Copper Wire Bonding: the Last Frontier of Cost Savings

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Business Development
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ASE GROUP

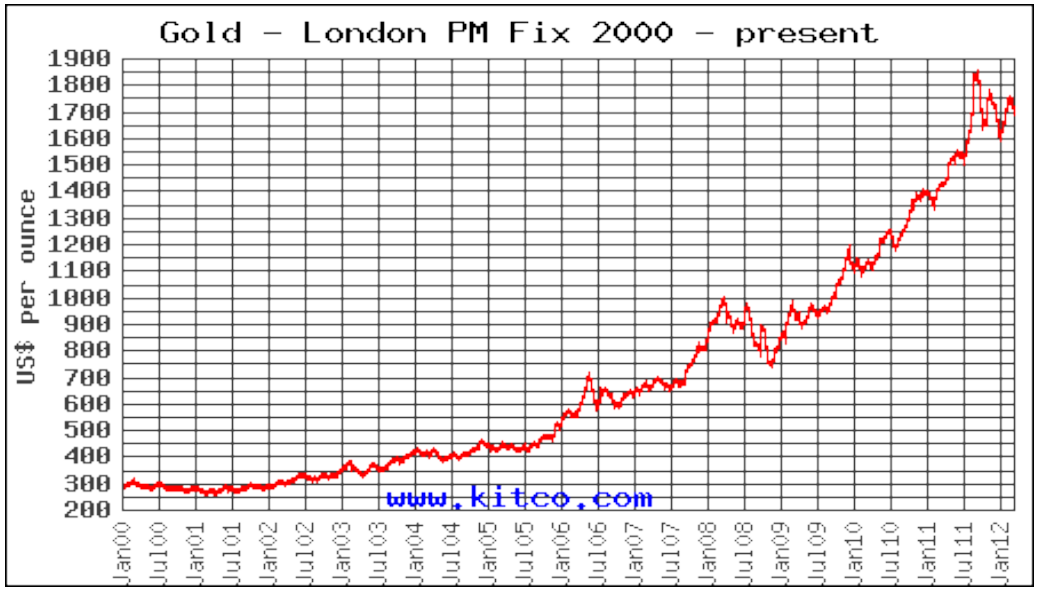
Outline

ASE GROUP

- Introduction
- Fundamental Study
- Reliability Study
- Monitoring Data
- High Volume Implementation
- Summary

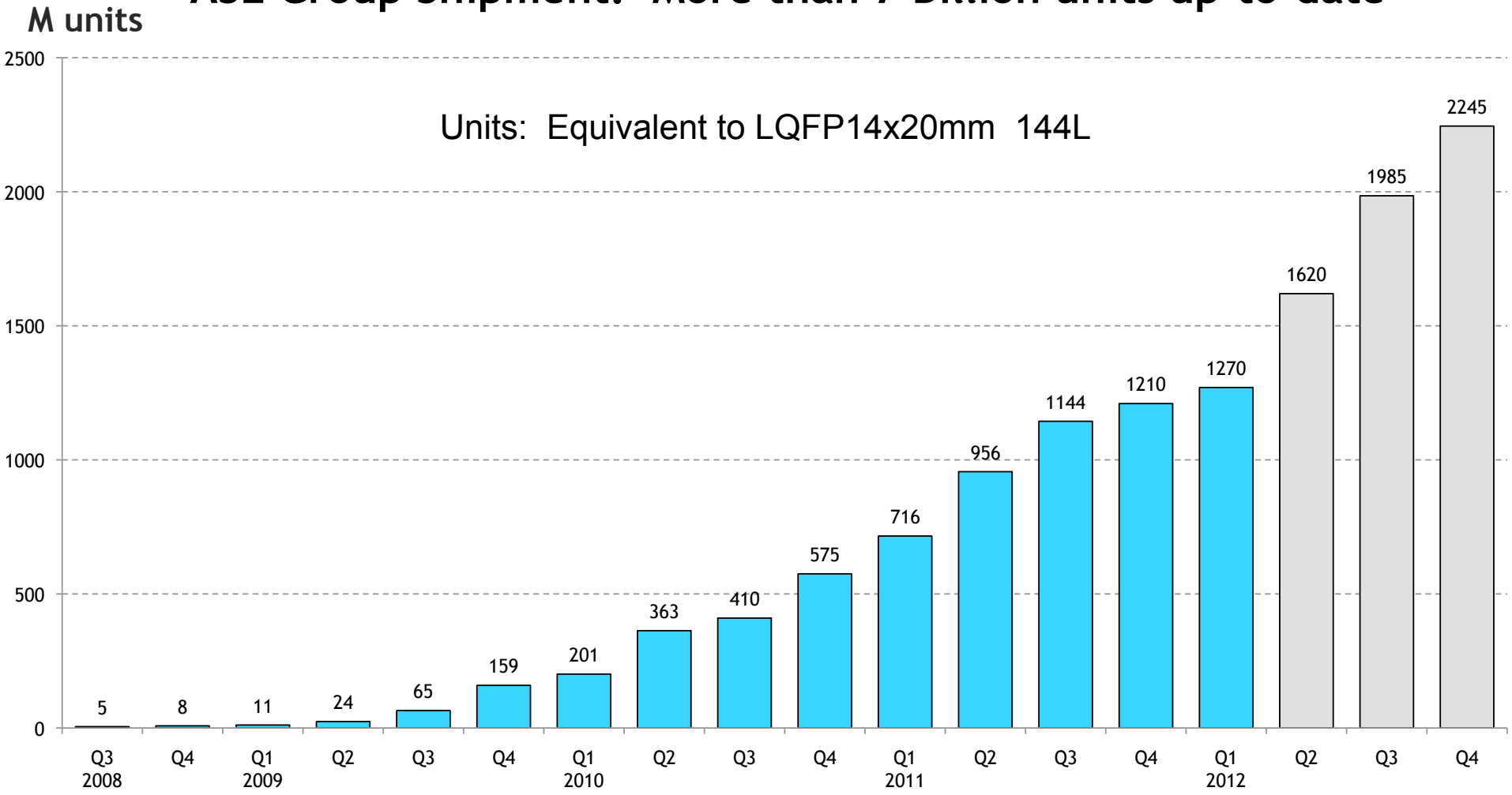
Introduction - ASE Cu wire-bonding history

- Fine wire active development since 2005 in ASE Kaohsiung
- ASE Chung-Li started HVM in Sep 2008
- Followed by ASE Kaohsiung, Shanghai, Malaysia, Korea and Japan.
- HVM covers:
  - 25/ 23 / 20 / 18 um Cu and Pd/Cu wire in QFP, SO, QFN, BGA packages.
  - wafers from ALL foundries, ALL nodes, with different structures.
- Overall yield is around 99.85%.

