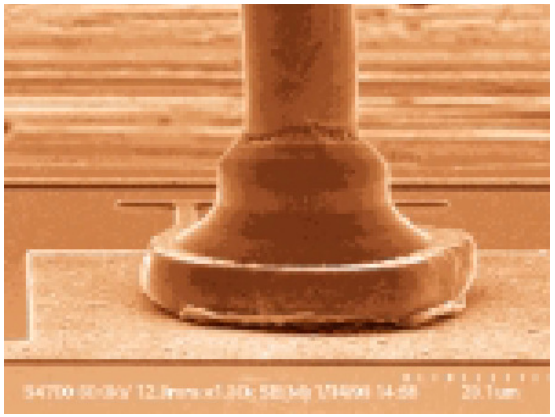
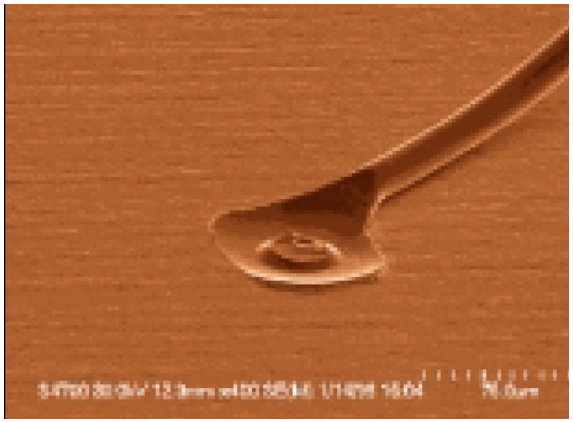
ESCCON 2016



