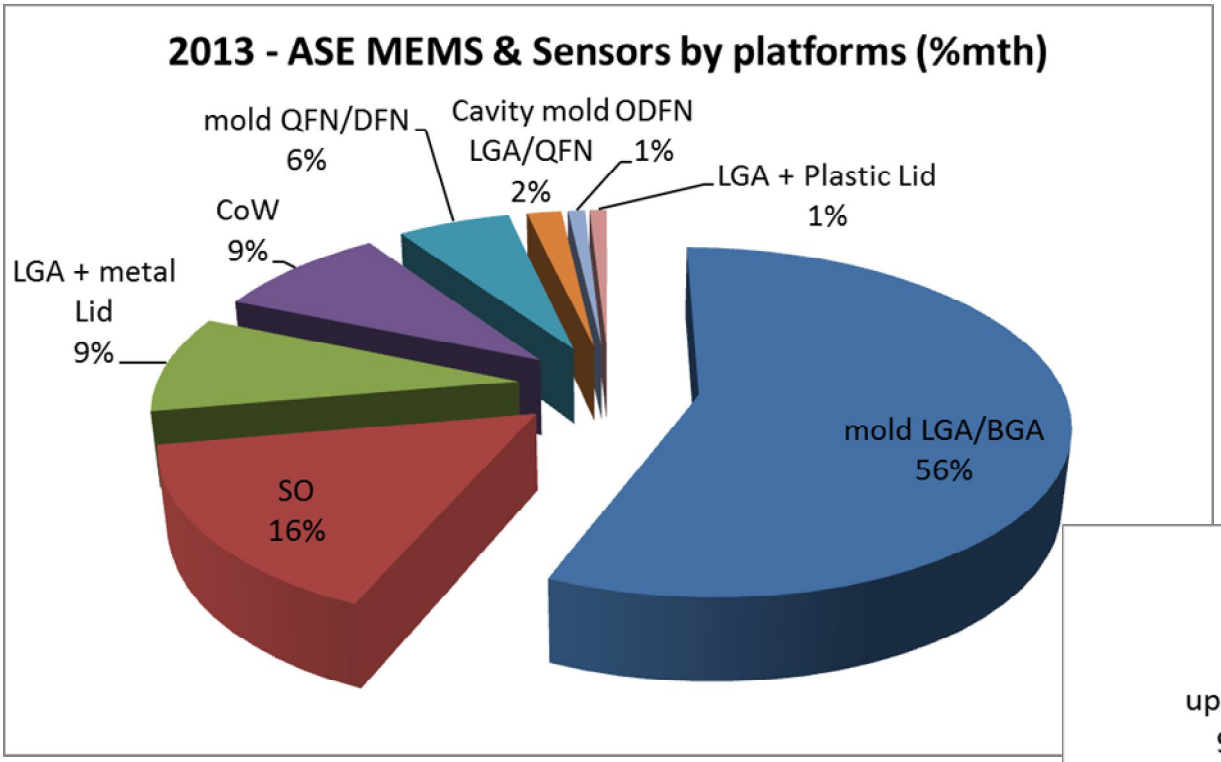
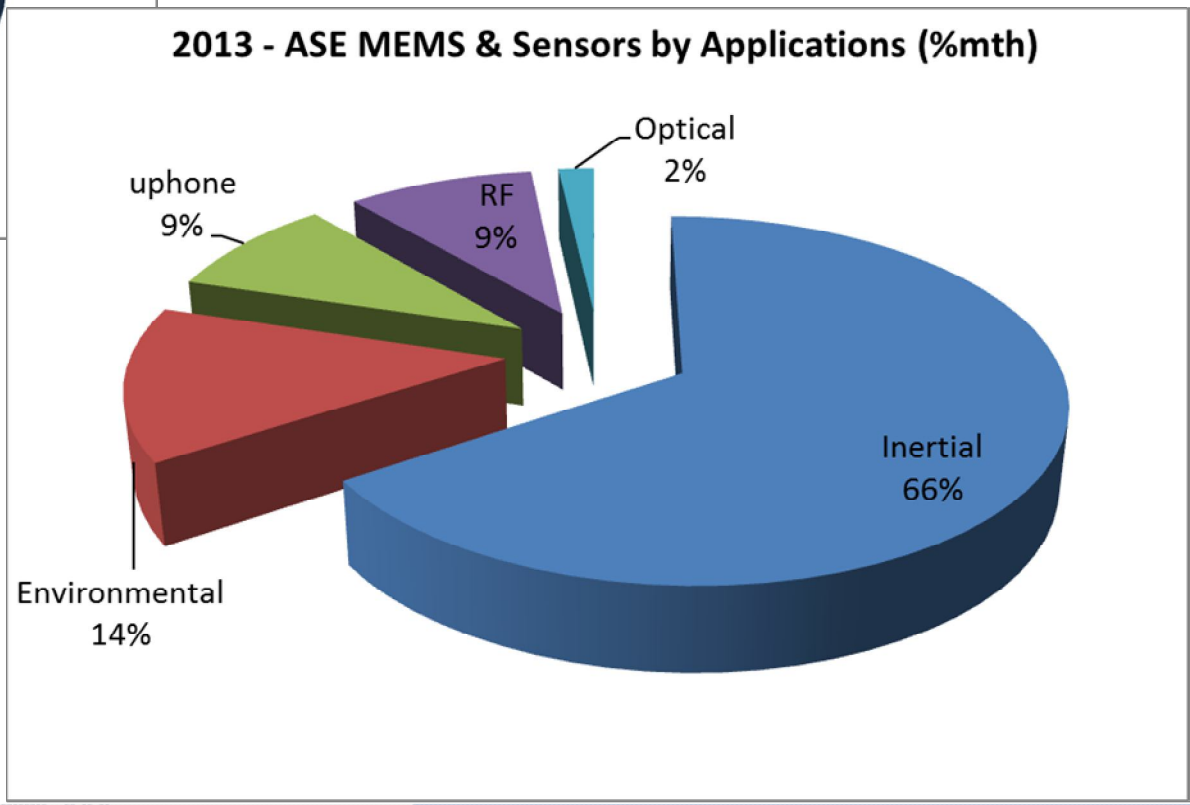
ASE Production Experience



% of volume (in Munits)



