Introduction of High Reliability Copper Bonding Wire for High Rel Industrial, A&D and Automotive Applications

William (Bud) Crockett Jr.
bcrockett/wc@gmail.com

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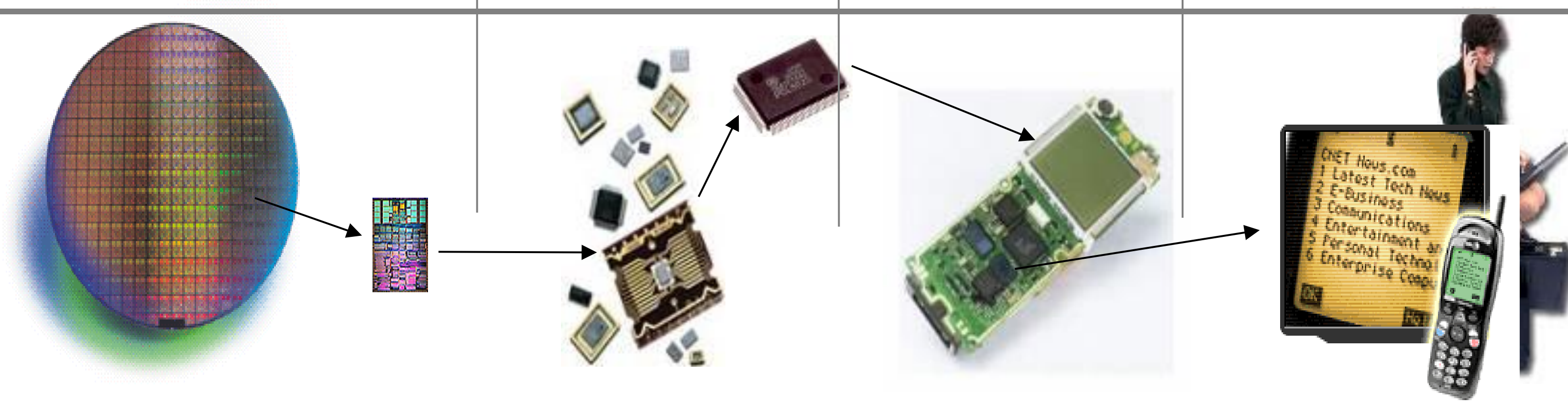
Our Industries

MICROCHIPS	Level 1	Level 2	ELECTRONICS
Silicon	IC Packaging	Circuit Board Assembly	System



In Global Electronics the most emphasized precious metal is Gold

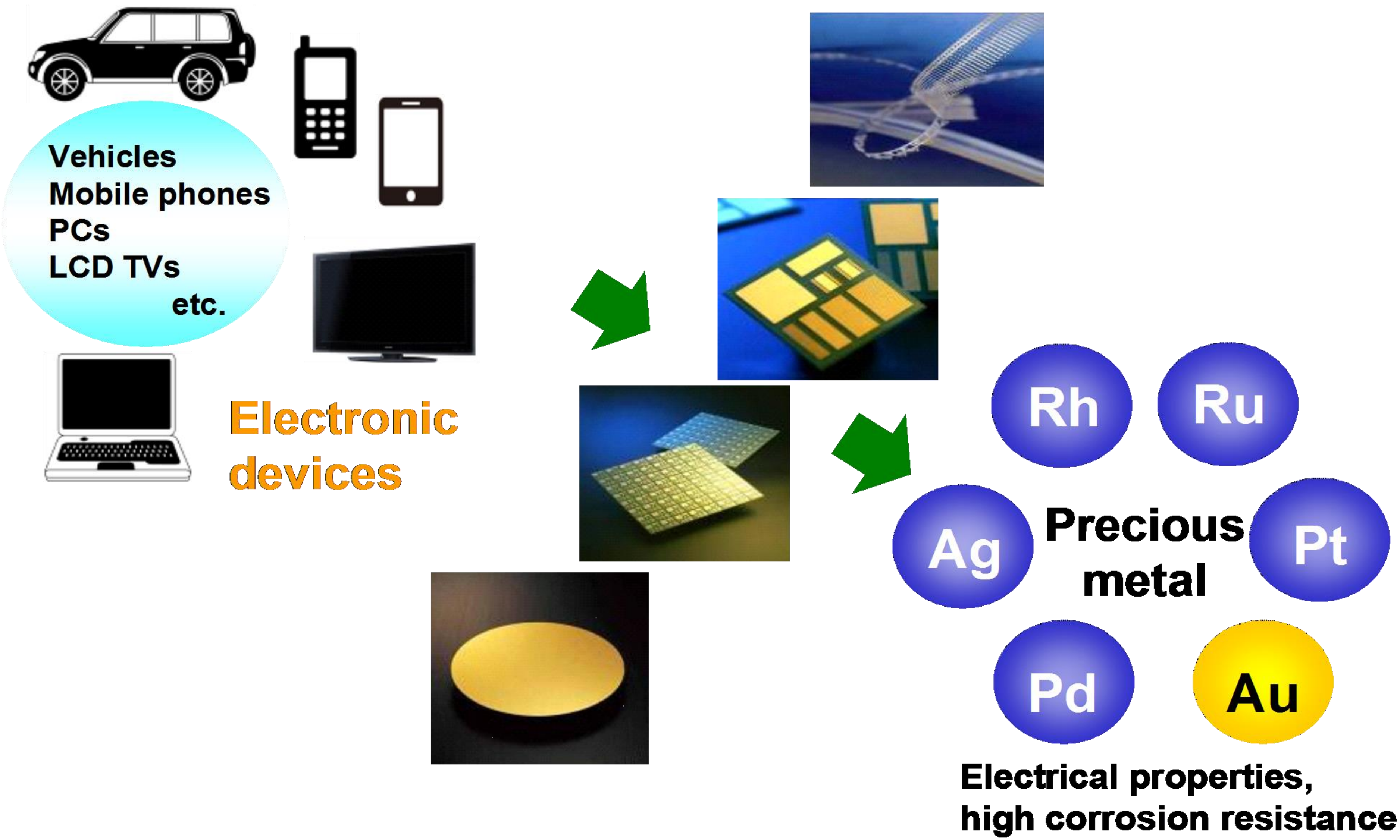
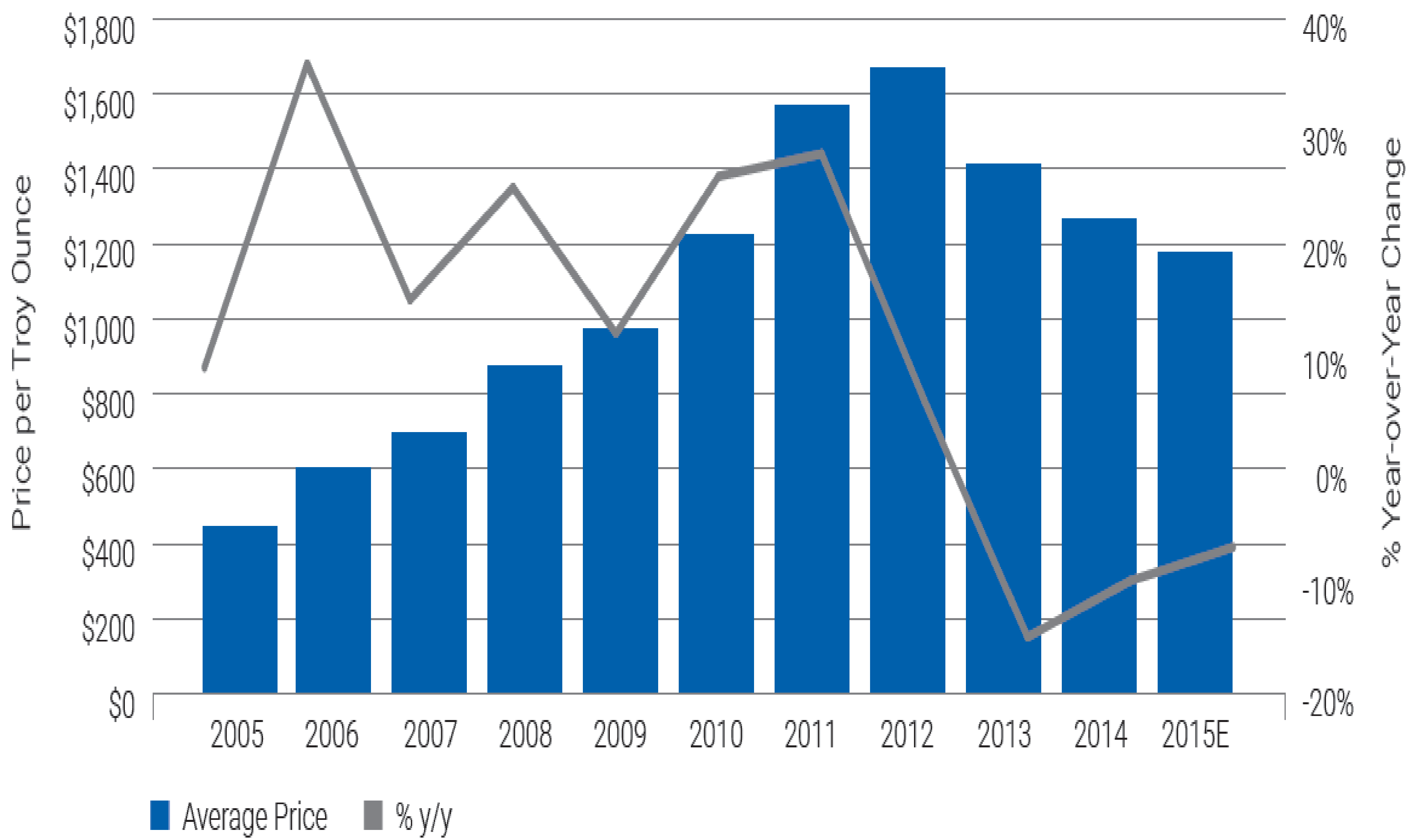