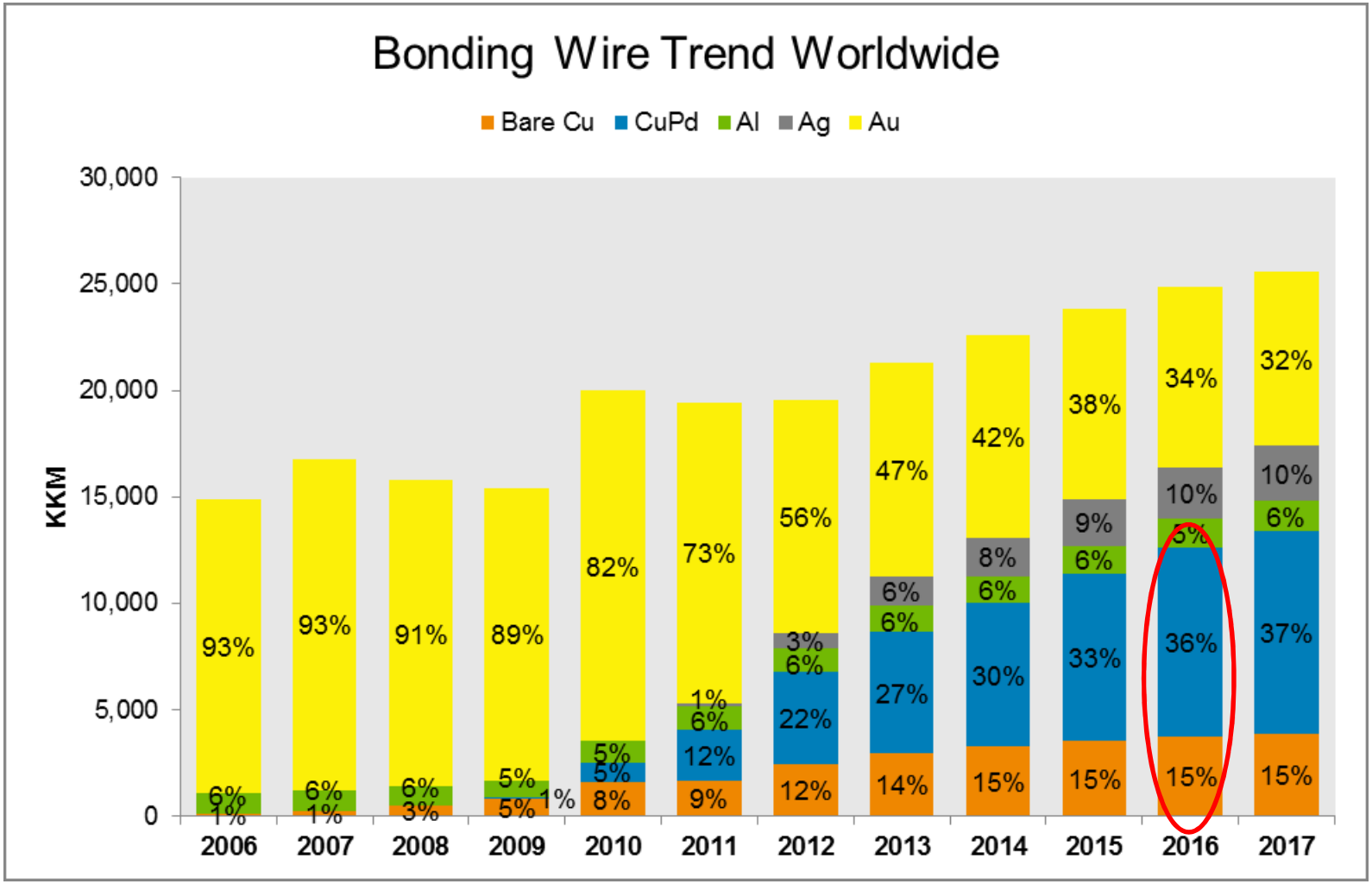


Cu Wire Reliability Evaluation, Implications for Space Components

Summary

- Wire Bonding Trend Worldwide
- Why Cu Wire?
- Why to replace Al Wire Bonding for Space Components?
- Cu or Au Wire Bonding?
- Known Cu Risks
- Cu Wire State of the Art
- Reliability Results
- Cu Wire Bonding applicable for Space Components?