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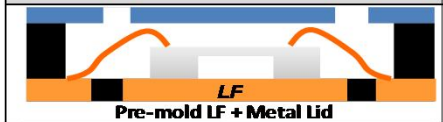
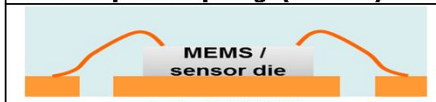
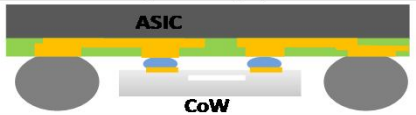
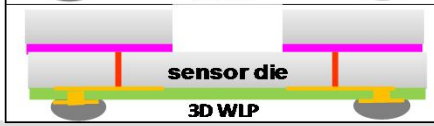
ASE Production Experience

Factory	ASEK	ASECL	ASEKr	ASEM
Platforms				
 Pre-mold LF + Metal Lid		**Available** **QFN/DFN + Metal Lid** No MP, Qualif for TPMS QFN 7x7, Feasibility for QFN 4X4 pressure sensor	**Available** **Condigned pre-mold pkge (SOIC, etc...)** MP: xxMu/mth (accelero, gyroscope, Pressure sensor, etc...)	**Available** **BGA/LGA** Metal Lid & glass No MP
 Pre-mold DFN/QFN + Plastic Lid		**Available, QFN/DFN** No MP *Qualif for gas sensor*		
 Overmolded package (QFN, LGA...)	**Available** **Starting HVM on LGA** Accelero & eCompass	**Available (HVM)** LGA (accelero): xxMu/mth QFN (accelero): xMu/mth	**Available (HVM)** LGA (accelero, ecompass, Gyro): xxMu/mth QFN (accelero): xMu/mth	
 Cavity ceramic LGA				**Available** No HVM for MEMS but CIS
 LGA + Metal lid		**Available, No MP** For pressure sensor & microphone	**Available, MP** µphone bottom port: xxMu/mth Available for Pressure sensor & combo: no MP	dev
 LGA + Plastic Lid		**Available** **metallized, 3D or plastic only** **MP for Optical LGA (xMu/mth)** feasibility/Qualif: µphone (3D Lid), UV & P sensor		
 Cavity molded package (LGA or LF)		**Available for QFN/DFN** no MP Qualif for TPMS	**Available, MP** DFN/QFN: xMu/mth LGA: no Prod	dev
 Optical LGA/QFN		**Available, MP** ALS xMu/mth		dev
 CoW		**Available, MP** Oscillator: ~xkwf/mth (xxMu)		
 WLCSP	**Available, MP magnetometer** Dev for temperature and gas flow sensor	**Available** **MP**		
 3D WLP	**Available** LVM (sensor and combo)			

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MEMS Packaging Evolution

- Market demand for integration of multiple MEMS devices: accelerometer, magnetometer, gyroscope & controller in the same package
- Heterogeneous integration: CMOS logic, memory, MEMS, passives, battery - are becoming key for communicative & autonomous MEMS SiP
- New requirements for safety devices are appearing – die redundancy within the same package
- There is a clear need for high functionality package solutions (multi die – stack or side-by-side, thinner, heterogeneous integration, etc...) at reasonable cost and small size
- Wafer Level Packaging, WLP with 3D interconnection (TSV, TGV), are driving integration for size reduction, better electrical connection and cost
- Standardization will come from the 3D WLP toolbox

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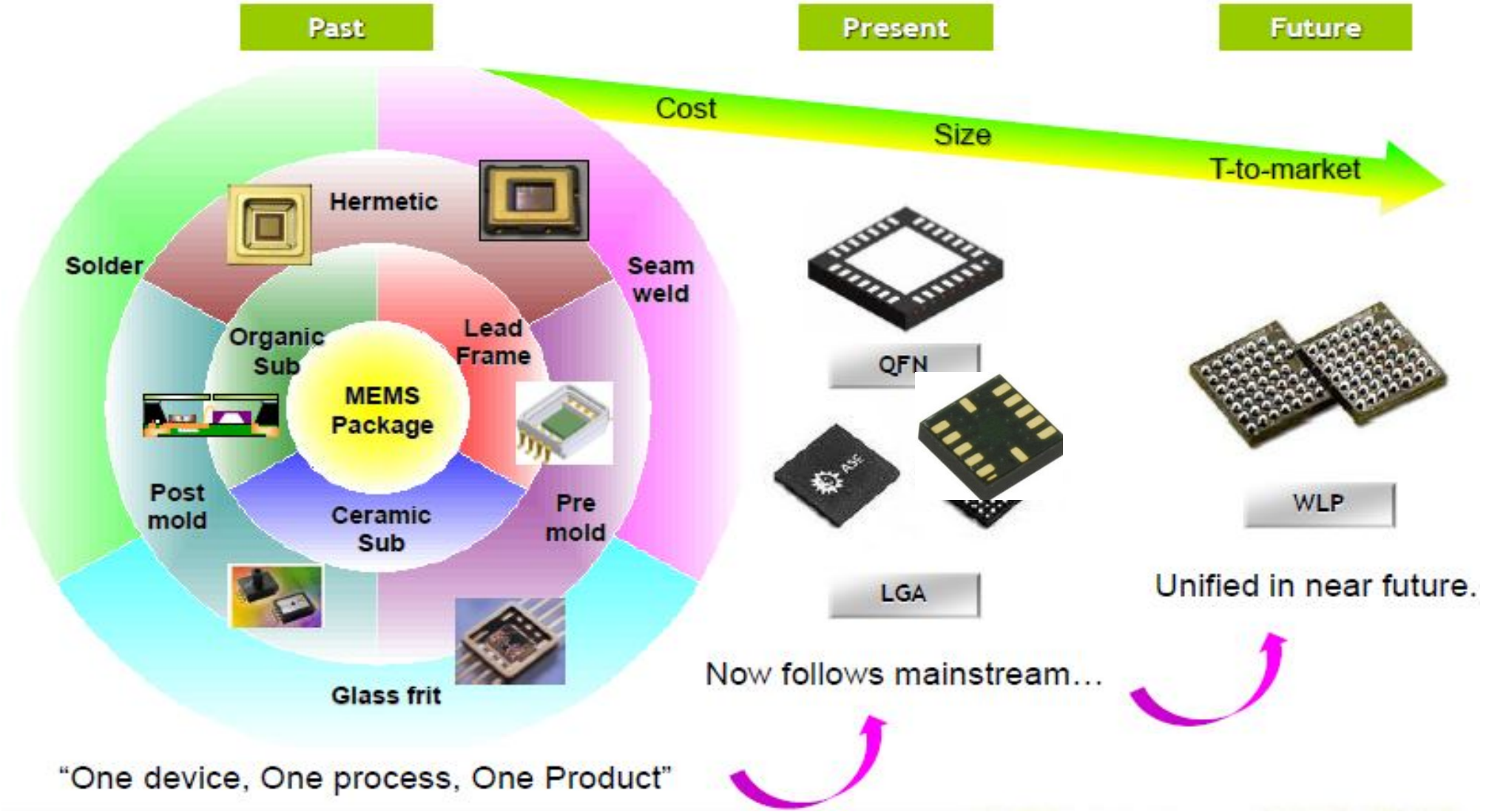
MEMS & Sensor Packaging: Challenges