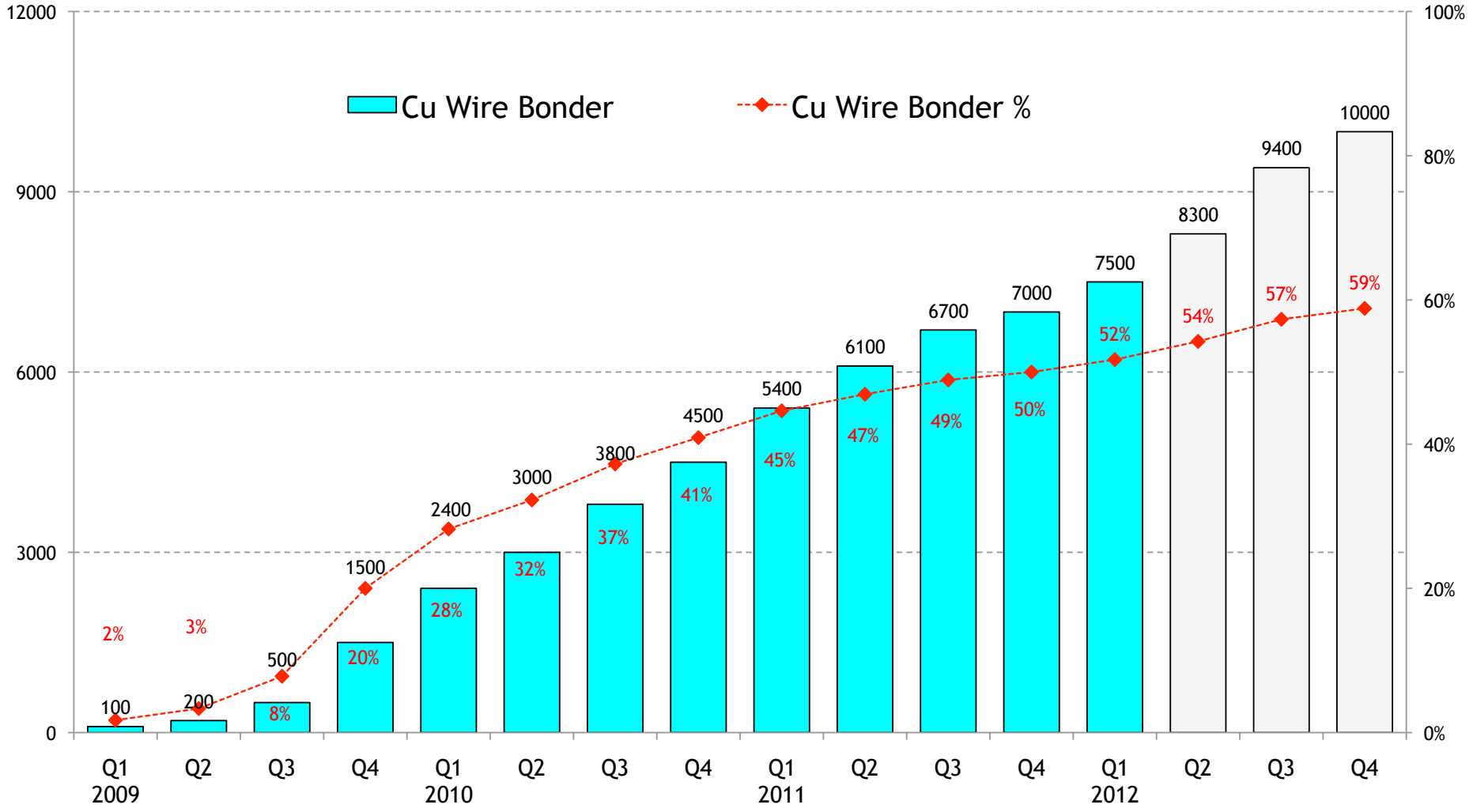


Introduction - ASE Production Unit Shipment

ASE Group Shipment: More than 7 Billion units up-to-date

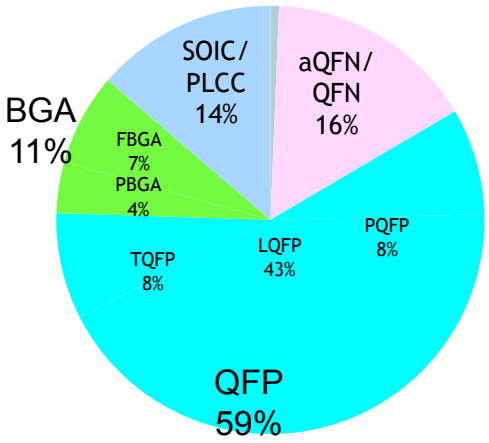


Introduction - ASE Cu wire Bonders Quantity

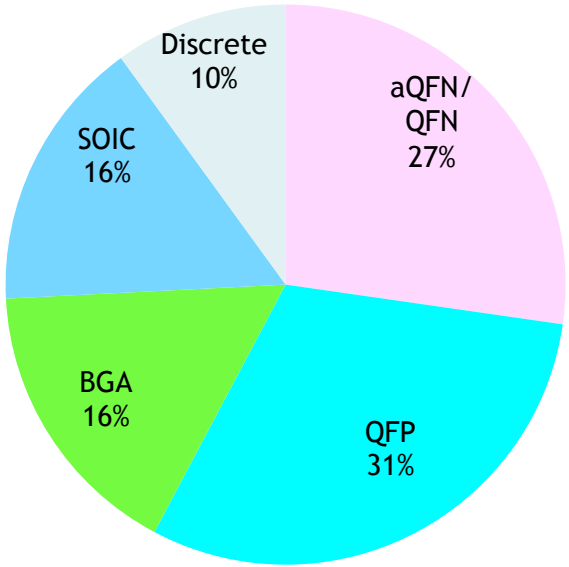


Introduction - Production Volumes by Package Types

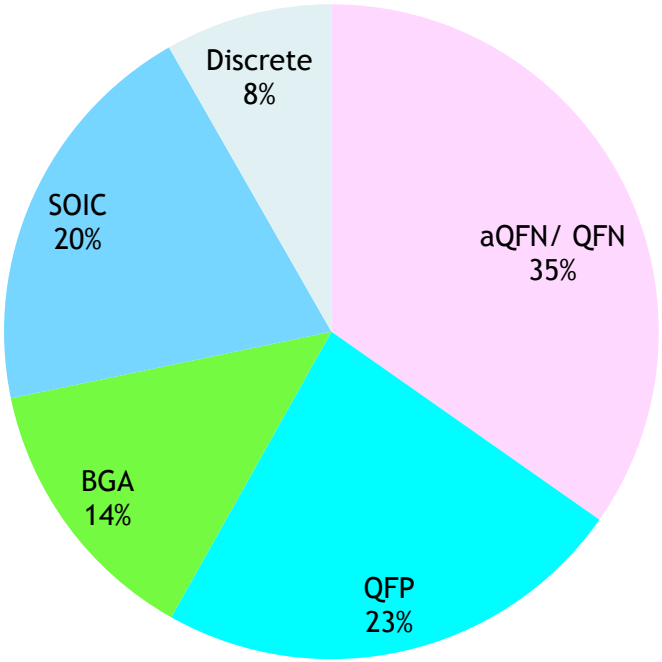
2009



2010

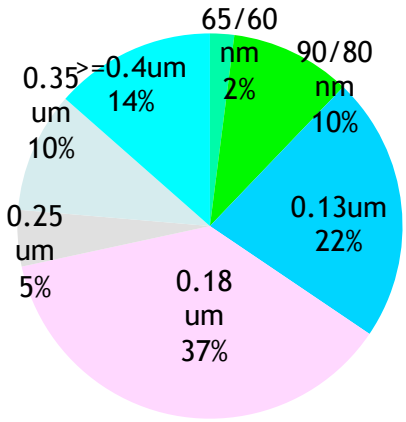


2011

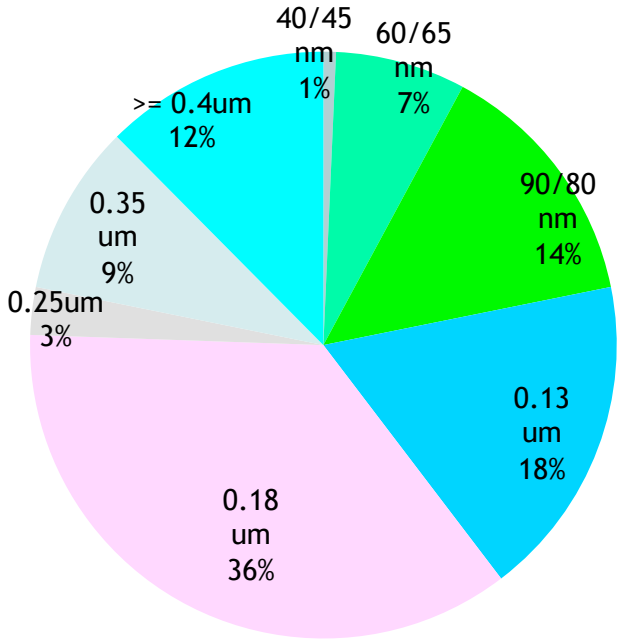


Introduction - Production Volumes by Wafer Nodes

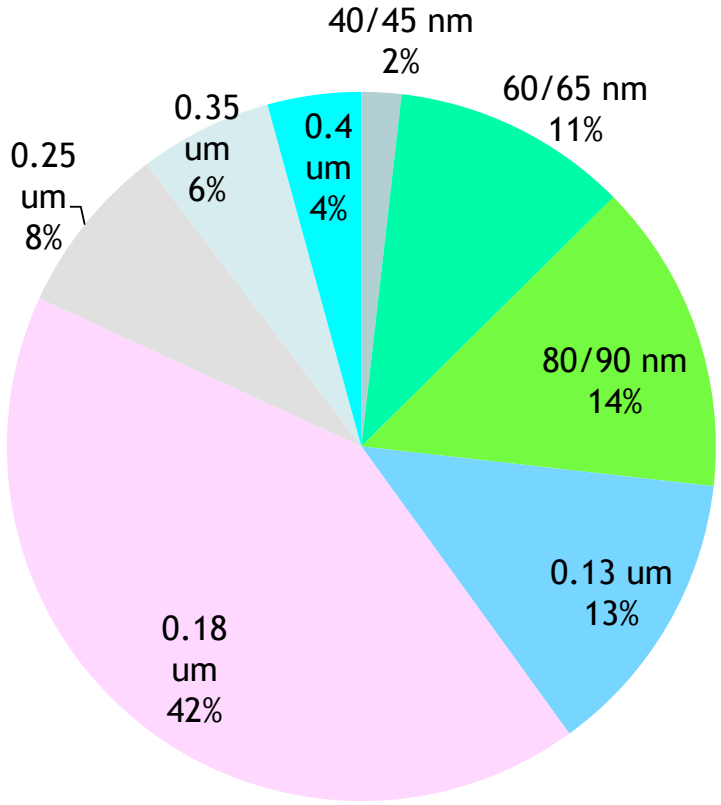
2009