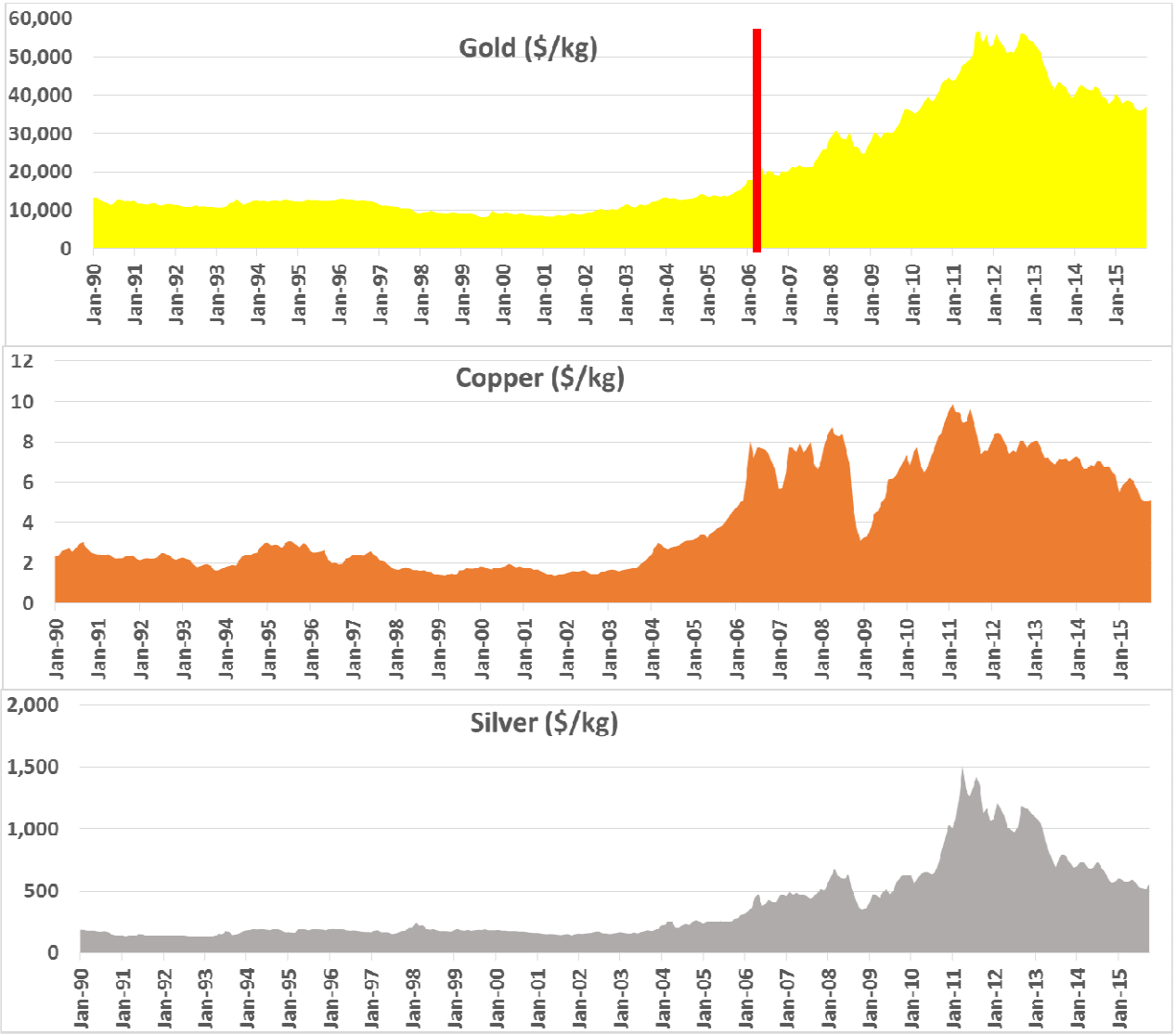
Wire Bonding Trend Worldwide



Source: SEMI Industry Research and StaMsMcs, November 2013

Why Cu Wire?

Cost



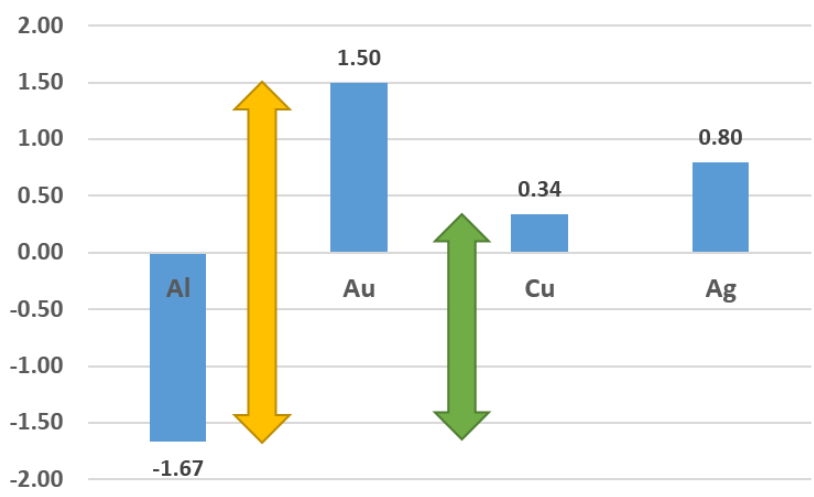
~Gold/10,000

~Gold/100

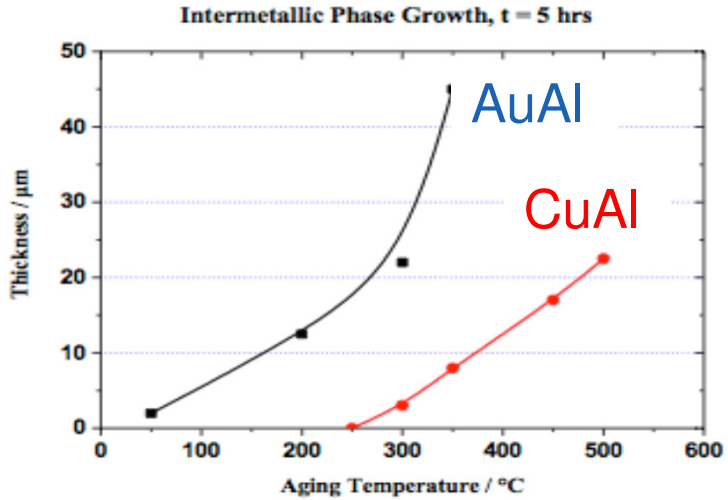
Why Cu Wire?