FIGURE 5.1 ANNUAL AVERAGE GOLD PRICING TRENDS



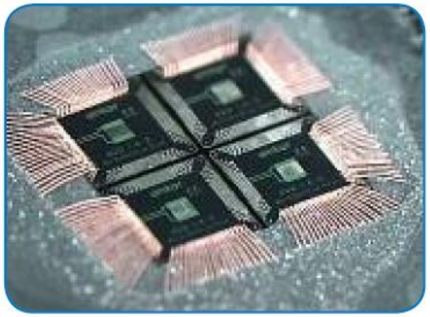
Source: www.kitco.com

Question is how to cut the device cost while using Gold (Au) metal?

1. Reduce the thickness of Au plating on the substrate

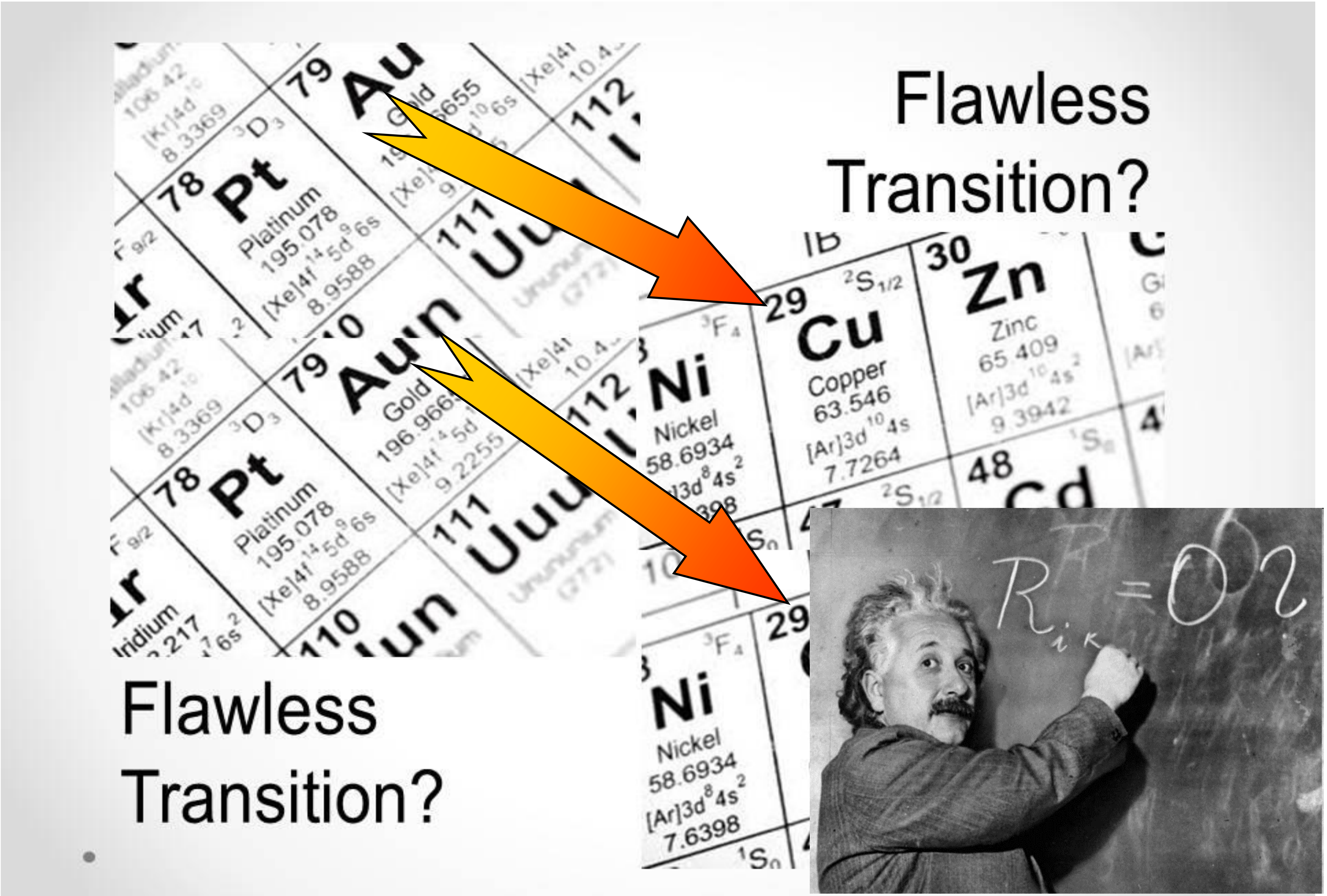
2. Use alternative metals instead of Au wire

Reduce the material cost of PKG



Target is to optimize the combination between the Surface finish material and Wire bond material