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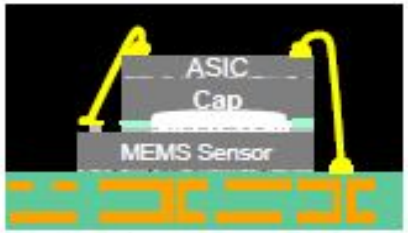
Example: Inertial MEMS Evolution

PAST…

→ Bulky form factor
→ High cost

MEMS accelerometer ceramic package
(Courtesy of MEMSIC)

PRESENT!



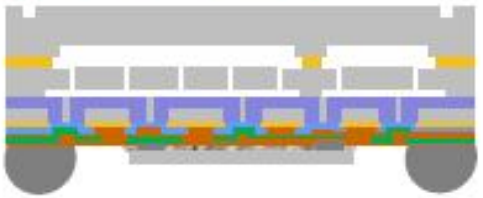
→ Reduced form factor
→ Flexible supply chain
→ Cost reduction

MEMS accelerometer plastic package with Wafer-level capping *(Courtesy of BOSCH)*

New needs:

- **Wafer level capping**
- **W2W or C2W assembly**
- **Vertical interconnection (TSV, TGV)**
- **Wafer level redistribution and balling**

FUTURE?



→ Ultimate size / cost reduction
→ Improved performance

MEMS accelerometer in 3D WLCSP package with TGV *(Courtesy of VTI / Murata)*

Courtesy of Yole Developpement

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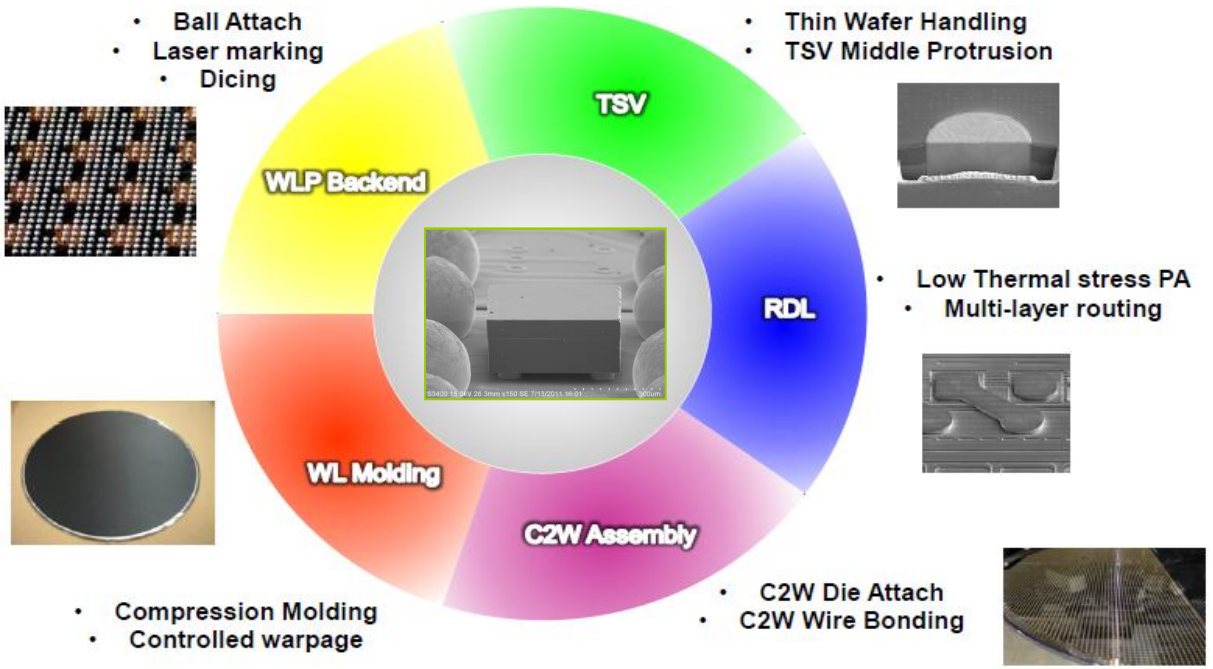
ASE MEMS & Sensor Packaging Evolution

→ *Wafer Level Packaging*

- MEMS & sensor integration requires active/sensing parts protection:
  - Growing need for Wafer Level capping either by wafer to wafer bonding or thin film wafer capping (survey at ASE)
- MEMS assembly is key:
  - Chip to chip is costly and technically limited
  - WLCSP is definitely a key advantage for size and cost reduction (e.g. magnetometer)
  - 3D WLP is the new big opportunity for size and cost reduction of complex devices
- Market demand for integration of multiple MEMS devices: accelerometer, magnetometer, gyroscope & controller in the same package
- New needs for highly integrated and compact architectures
- ASE is now offering a new 3D WLP tool box to enable compact and complex MEMS architectures



Technology needs:

- Wafer level capping
  - C2W assembly
  - Wafer molding
- Vertical interconnection (TSV)
- Wafer level redistribution and balling