Technical Parameters

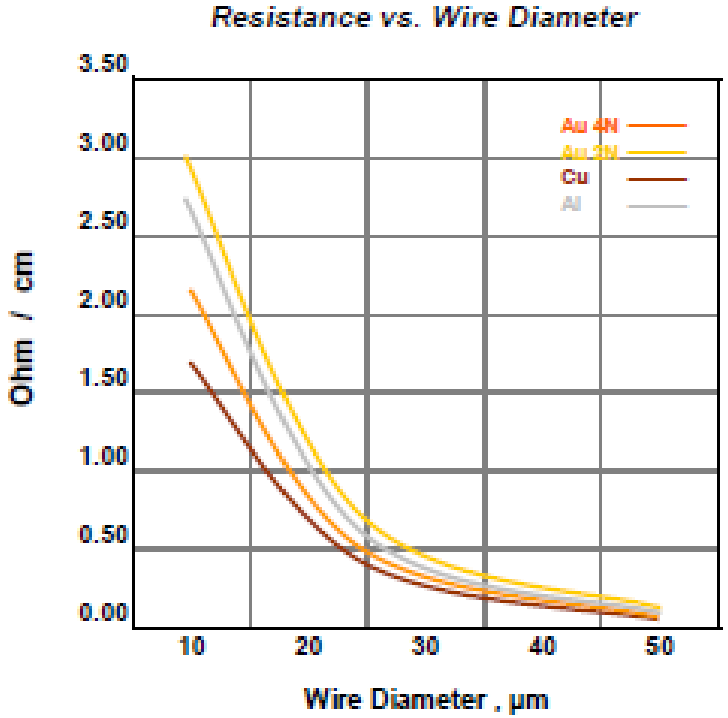
Electrode potential



Intermetallic growing



Electrical resistance

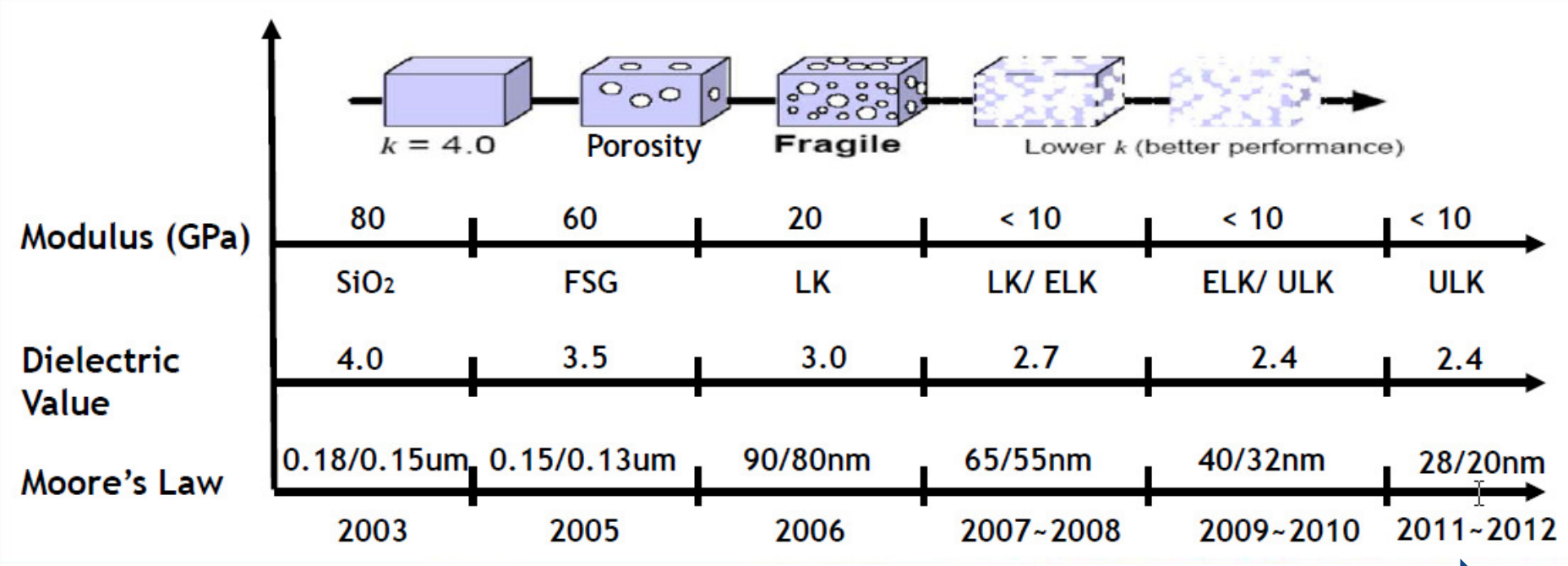


Thermal conductivity

Material of wire	Thermal Conductivity (W/m.K)	Comparison
Gold	318	1
Copper	390	1.23