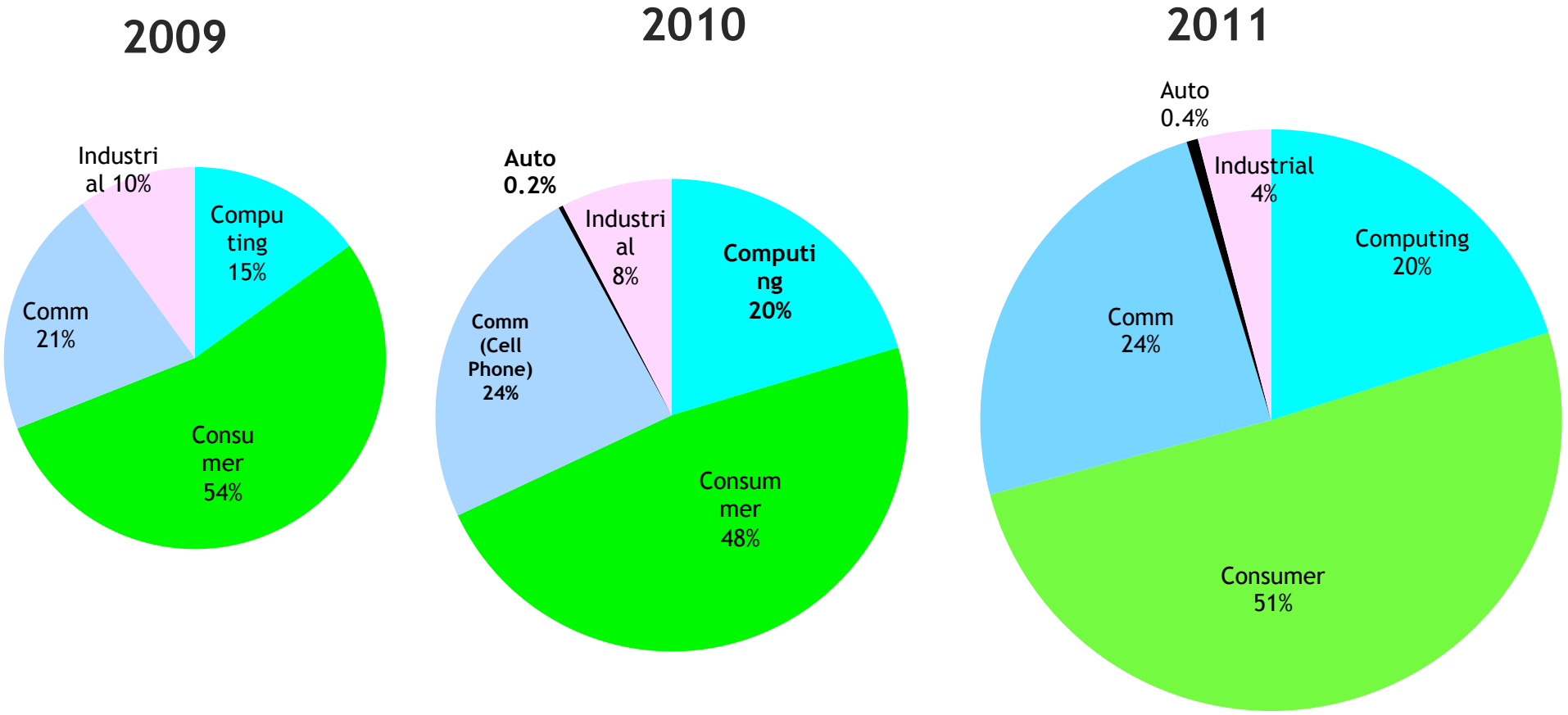
2010



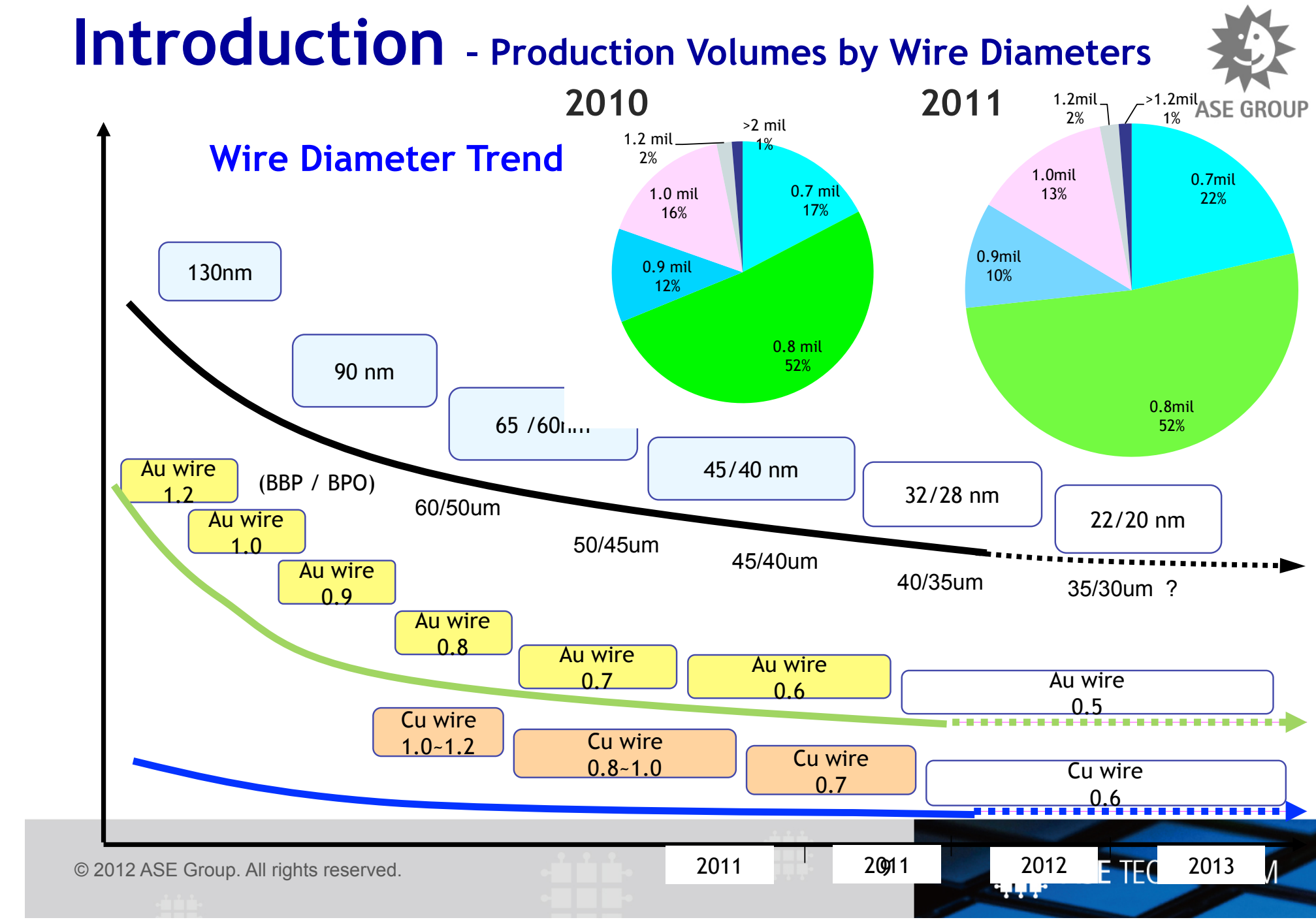
2011



Introduction - Production Volumes by Applications



Introduction - Production Volumes by Wire Diameters



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- **Fundamental Study**
- Reliability Study
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Fundamental Study

Cu Wire vs Au Wire : Raw Material Properties

Pros:

1. Lower Material Cost
2. Lower Electrical resistivity
3. Better Thermal Conductivity
4. Better Mechanical Properties
5. Slower IMC Growth.