Bonding Wire Transition Gold => Copper



Copper vs. Gold

Advantages

- Low Material Cost (Approx 30-50% lower than Au)
- Better Conductivity (Approx 20% better than Au)
- Higher Fusing Current (Approx 30% higher than Au)
- Low Reaction Rates (Cu/Al IMC @ 150-300C 10x slower Au/Al)

Disadvantages

- Need N2 or Forming Gas (Gas necessary for Copper wb)
- Higher Mechanical Strength (FAB hardness, Work Hardening)
- Narrow parameter window at 1st &2nd bonding process
- Require halogen free resin
- Need additional investments (Cu bonder, Forming gas piping)

Gold & Copper Comparisons

1.0 mil copper wire and gold wire properties comparison.[3, 4]

	Cu wire	Au wire
Electrical Resistivity, uohm-cm	1.7	2.3
FAB Hardness, Hv	~ 80	~ 60
Ball Bond Hardness, Hv	~ 128	~ 80
Tensile Strength, gms	8 – 15	10 – 15
Elongation, %	8 – 16	2 – 6

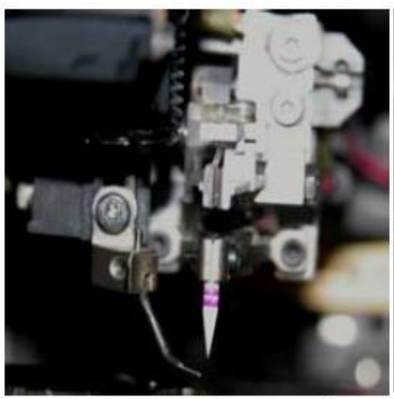


Figure 1a. EFO assembly for gold wire.

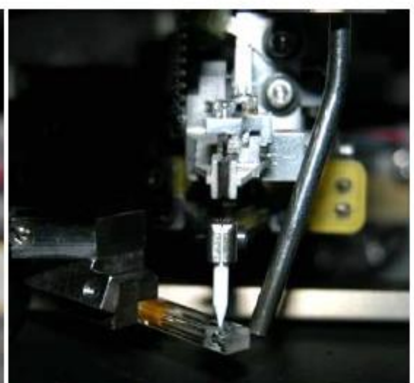
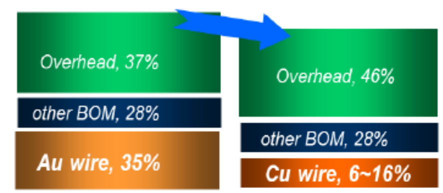


Figure 1b. EFO assembly with forming gas supply for copper wire.

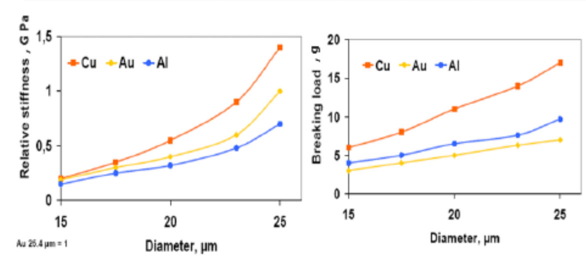
Cost Saving



Better Electrical Conductivity

Physical properties	unit	Cu	Au	Improve
Heat conductivity	W/m.K	395	315	25%
Electric resistance	Mic- ohm.cm	1.67	2.4	43%

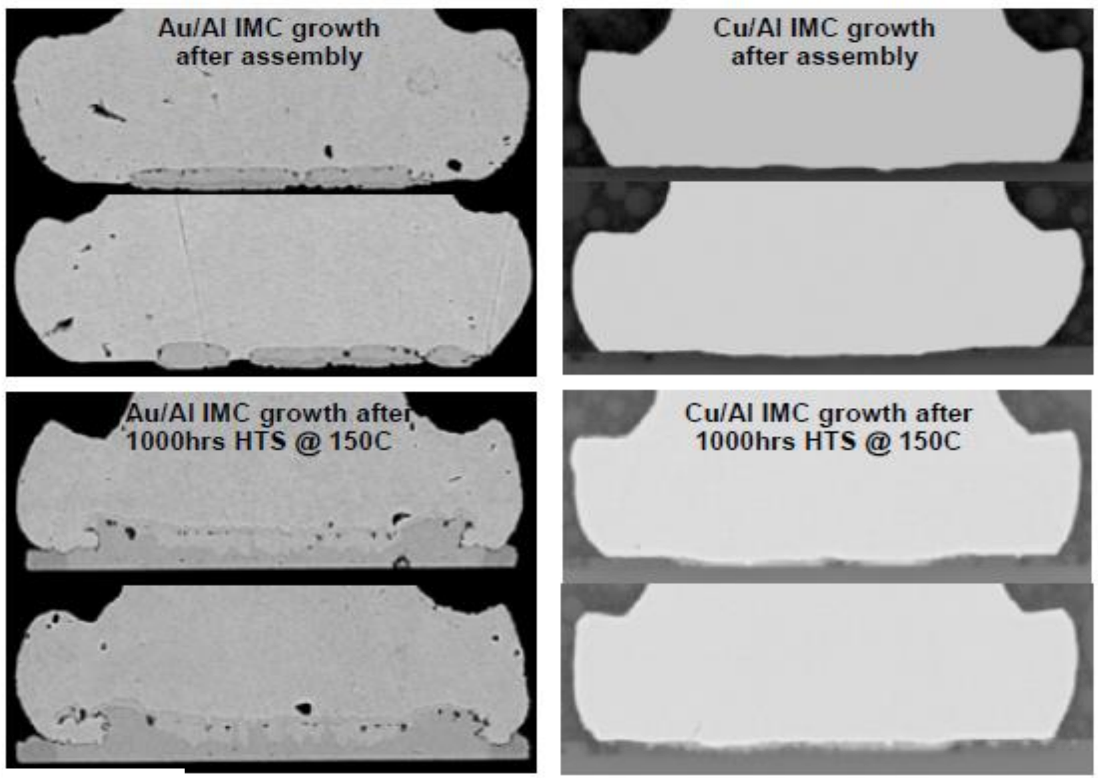
Better Mechanical Properties



Gold & Copper Comparisons

Cu/Al vs. Au/Al IMC reaction rate comparison.

Temperature (deg C)	Cu/Al, K (cm^2/s)	Au/Al, K (cm^2/s)
150	1.878×10^{-16}	1.1×10^{-14}
280	2.645×10^{-13}	2.4×10^{-11}
350	3.747×10^{-12}	3.9×10^{-10}