Why to replace Al Wire Bonding for Space Components?

Si Technology Shrinkage ⇒ More Fragile Dielectric Layers

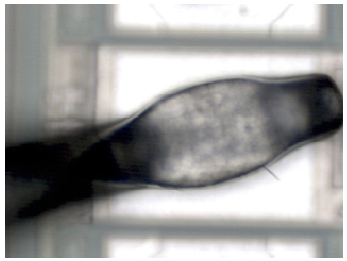


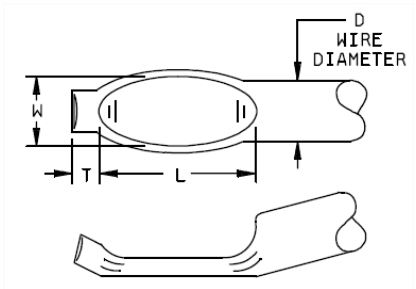
Al wire ⇒ Ultrasonic wire bonding

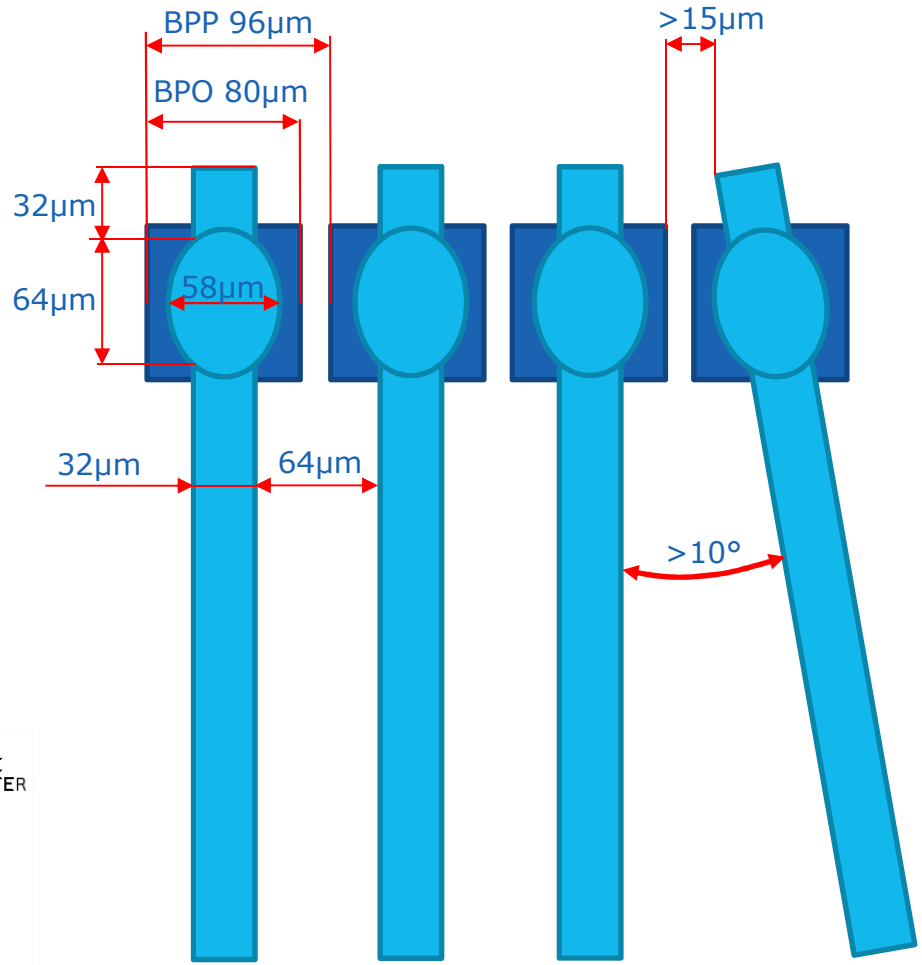
Why to replace Al Wire Bonding for Space Components?