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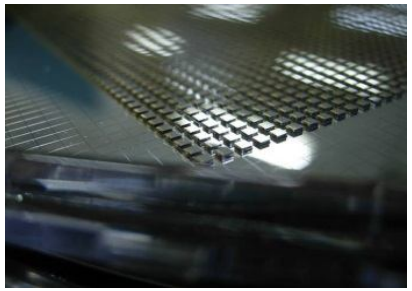
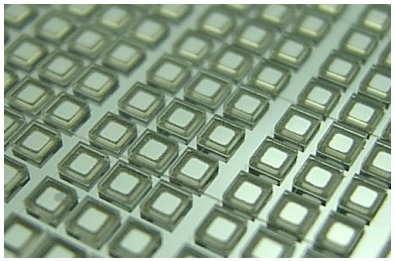
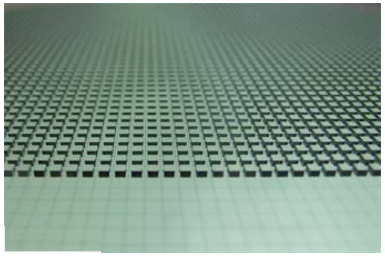
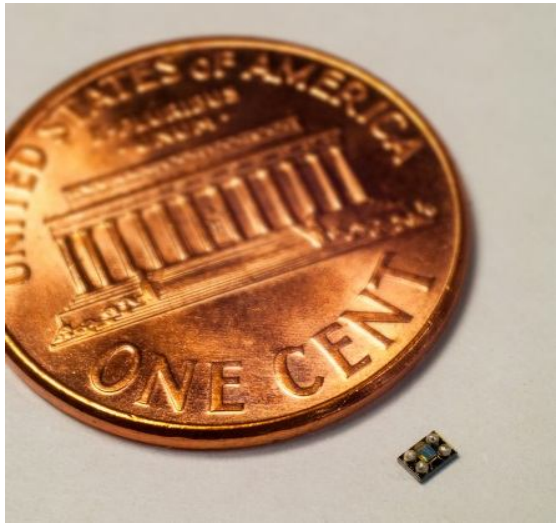
ASE Wafer Level MEMS

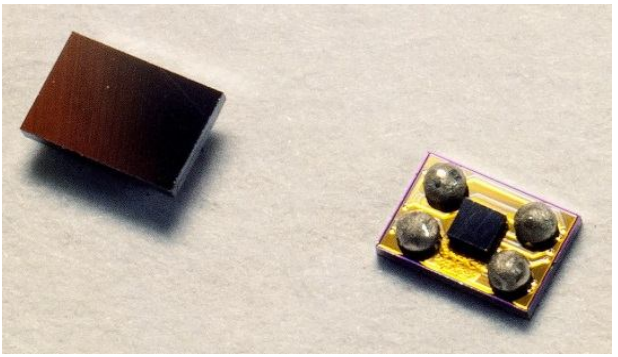
- WL MEMS as single WLCSP or as Chip to Wafer Assembly