Cons:

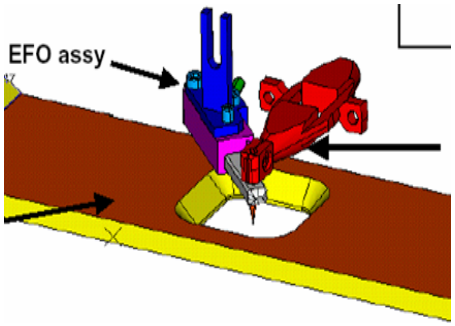
1. Surface Oxidation
    1. Inert gas requirement
2. Hardness Impact Al Pad
3. EFO kit requirement

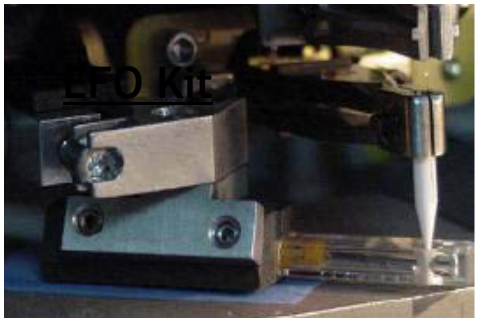
Bonding Wire	Au	Cu
Atomic weight (g/mol)	197	64
Density (g/cm-3)	19.3	8.94
Melting point	1066 °C	1085°C
Boiling point	2856 °C,	2562 °C
Electrical resistivity (nΩ·m -20 °C-)	22.1	**16.8**
Thermal conductivity (W·m−1·K−1 -300 K-)	318	**401**
Young's modulus (Gpa)	79	**110–128**
Vickers hardness (Mpa)	216	**369**

Fundamental Study

Process Control:

EFO kit with Forming gas:

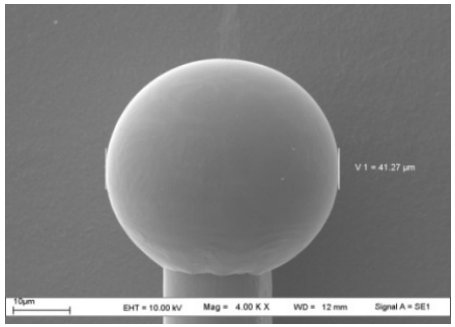




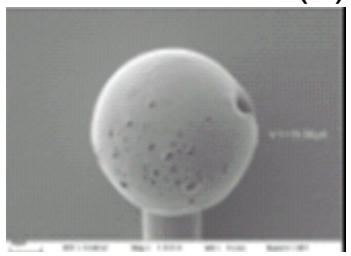
For Stable / Symmetric FAB :

(a) Control EFO process.

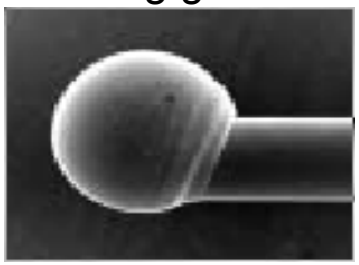
(b) Forming gas rate.