Si Technology Shrinkage ⇒ Lower Bonding Dimensions

- To Date (ATMEL 150nm)
  - Dielectric: SiO_2 – FSG
  - Al wire diameter D= 32µm
  - Ultrasonic wedge bonding
    - Angle limitation
  - Min bond pad pitch: 96µm
    - 2 row staggered
    - 2D insulation: ≥64µm
  - Bond pad opening: 80µm
    - W std 1.8D= 58µm
    - L std 2D= 64µm
    - T std 1D= 32µm



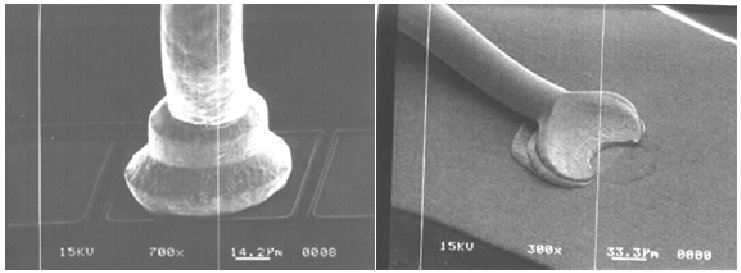


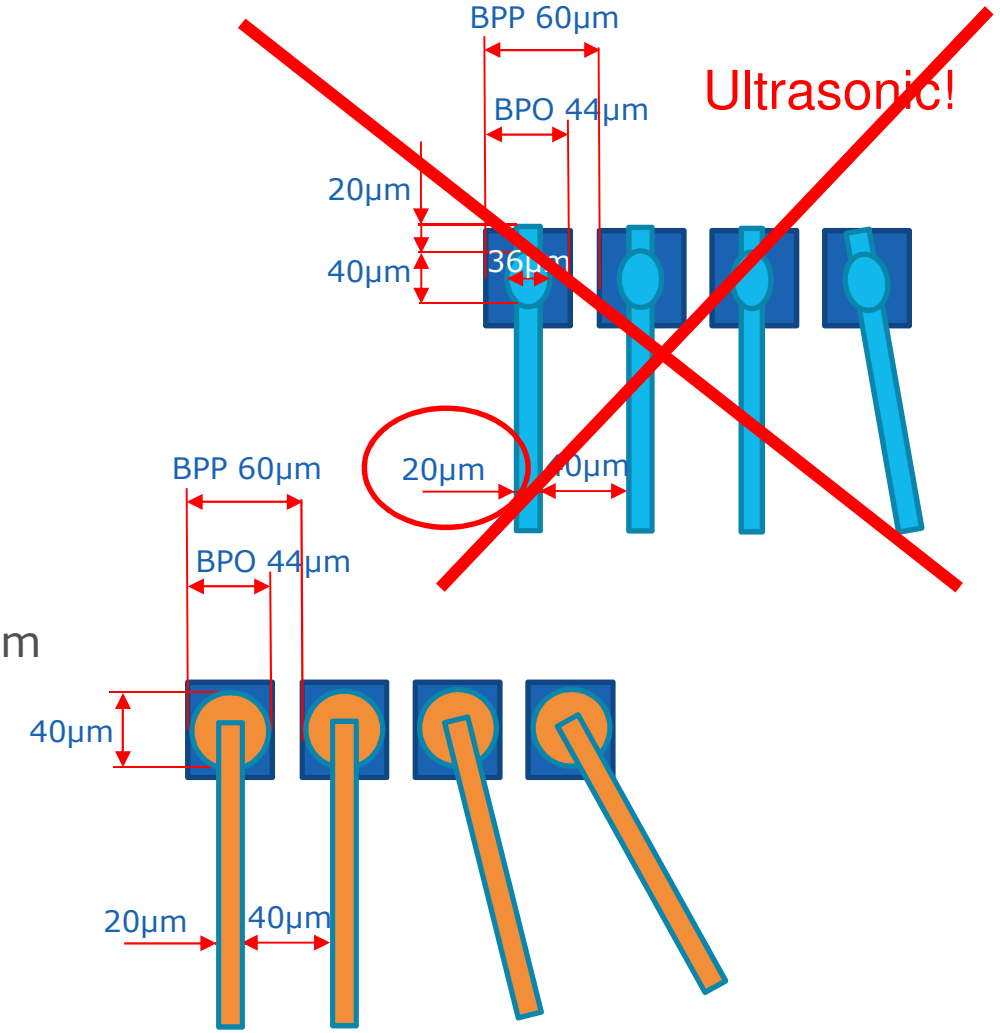


Why to replace Al Wire Bonding for Space Components?

Si Technology Shrinkage ☐ Lower Bonding Dimensions

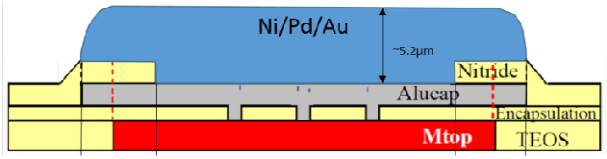
- To Come (65nm)
  - Dielectric: LowK
  - Wire diameter D= 20µm
  - Thermosonic ball bonding
    - No angle limitation
  - Min bond pad pitch: 60µm
    - 2 rows
    - 2D insulation
  - Bond pad opening: 44µm
  - Ball diameter min: 2D= 40µm





Cu or Au Wire Bonding for Space Components?

- Au wire on Al bond pad