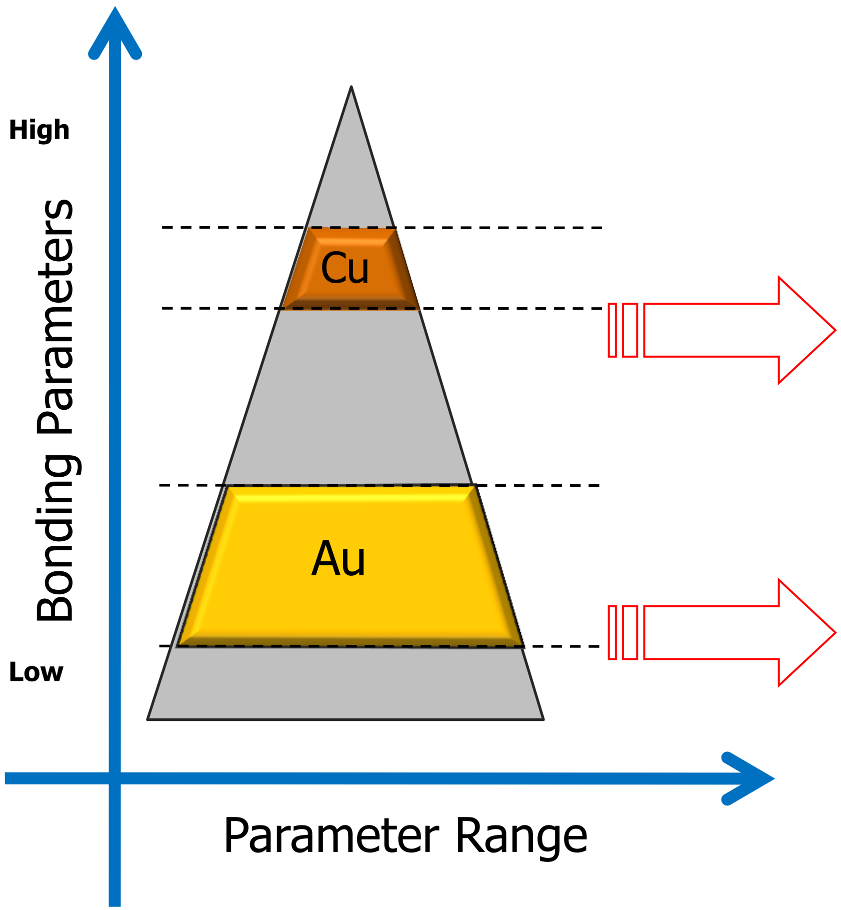


Au/Al vs Cu/Al IMC growth rate comparison.

Copper Wire Challenges (US/Mex Customers)

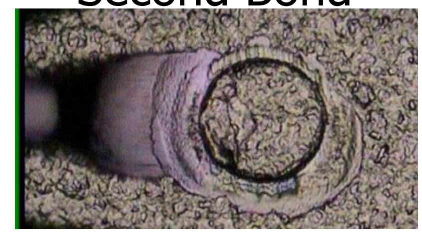
- Challenges of Bare Copper Wire
  - Copper Wire is Hard
  - Die pad crack
  - Al pad splash
  - Narrow process windows (Short tail, fish tail, lifted bonds)
  - FAB (Forming Gas N2H2)
  - Capillary life
  - Reliability (PCT/HAST Failures, Oxidation)

Cu Wire Bonding Process Window Comparison



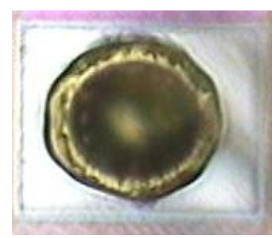
First Bond

Second Bond



High Parameters
Narrow Range

More Force/Impact
Narrow Range



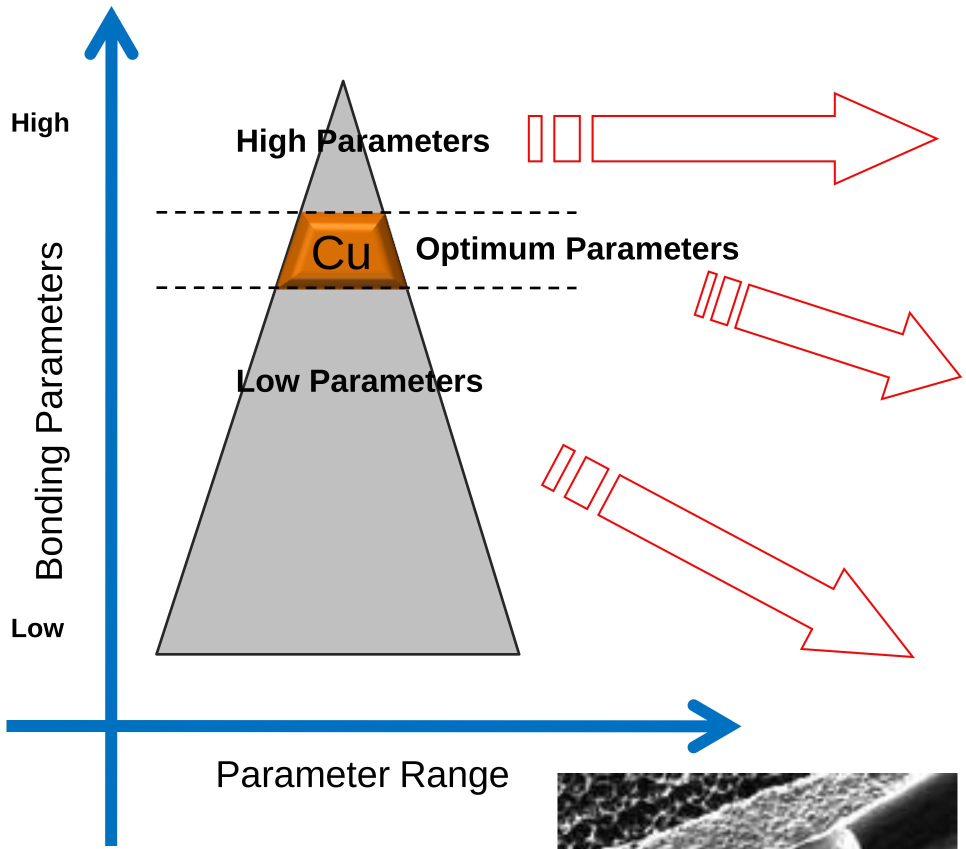
Low Parameters
Wide Range

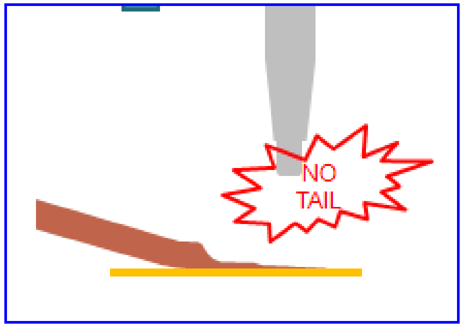
Std Parameters
Wide Range

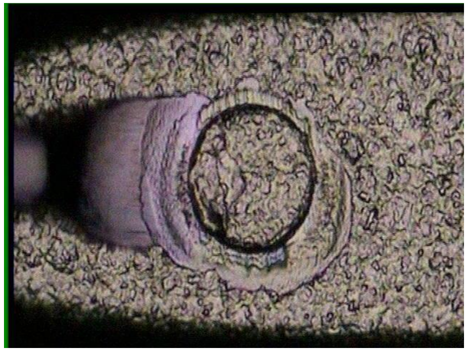
1) Copper wire is harder than Gold wire
2) Copper processes have work hardening issues during looping formation