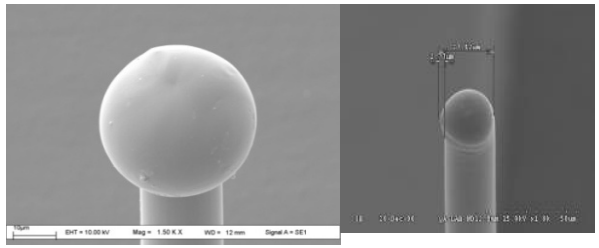
Good FAB



Void



Asymmetry

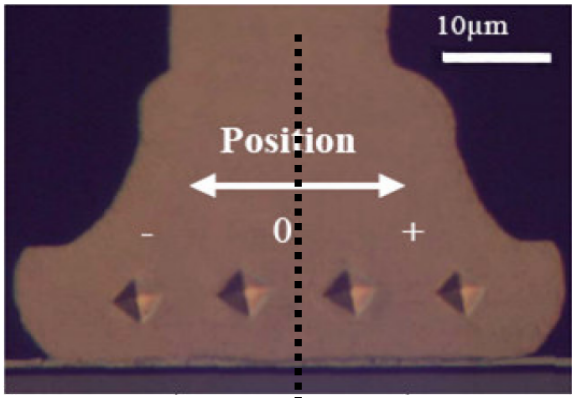


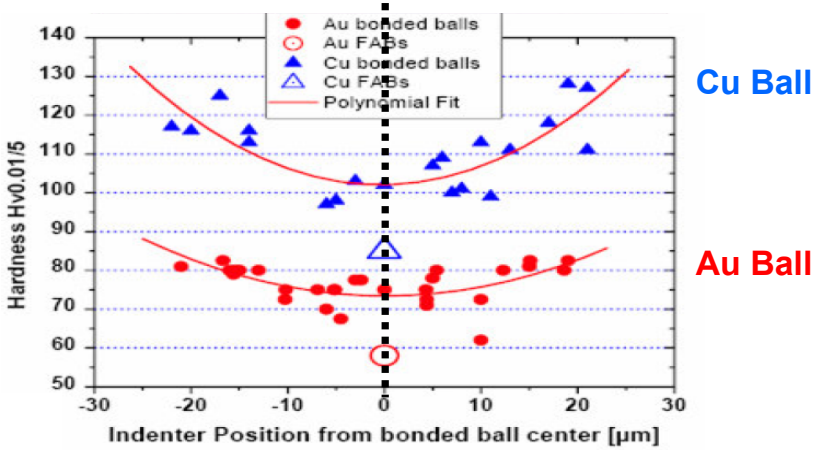
Unstable FAB

Fundamental Study

Cu Wire vs Au Wire : Hardness

Hardness

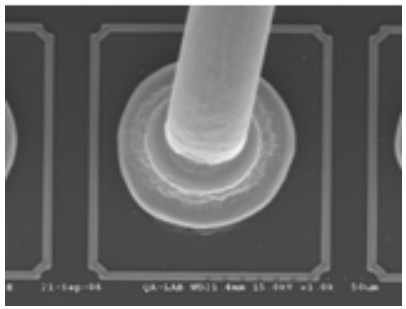


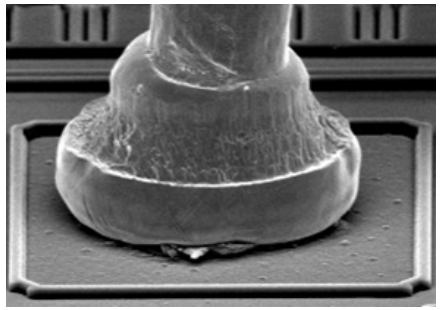


Cu Ball

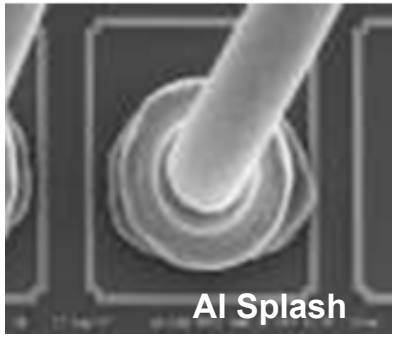
Au Ball

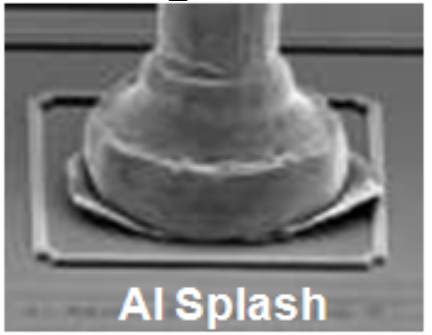
Au Wire Bonding





Cu Wire Bonding



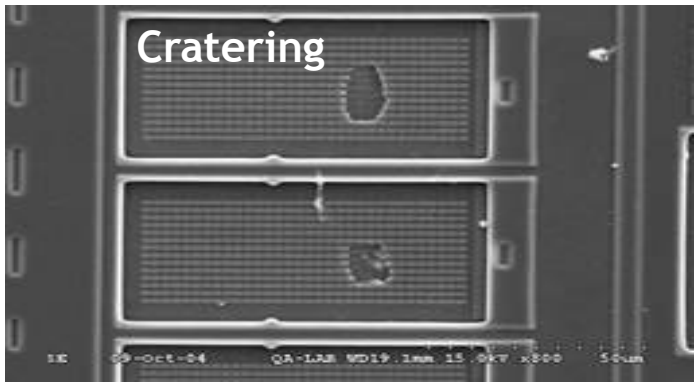


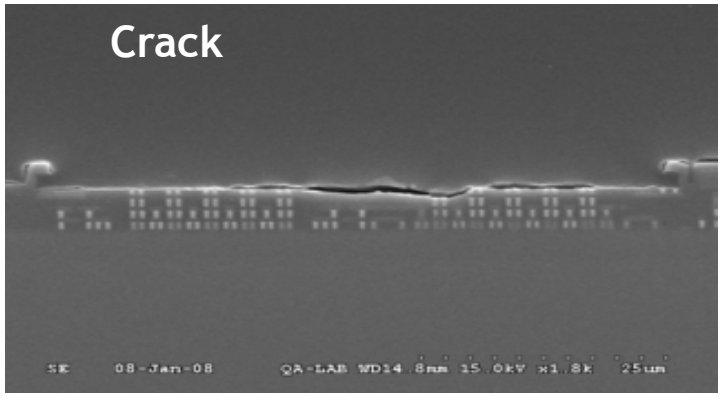
Source: Johnny Yeung, Challenges for Copper Wire Bonding, KnS , 2008

Fundamental Study

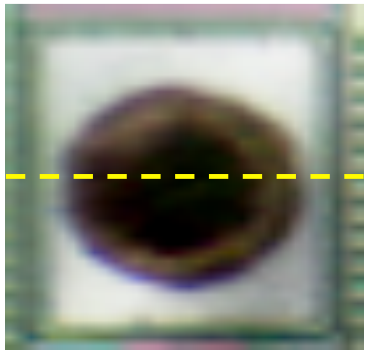
Process Control:

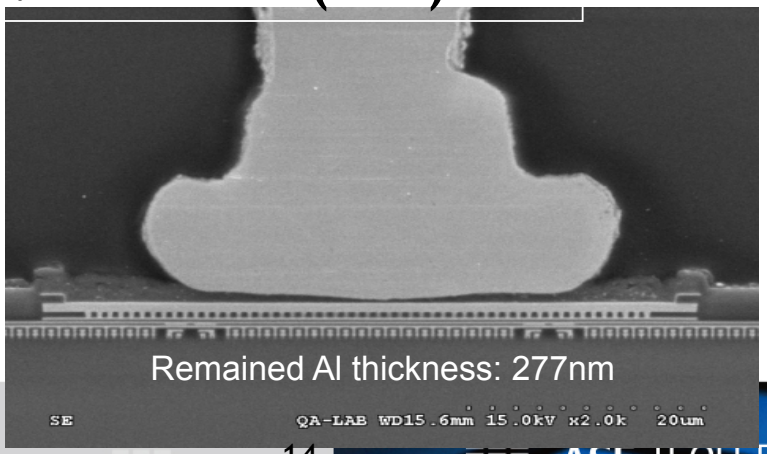
Cratering / Cracking Test





Al thickness remaining : > 100nm (min)





Al thickness remaining should > 100nm.

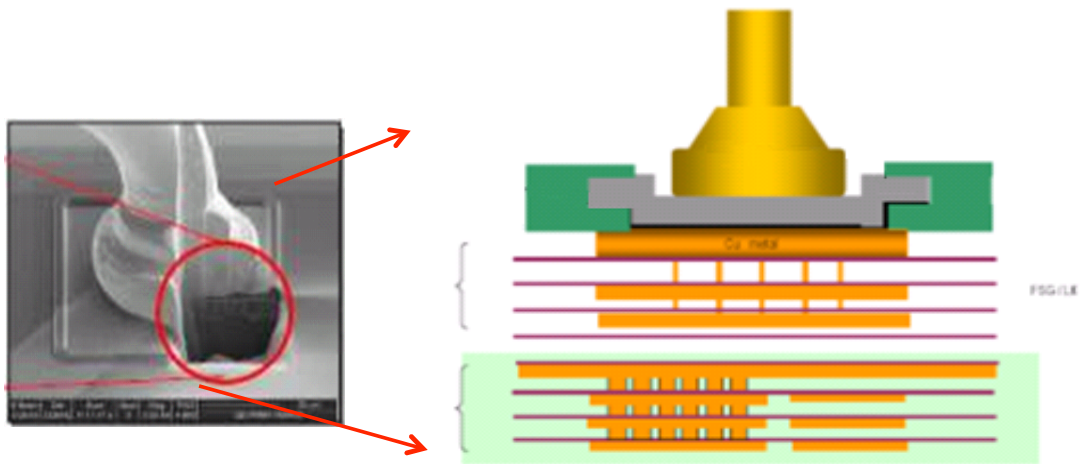
Fundamental Study

Process Control:

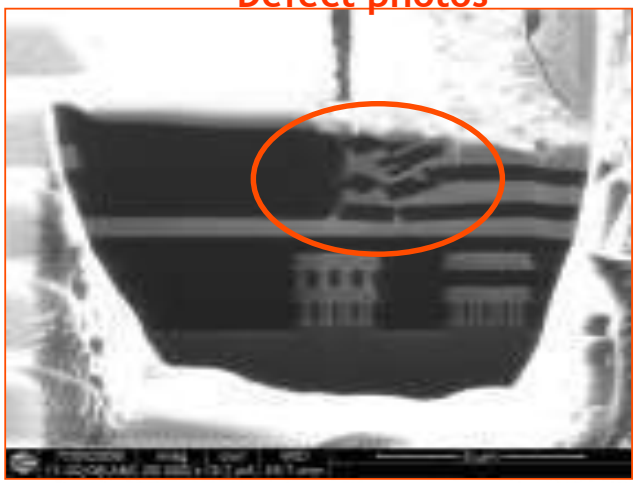
CUP Design & LowK Wafer

- Fine Pitch
- Small Pad opening
- Circuit Under Pad
- Cu / low K

- ◆High energy transformation capillary.
- ◆Parameter optimization.
- ◆Ball shape control.
- ◆Ball shear inspection.