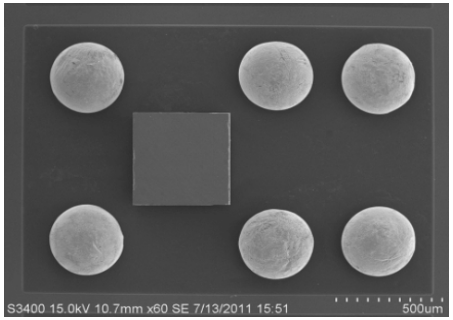


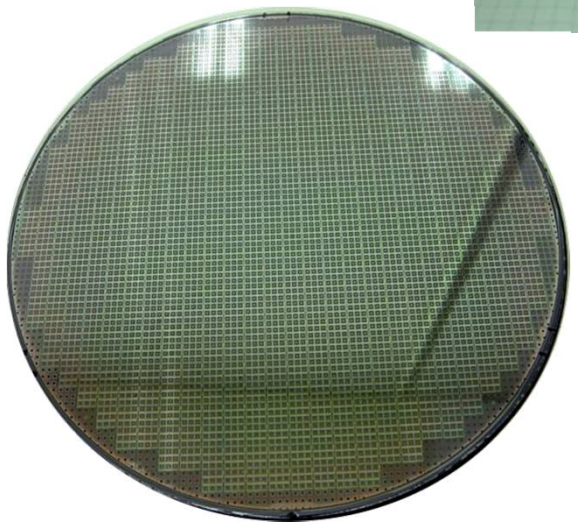


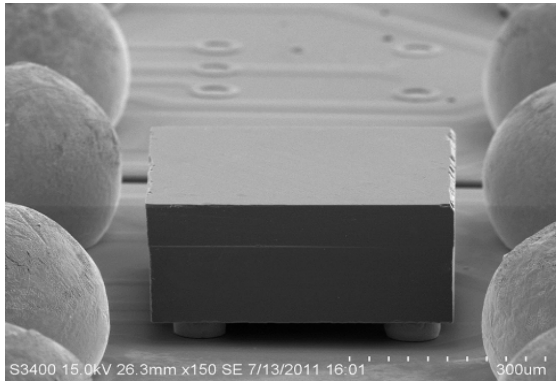


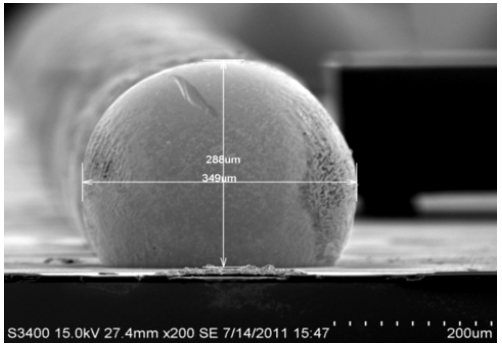


Oscillator MEMS on ASIC – C2W









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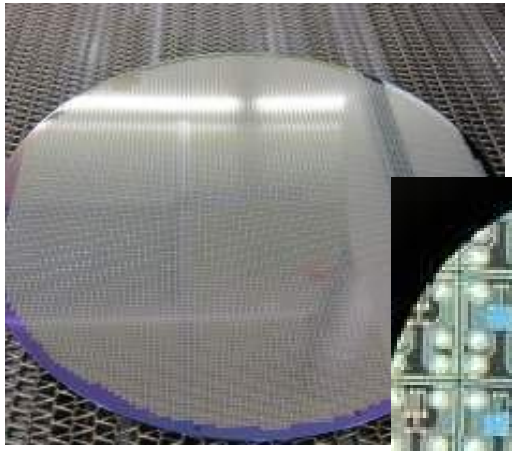
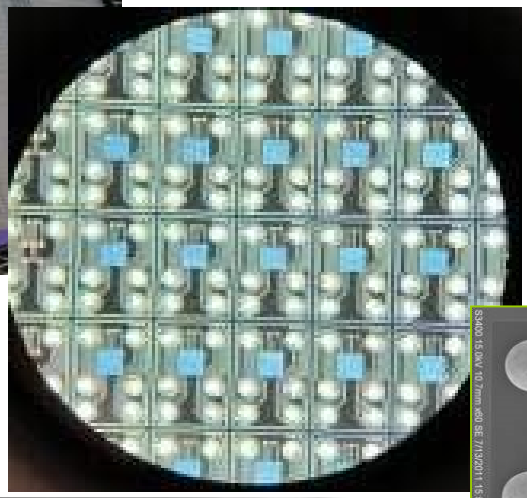
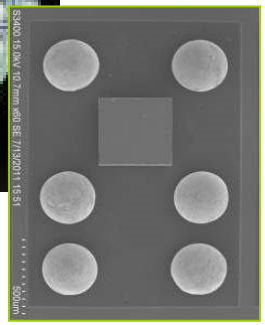
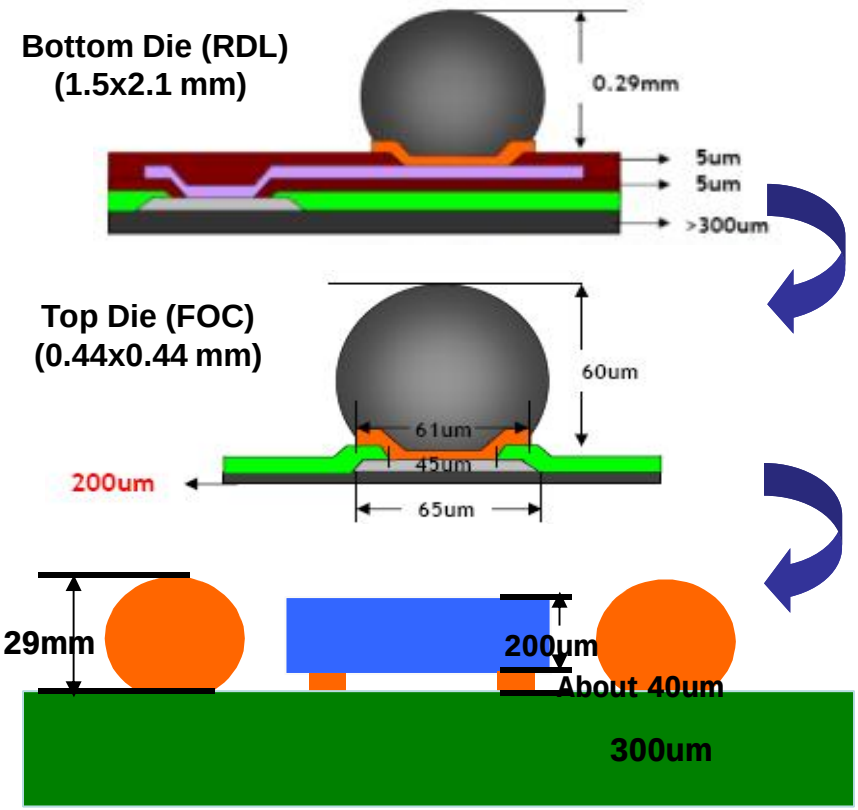
ASE MEMS – C2W WLP

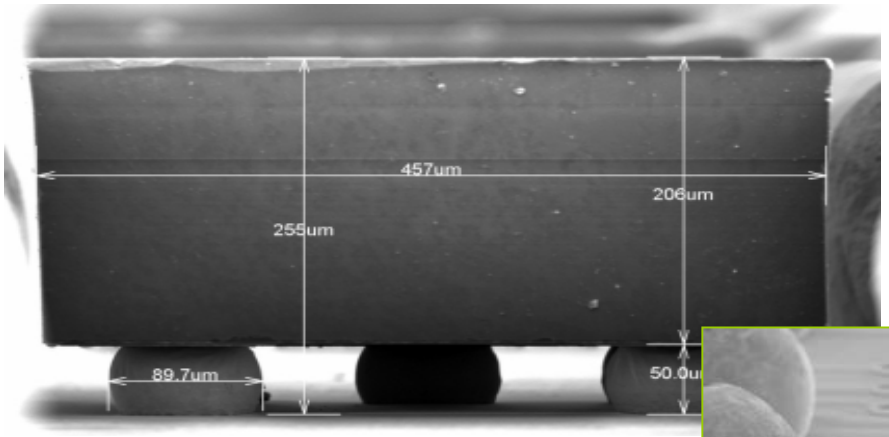
Material	Description
Die thickness	Mother die (ASIC): 300um Daughter die (MEMS) : 200um
Bump pitch (MEMS)	145 um
Bump No.	ASIC: 6 / MEMS: 5
Application	oscillator

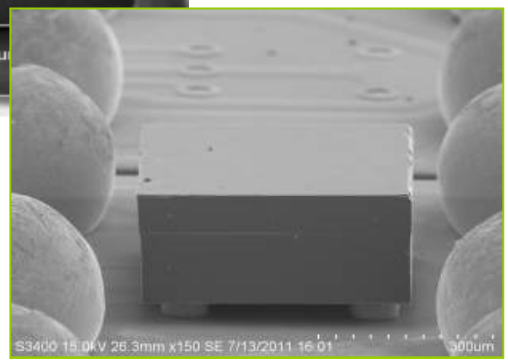












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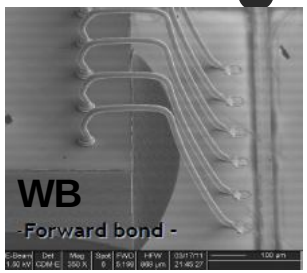
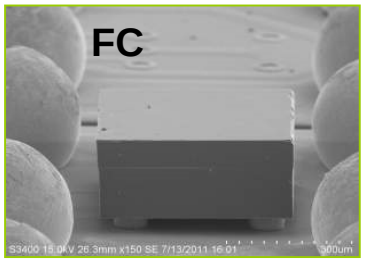
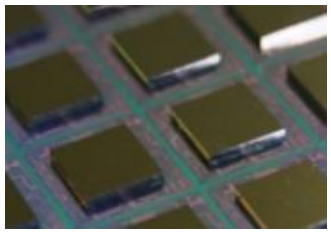
ASE MEMS & Sensor Packaging Toolbox Evolution