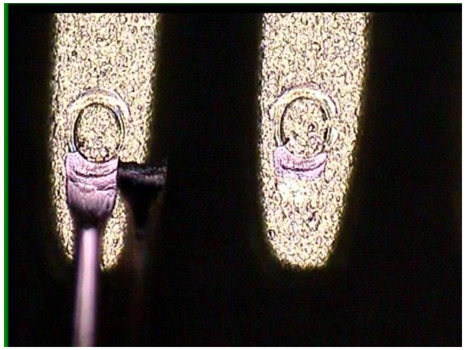
Existing Common problem in Cu bonding

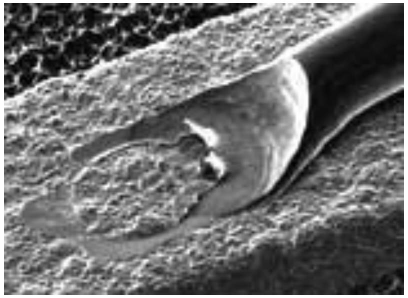
Short tail / No tail issue



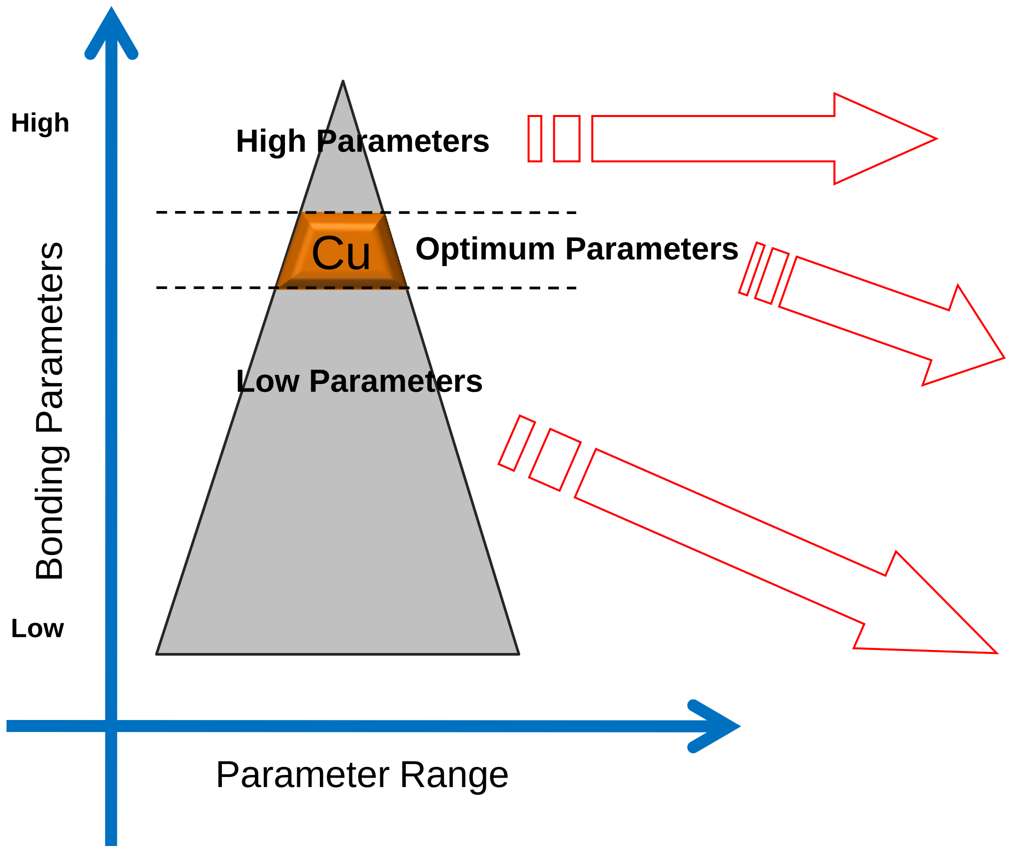




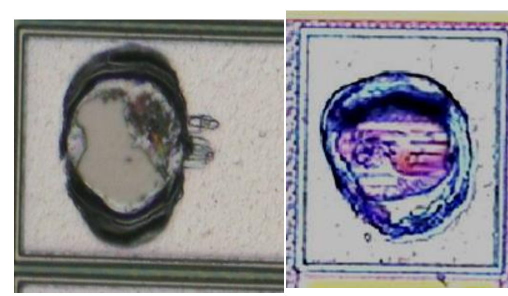


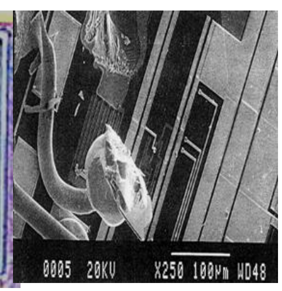


More Common problems in Cu bonding



Aluminum splashing shorting to adjacent pad

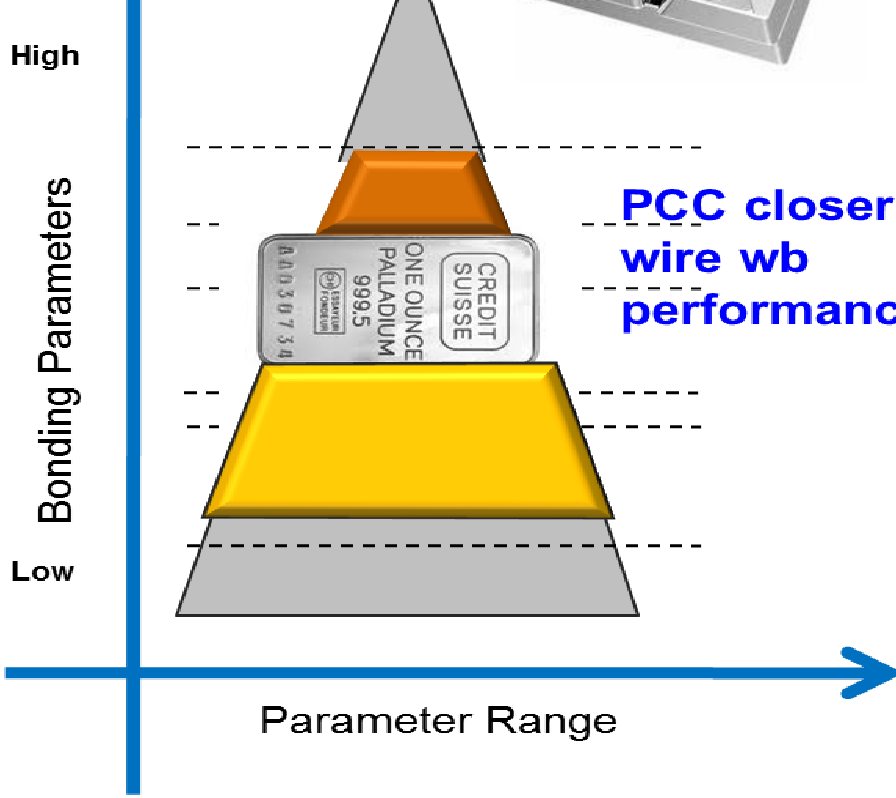




Lifted Metal

1) Die pad-to-pad shorting (Al splash) high parameters
2) Lifted metal occurs at lower side of optimum parameters

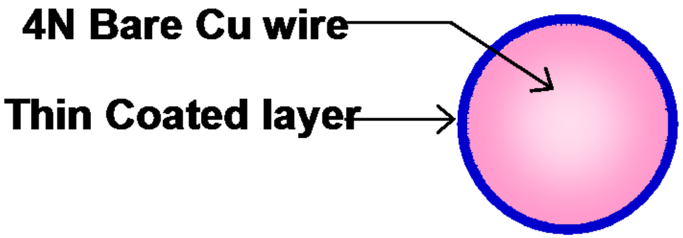
How to achieve process window closer to Au wire and solve Cu wire surface oxidation?