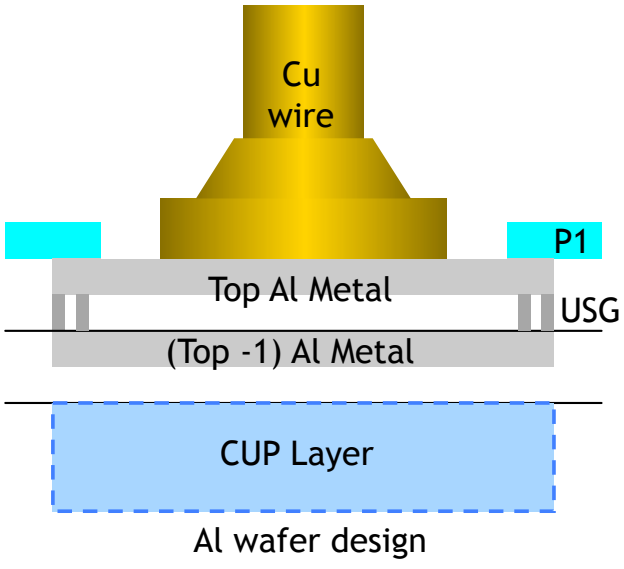
Defect photos



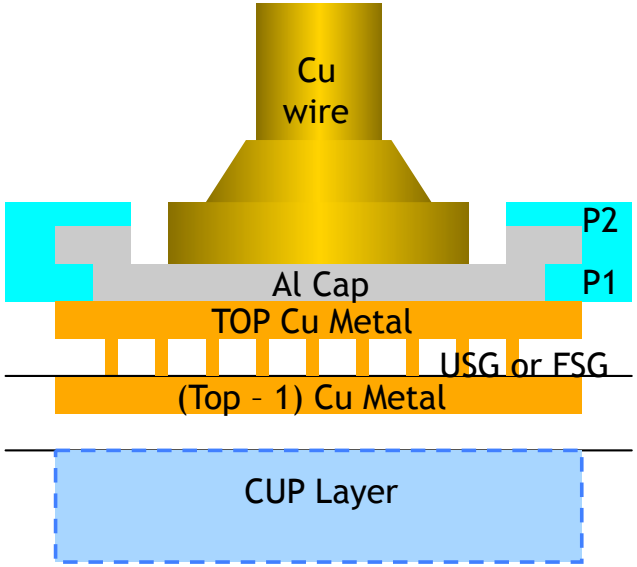
Fundamental Study

Design Guideline : CUP Bonding

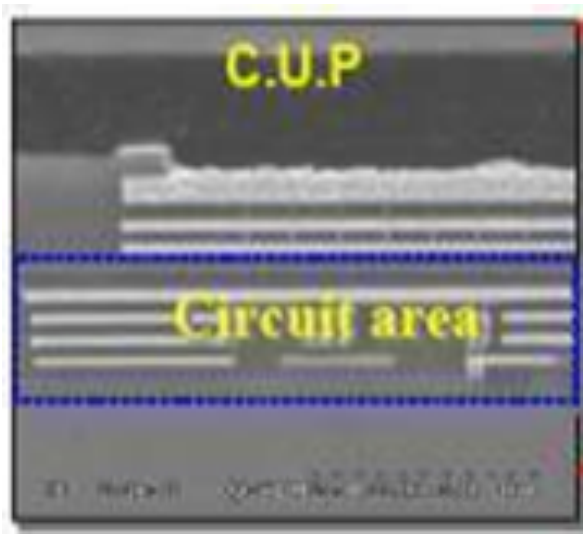
- The top 2 metal layers (Top and Top-1) can not be circuit layers
- The top 2 metal layers (Top and Top-1) must be solid layer and must be larger than bond pad



Al wafer design

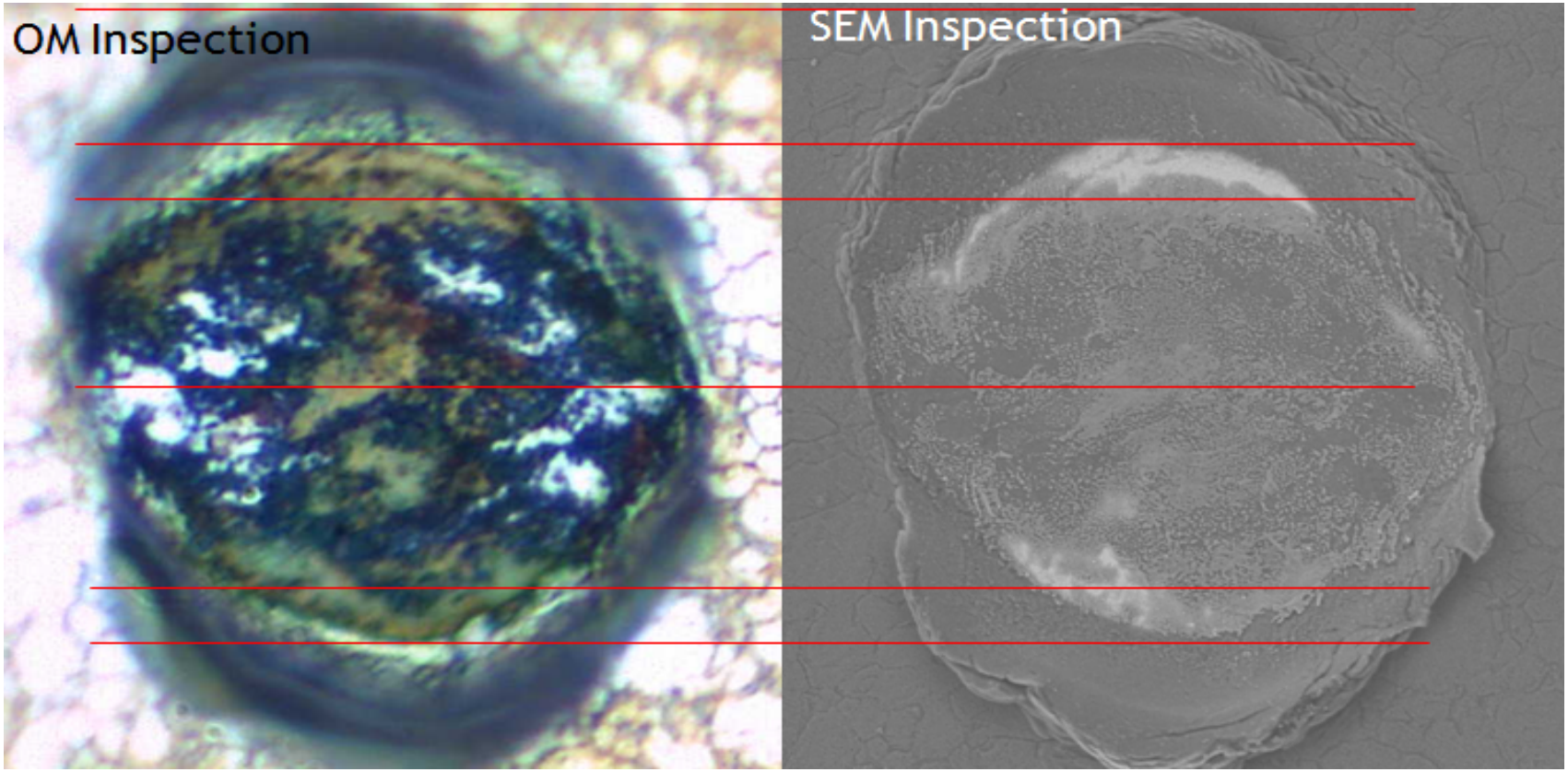


Cu wafer design

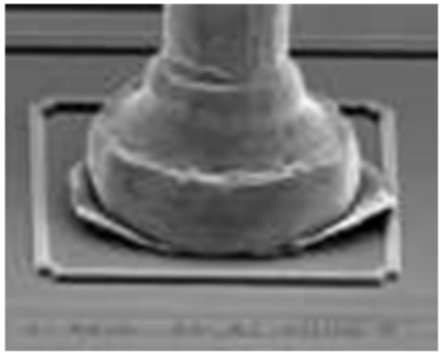


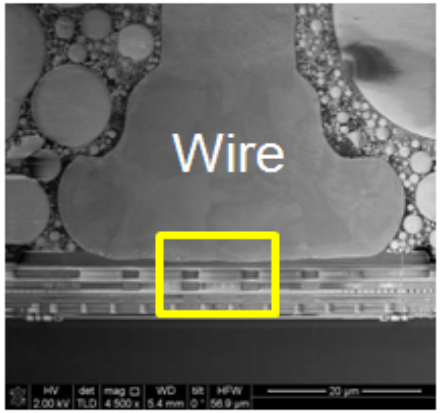
Reliability Test

Cu-Al IMC Inspection

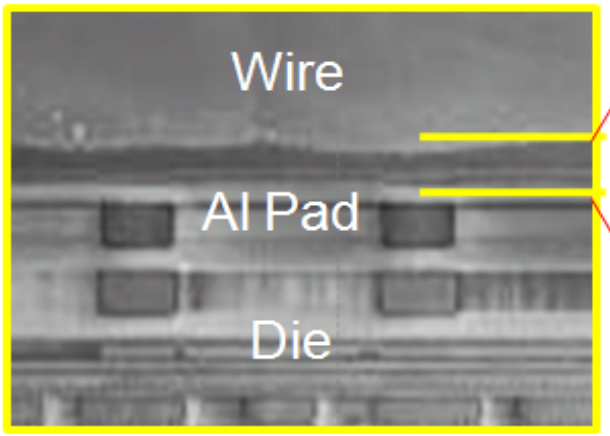


Reliability Test

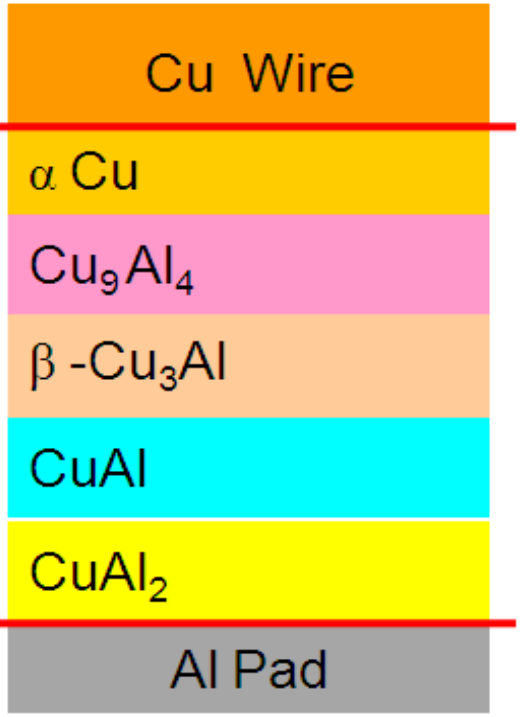




Intermetallic Compound (IMC)