Die attach (MEMS or ASIC) to wafer (MEMS or ASIC):

- WB (tape attach), Au wire
- FC attach MR or TCB, solder or Cu pillar*, NCP or CUF







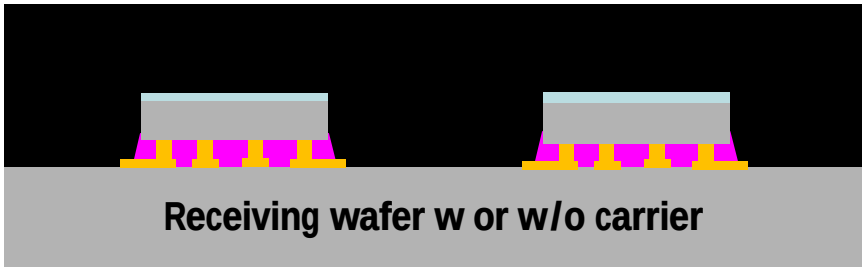
C2W

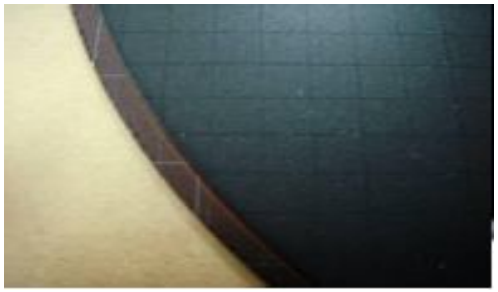
ASE 3D WLP MEMS toolbox

ASE GROUP

Wafer Level Molding:

- Wafer scale molding after either FC or WB (compression molding)

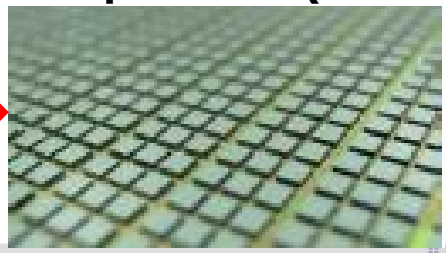


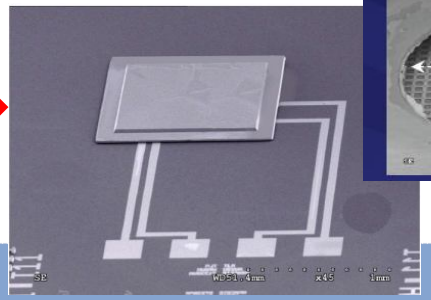


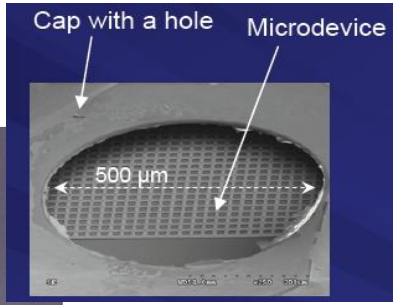
Molded wafer after die to wafer attachment

Wafer to wafer bonding (device capping):

- Top wafer: Si, Glass, active die wafer (dev)
- Bottom wafer: Si
- Bonding technology: polymer, glass frit
- On going (dev): metal bonding (solder, eutectic)
- thin film capping, wafer scale plastic lid (under survey)







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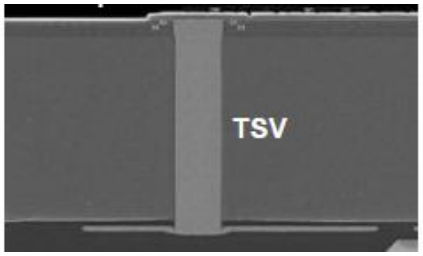
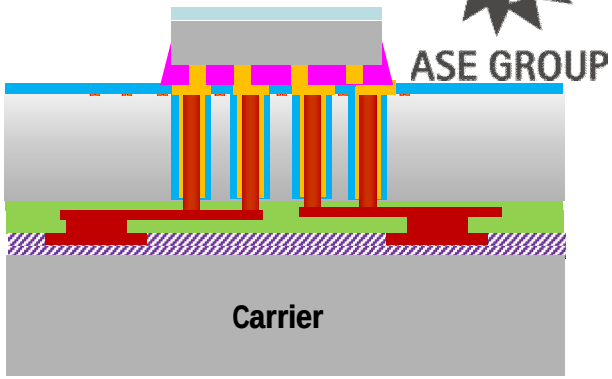
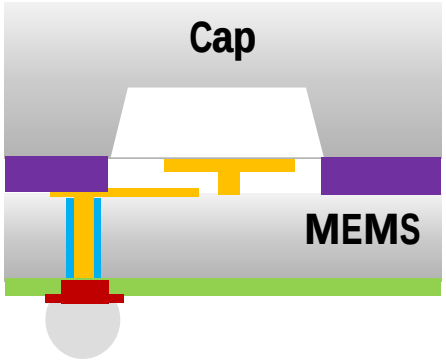
ASE MEMS & Sensor Packaging Toolbox Evolution

Capability to temporary bond wafer on carrier:

- Carrier type: Glass
- Temporary adhesive material: polymer
- Max T: 220°C







ASE 3D WLP MEMS toolbox

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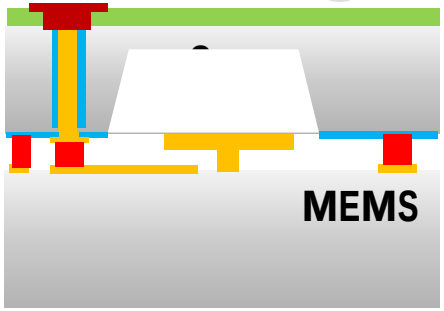
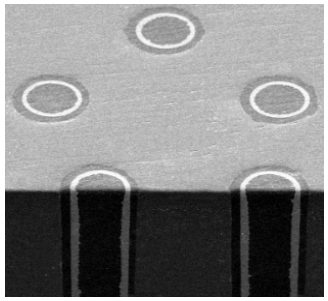
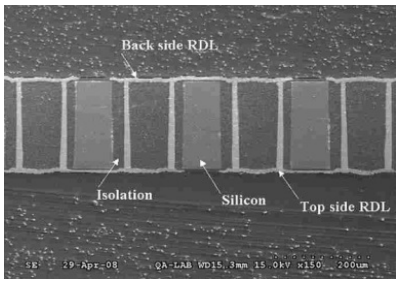
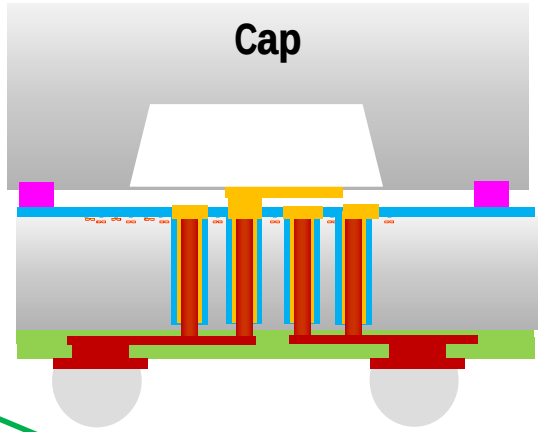


Via last manufacturing capability

- DRIE of TSV last
- Via isolation & Cu fill
- Passivation and RDL







Via first or middle processing

- Wafer thinning and TSV opening
- Passivation and RDL

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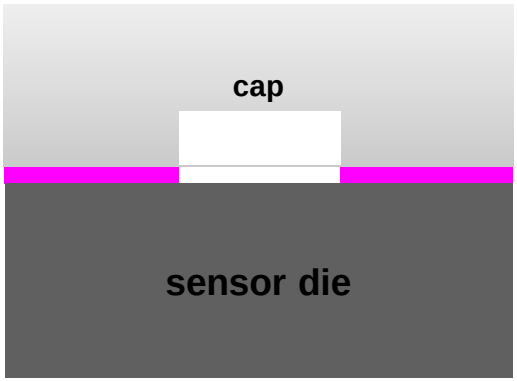
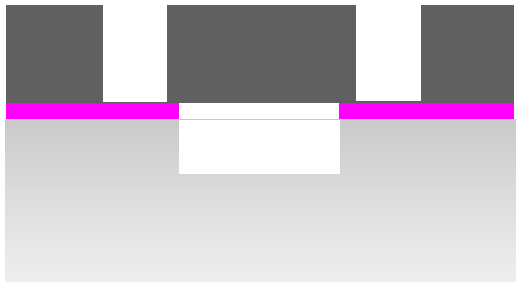
ASE TSV Last – generic flow for single die package

Drawing not at scale

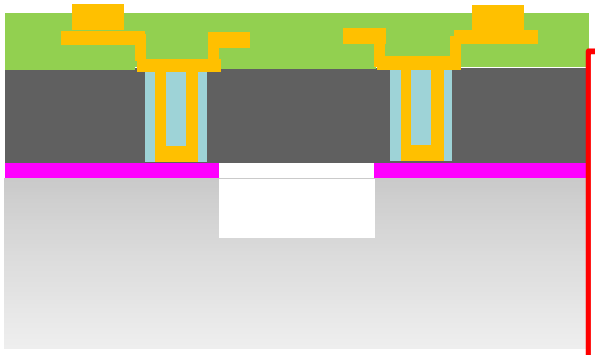
Process 100% done by ASE, current production on 200mm wafers



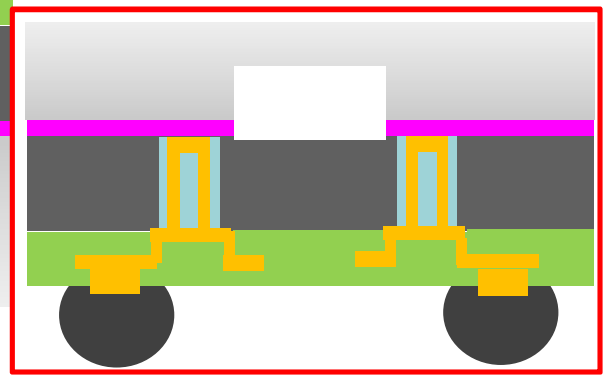
Wafer to wafer bonding



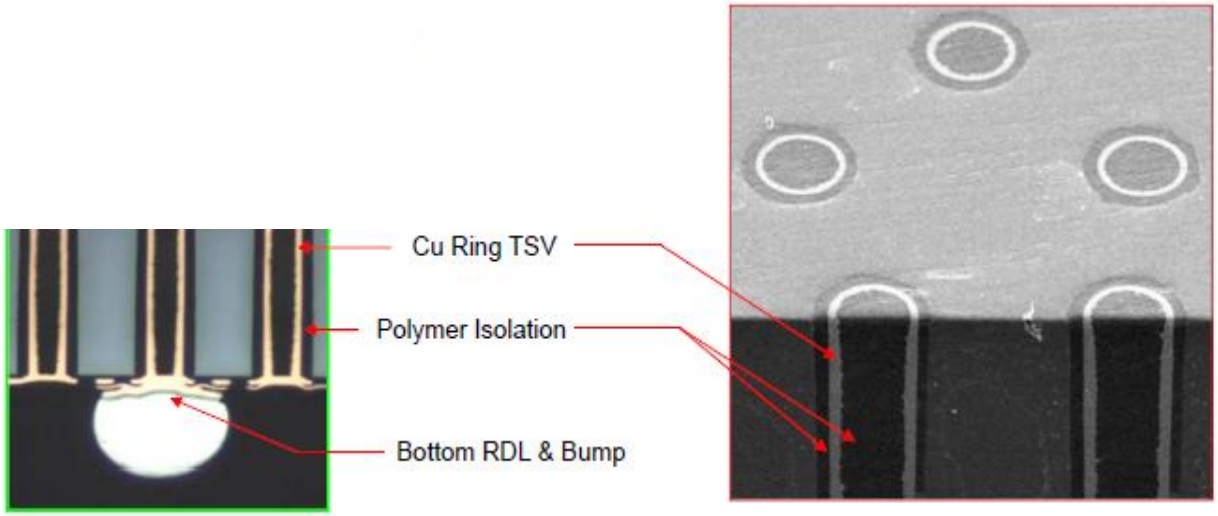
Thinning & etching



TSV filling & redistribution



Cap thinning, de-tape, cleaning, marking, singulation and TNR



TSV last with polymer isolation:

-Isolation thickness up to 10um
-Good electrical performance & low leakage
-Good sidewall conformity & uniformity
-Low process temperature (below 250°C)
-Low via / Si stress
-Minimized warpage
HVM started on 200mm environmental sensor, high yield and reliability according to plan.