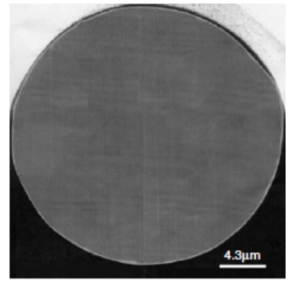


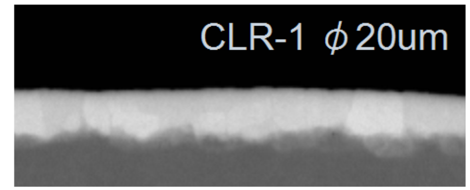
PCC closer to Au wire wb performance

Pd coated

Palladium Coated Wire:

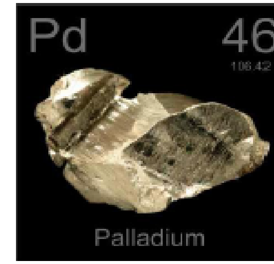






Comparison with Bare Copper wire	
Advantage	**Disadvantage**
Longer Spool Lengths (1km – 5km/spool) **Wider 2nd bond window/Higher 2nd bond pull** **Chemical Stability** **Better HAST (BGA)** **Longer shelf life; 6 months after manufacturing date, 1 month after opening package (bare Cu 1-week after opening)**	**Price is higher than bare copper** **(Au relative value 1.0, bare Cu 0.2, PdCu 0.4 in HVM)** **FAB is harder (possible pad damage)** **Capillary Life**

Palladium Coated Copper Wire

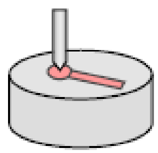


- Atomic # 46 Member of the Platinum Group Metals (PGM)
  - ½ worlds supply goes into catalytic converters
  - Palladium is used as an oxidation catalyst
  - Palladium has lowest melting point of the PGM'S
    - It is soft and ductile when annealed and greatly increases its strength and hardness when it is cold-worked
  - 3N Copper FAB is 30% harder than Au FAB
  - PdCu alloy FAB harder than bare Cu FAB
- Oxidation Free (longer storage/shelf & bonder life)
- Palladium Copper bonded products are 'one-to-one' pin compatible with Au bonded products.
  - No form, fit or function change
- SMT and System level customers do not need to do anything different in receipt and use of the Palladium Copper products

Au/Cu/PCC Hardness & Compression Comparisons

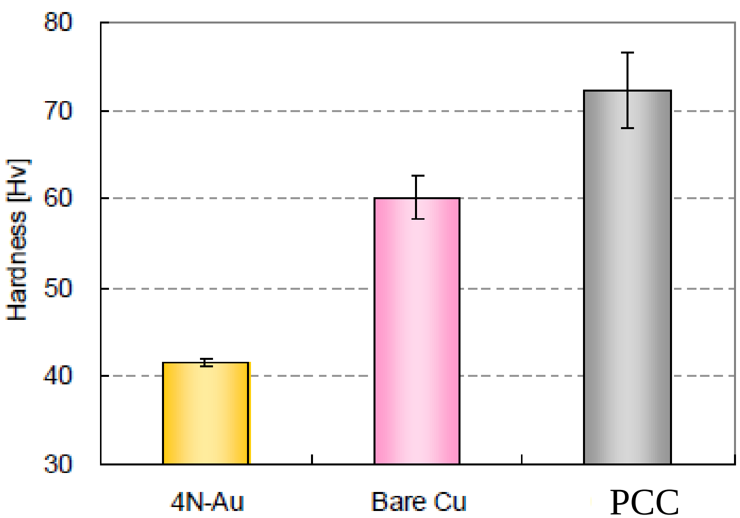
- Cross section Hv hardness of FAB

【FAB Making condition】
- Wire: ϕ20μm
- FAB: 40μm
- Bonder : Maxum plus
- Gas : N_2-5%H_2



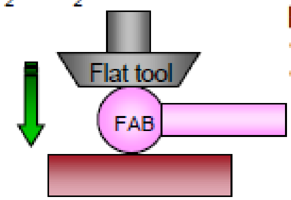
【Measurement Equipment】
- Hardness Tester : MVK-3 (AKASHI)

【Measurement condition】
- Force : 2 gf
- Press Speed : 3μm/sec
- Hold time : 10sec
- Measurement count n=5 each



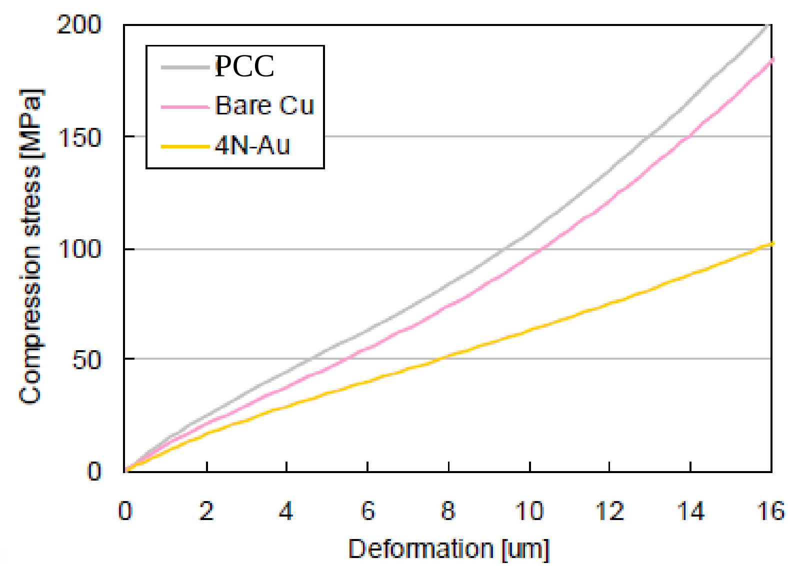
- Compression stress of FAB is squashed side direction

【FAB Making condition】
- Wire: ϕ20μm
- FAB: ϕ40μm
- Bonder : Shinkawa UTC-1000
- Gas : N_2-5%H_2



【Measurement Equipment】
- Compression Tester : MCT-W500 (SHIMADZU)
- Measurement count n=10 each

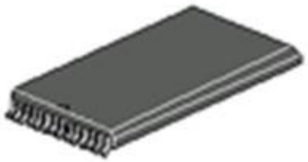
【Measurement Conditions】
- Compression speed: 100mN/sec
- Maximum Load: 1000mN