IMC



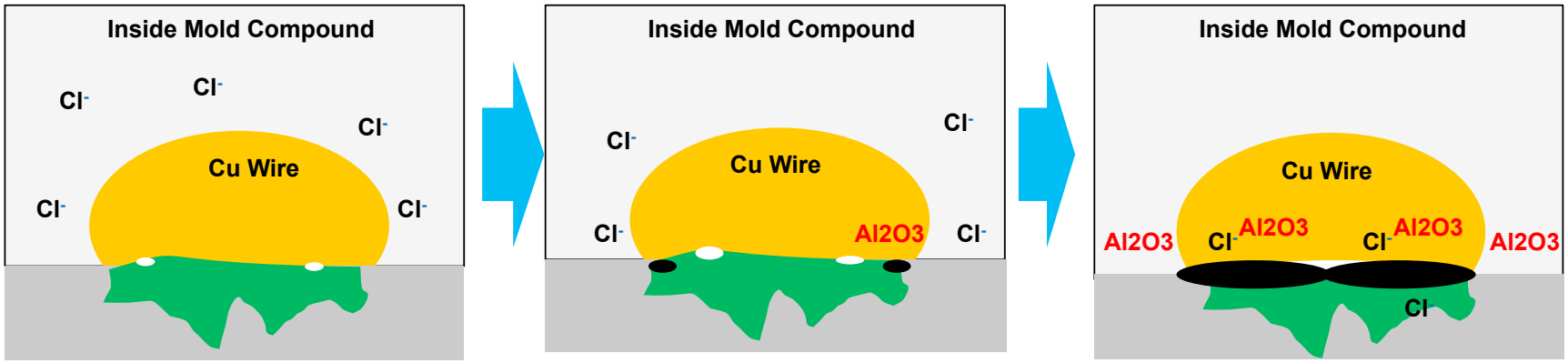
1991Oka1: H. Okamoto, Al-Au (Aluminum- Gold), ***J. Phase*** *Equilib., Vol 12 (No. 1), 1991, p 114-115*

2004 M. Li, C. Li, F. Wang, D. Luo, and W. Zhang, Thermodynamic,Assessment of the Al- Au System, *J. Alloys Compd.*,

Studies and Learning

Reliability Test Improvement

Mold Compound Cl ions - low ppm required



" Cl^- " ions reacts with IMC & creates "Al_2O_3" with high resistivity,

The mechanism for open failure in biased HAST test

$$Cu_9Al_4+6HCl+3O_2+nH_2O \rightarrow 2AlCl_3+2Al(OH)_3^* +9Cu+nH_2O$$

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Monitoring Data

Package Type	Body Size	PCT	TCT	HAST	HTS	THT
		hrs	cycles	hrs	hrs	hrs
QFN	6 x 6		2,000	200	2,000	2,000
QFN	8 x 8		2,000	200	2,000	2,000
QFN	9 x 9	936*	6500*	178*	4500*	
aQFN	11.5 x 11.5	168	500*		500*	
QFP	14 x 20	2016	6000		3500	
QFP	28 x 28	1272	6,000		4,000	
LQP	10 x 10	336	2,000	192	2,000	
LQFP	14 x 14	264	1,500			
LQFP	20 x 20	336	2,000	192	2,000	
LQFP	24 x 24	264*	1,500*	144*	1,500*	
TQFP	14 x 14		2,000	400	2,000	2,000
HQFP	14 x 20	336	1,000*	548*	3,500*	
TFBGA	9 x 9		3,500	144		
TFBGA	12 x 12		6,000*	864	2,000	
LFBGA	16 x 16		1,500	168	1,500	
HSBGA	27 x 27	336	4,000	336	4,000	
* test in progress						

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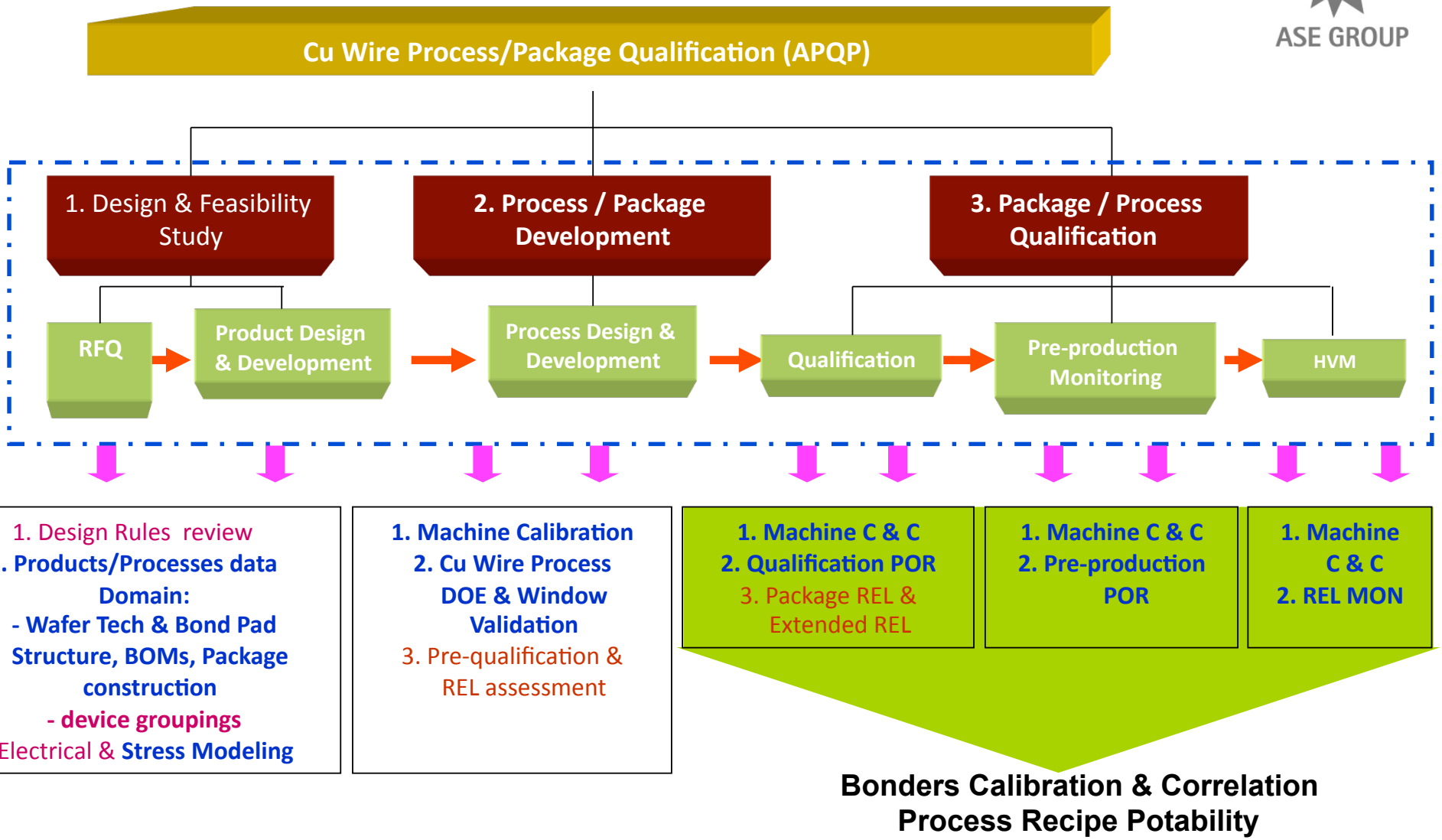
Cu Wire Product/Process Qualification Flow Overview