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ASE MEMS & Sensor WLP Roadmap

Key Technologies	Today	2013	2014	2015
Cap Material (WL)	Glass, Si	Glass, Si	Glass, Si	Glass, Si
Cap Sealing (WL)	Glass frit Polymer	Glass Frit Polymer	Glass Frit Polymer	Polymer Metal
Seal Pattern	300 um 200 um	300 um 200 um	300 um 200 um	300 um 200 um 100 um
Wafer th. (TSV depth)	100 um	100 um	75 um	75 um
TSV dia. min. (via last)	60 um	60 um	50 um	30 um
RDL L/S min.	10/10 um	10/10 um	5/5 um	5/5 um
PA Resolution min.	10 um	10 um	10 um	5 um
Ball Size	0.25 mm	0.2 mm	0.15 mm	0.15 mm

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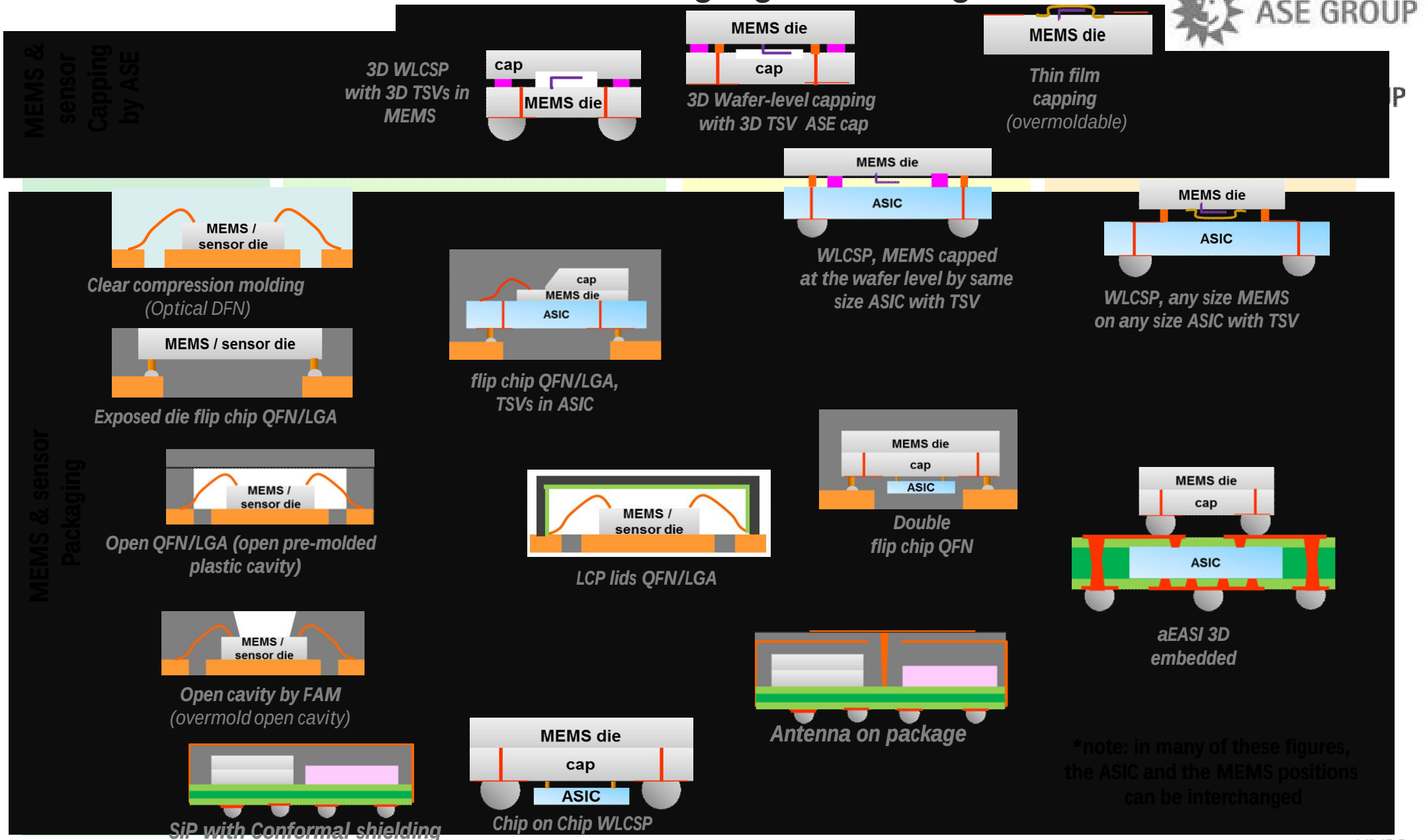
ASE Vision - MEMS & Sensor Packaging and Integration



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Summary

- Packaging accounts for 20-60% of the MEMS/Sensor device BOM and is a key part of the MEMS function and design
- Packaging creates additional value as the MEMS/Sensor device is integrated into a system (SiP, module)
- Contradictory market requirements: differentiation and standardization
- Standardization enables high volume production (second sourcing, cost efficiency through technology sharing)
- Cost effective integration can be achieved with MEMS/Sensor Wafer Level Packaging
- Each WLP is unique. Standardization is in the toolbox – combination of “standard” building blocks
- ASE hopes to set the standard with differentiating solutions: WLP and 3D integration

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Thank You

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