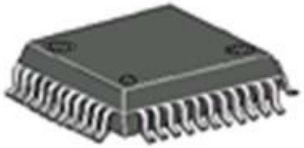
Package type using Cu in production

SOP

TSOP



QFP

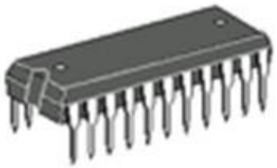


QFN

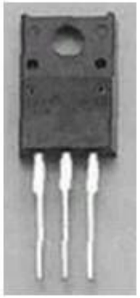
BGA

LGA

DIP



Discrete



Cu Wire is applied even to high pin counts packages

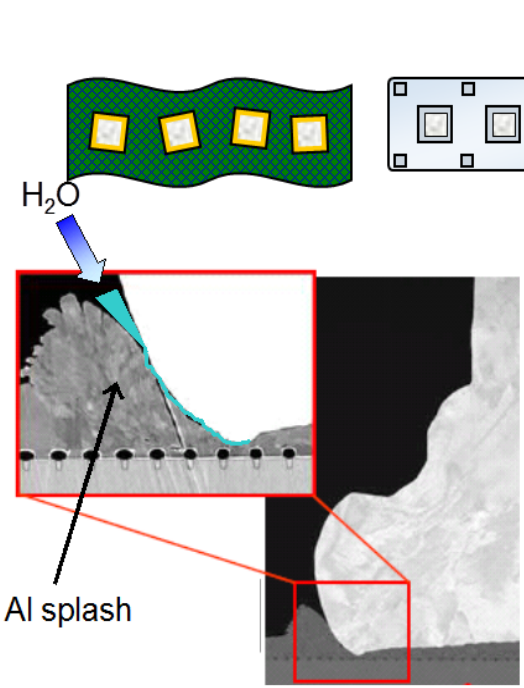
Reliability

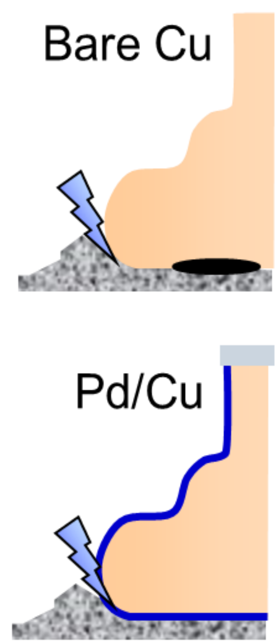
Mechanism of HAST/PCT failures-BGA w/Copper Wire

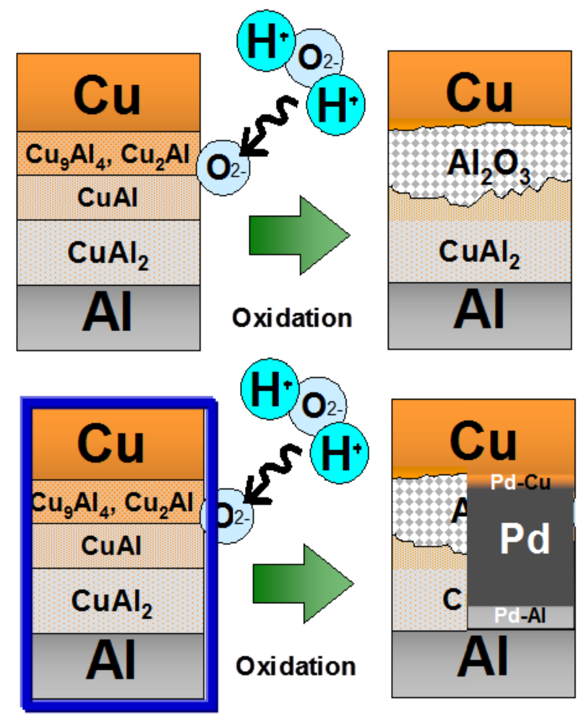
- Cu/Al boundary attacked by moisture on HAST/PCT test of BGA.

- Main failure comes from the corrosion of the First Bond interface leading to crack along the copper ball bond and aluminum bondpad.
- This is called ‘Galvanic’ corrosion which is between Cu-Al IMC and copper bonded ball

- It is presumed that the possibility of preventing moisture attack is HIGH if Pd exists on the copper surface.

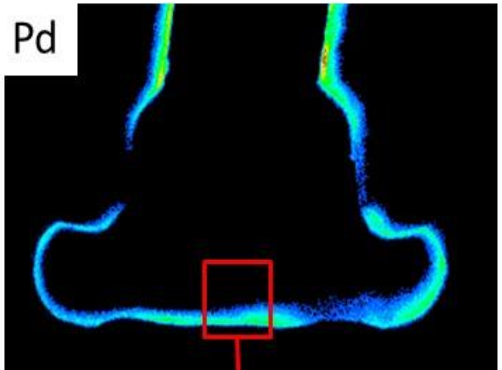




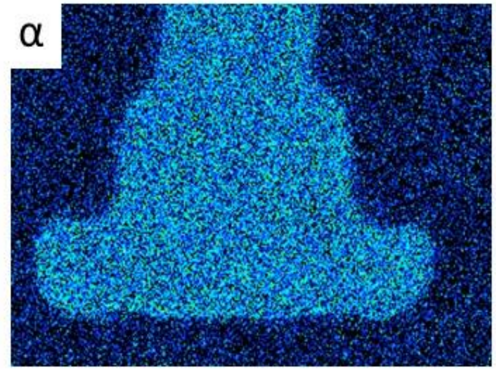


How to prevent corrosion

1. Improve Pd distribution



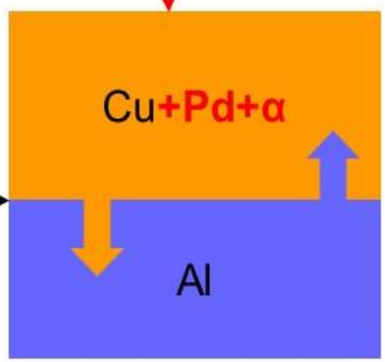
2. Alloying core Cu



EPMA mapping

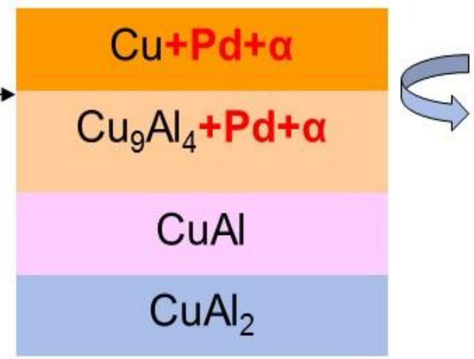
as bond

Original interface



The weakest interface

Heat treatment



S, Cl

During reliability test, Al defuse into Cu and the weakest interface move up to Cu side. Therefor, Pd and alloy element α exist around the weakest interface.