Device Groupings & Data Base

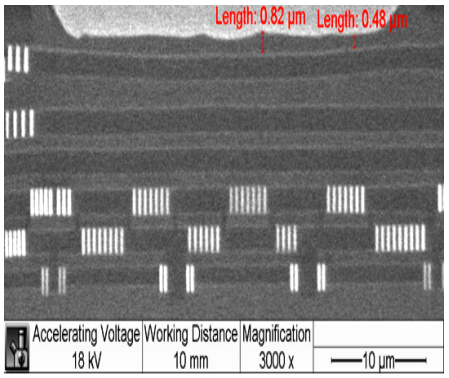
Wire Diameter

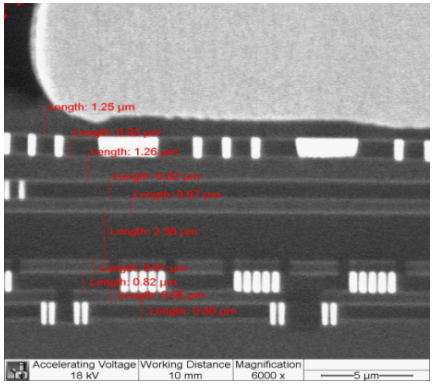
- > 1 mil Diameter
- < 0.9mil Diameter

- BPO
- Wire Length
- Multi-tiers

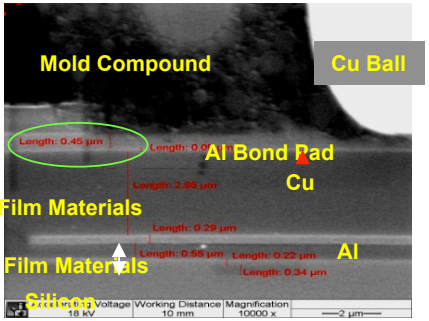
Bondpad Structure

- Wafer Nodes
- Via Structure
- CUP / Non CUP
- Under-layer Metal Stacking



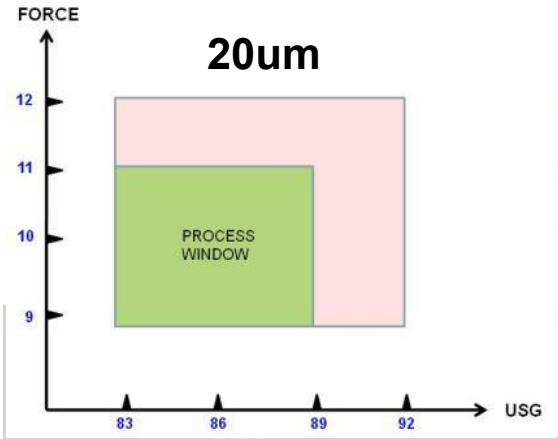


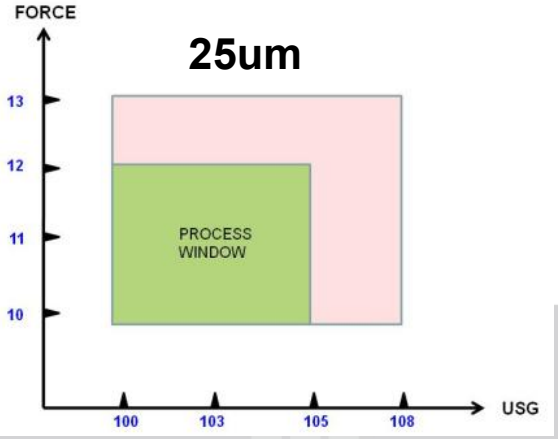
0.45um Al thickness



BOM Selection, Package StressModelling (bHAST solution)

Wirebonder Calibration & Correlation





Cu-Wire Package In High Volume Manufacturing

Wirebond Process/Quality/Material Controls

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Cu Wire Bond Process Control

WB Parameters & Control

- Locked and can be adjusted within controlled range
- 1st Bond and 2nd Bond- USG and Bond Force
- EFO Fire Time- Control the size of FAB

WB WIP Staging Time Control

- Plasma to WB
- WB processing time

Gas Flow Rate control

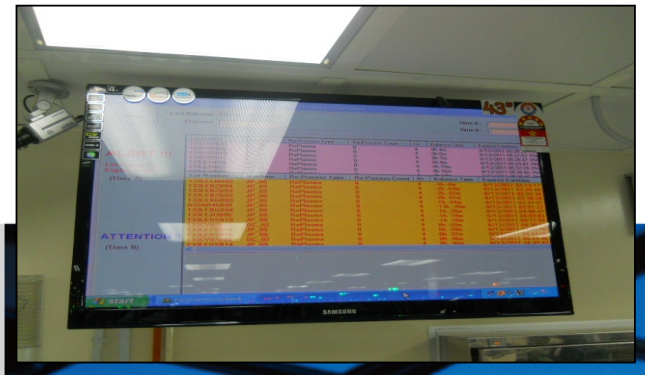
- Forming Gas (Bare copper wire)
- N2 Gas (Pd coated wire only)

Set-up/Conversion buy-off

- Free Air Ball(FAB) – wire type change
- WB Quality Characteristics
- Copper wire bonder MTMV
- Regular calibration & correlation

Cu Wire Material Controls

- **System control through MES-system Integrated Controls**



More Challenges to be addressed

- Advanced Nodes
- Legacy Products
- Automotive & Advanced Network Systems
- New Package Technologies
- Collaborative Research with Universities, suppliers, and research institutes

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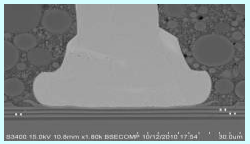
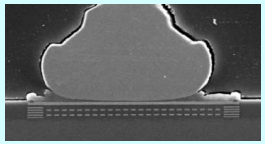
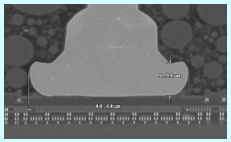
Cu Wire Technology

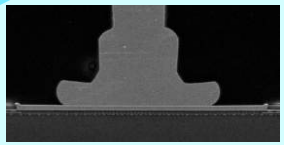
Wafer Tech.

Wafer Node 0.18um/0.15um	Wafer Node (LK) 0.13um/90nm/65nm	Wafer Node (ELK) 45nm/40nm	Wafer Node (ELK) 28nm
BPP62um/BPO55um	BPP52um/BPO45um	BPP45um/BPO40um	BPP40um/BPO35um

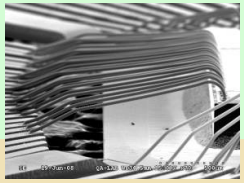

Al wafer

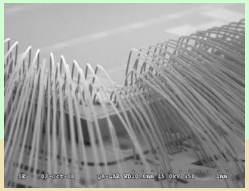

Cu wafer

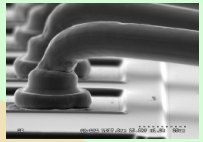

CUP wafer


NiAu/NiPd pad

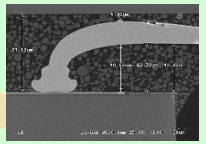
Package Tech.

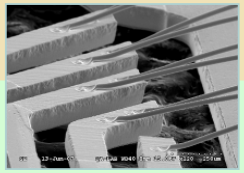

In-line/Staggered

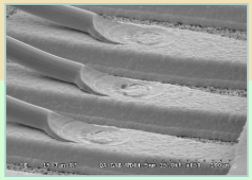

Tri-tier/Quar-tier

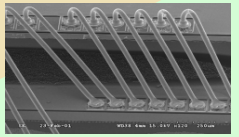

Low loop

Stack die


FOW


L/F PKG


Substrate PKG


Pad to pad

2009 2010 2011 2012

New wafer technology overview

- For BGA PKG:
  - Au wire MP on 40nm wafer, available on 28nm wafer technology
  - Cu wire MP on 40nm wafer, Qual lot build on 28nm wafer, expect Qual finish on Y2012Q1
- For QFP PKG:
  - Au wire MP on 40nm wafer, under plan on 28nm wafer
  - Cu wire MP on 40nm wafer, under plan on 28nm wafer

Summary

ASE GROUP

- Fine pitch Cu wire-bonding ramped successfully into high volume production in all sites .

- Close collaboration and partnership with equipment and materials suppliers.

- Devices from advanced wafer nodes from different foundries in broad spectrum of packages

- ASE has 6 years experience in Cu wire-bonding, total shipment will exceeded 7 billion units at end of 2011

- Reliability demonstrated to exceeded up to 6X standard JEDEC testing and is continuing.

ASE GROUP

Thank You

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