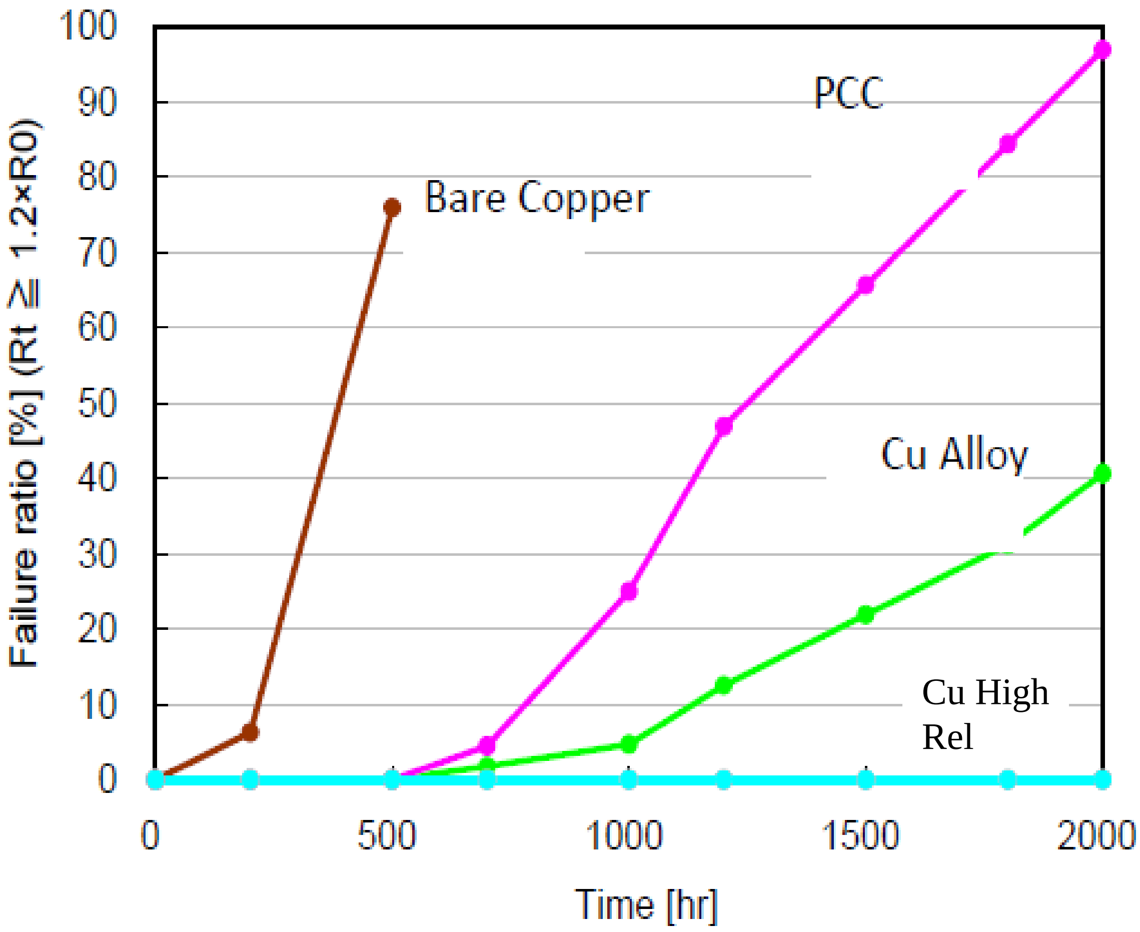
High reliability PCC wire type

Wire type	Electrical resistivity (μ・Ω・cm)	Improve Pd distribution	Better looping	Alloying core Cu
PdCu	1.9			
4N core	1.9			
3N core	2.0			
2N core	2.3			

Reliability Results of HTS 200degC

- CHR type showed best performance amongst all samples

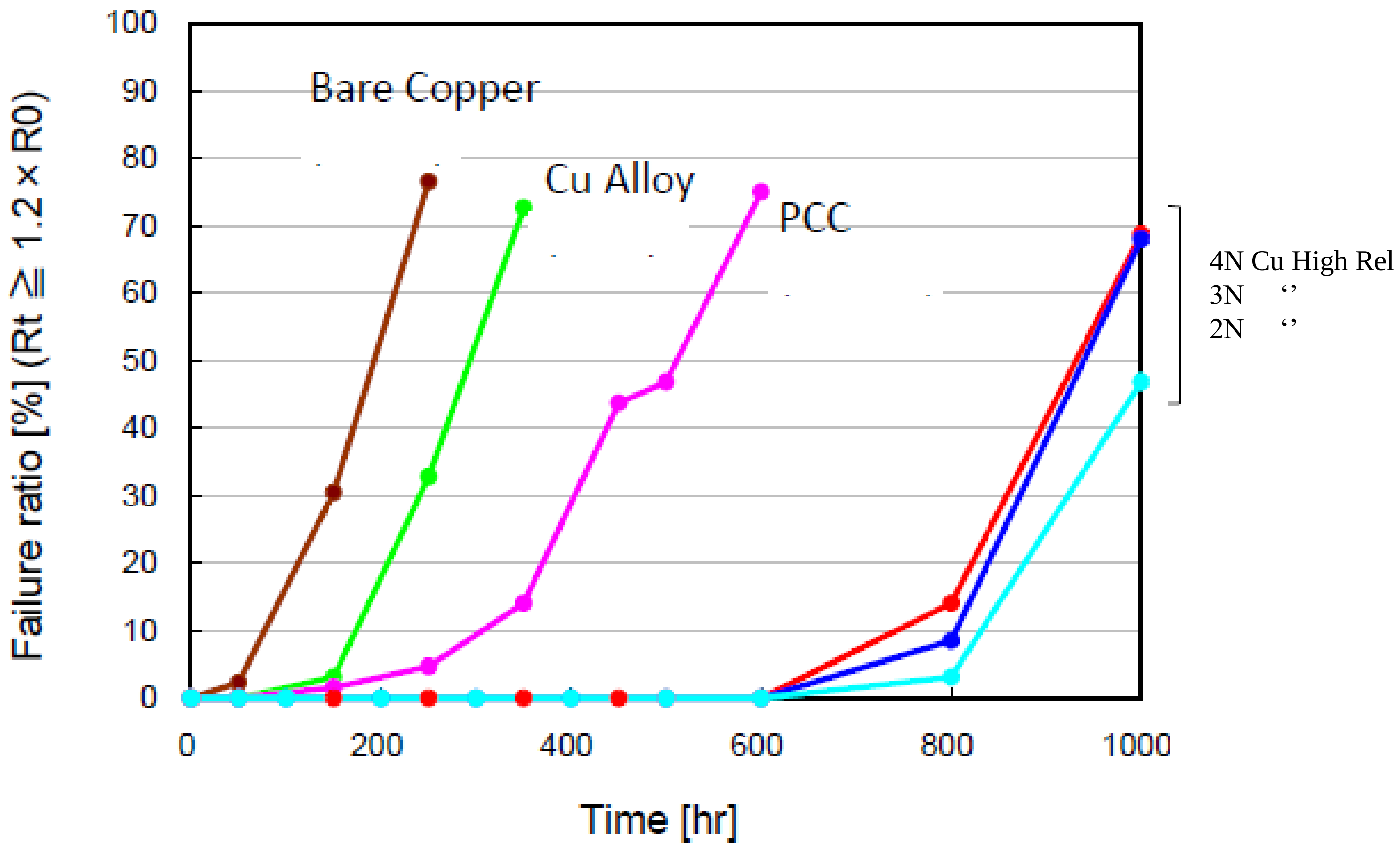
Substrate : PBGA	Bonding : PRO Cu	EFO Current : 65mA
Resin : Halogen Free	Wire Dia : 18um	Deformed Ball : 36um & 9um thickness



Reliability Results of HAST 130degC 85%RH

- CHR type showed best performance amongst all samples

Substrate : PBGA	Bonding : PRO Cu	EFO Current : 65mA
Resin : with Halogen	Wire Dia : 18um	Deformed Ball : 36um & 9um thickness



Benefit Comparison Summary

Categories	Items to compare	Bare gold	Bare copper	PdCu Wire	Comments (on copper and/or PdCu Wire)
Enabling capability	**Material storage, bonder life, long spool lengths**	√	X	√	General benefits from PdCu wire (robust bonding process, no oxidation, etc.)
Economics	**Cost savings (wire cost)**	X	√	√	Lower material cost
	Extra cost for wire bonding	√	X	Δ	Copper kit and use of forming gas during bonding
Performance	**Electrical resistivity**	X	√	√	About 20% lower
	Long term reliability	X	√	Δ	Slow IMC formation
	Heat dissipation	X	√	√	Higher thermal conductivity
	Wire bonding (first bond)	√	X	Δ	Cratering on pad structure
	Wire bonding (second bond)	√	X	√	Narrow bonding window bare copper on some surfaces
	Capillary life	√	X	Δ	Could be improved with PdCu wire

X : Worse, √ : Better, Δ: Potential improvement compared to bare copper

Thank You For Your Attention!