  - Intermetallic growing
    - Life-time 17 years @110°C?
  - Au/Al corrosion risk
    - Low in hermetic package
  - Tight process window
    - Intermetallic
  - Cost
  - Not Compliant with 883/level S
    - Possibility for gold bumping



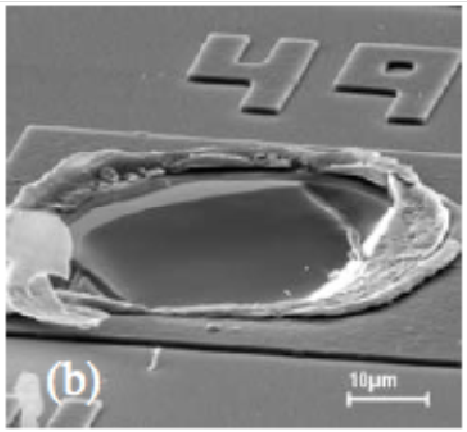
- Cu wire on Al bond pad
  - Low intermetallic growing
    - Life-time 17 years @110°C
  - Cu/Al corrosion risk
    - Low in hermetic package
  - Tight process window
    - Pad crack / Al splash
  - Low cost
  - Not Compliant with 883/level S

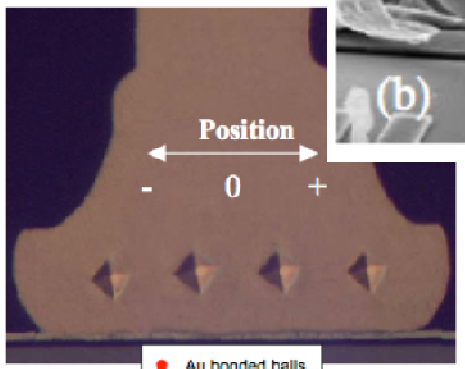
A.3.5.5.2 Internal wire size and material. For class level S microcircuits, the internal wire diameter shall be 0.001 inch minimum (0.0254 mm) or of sufficient diameter to meet the minimum fusing requirements and bond pull strength requirements with the approval of qualifying activity. The internal lead wire shall be the same metal as the die metallization.

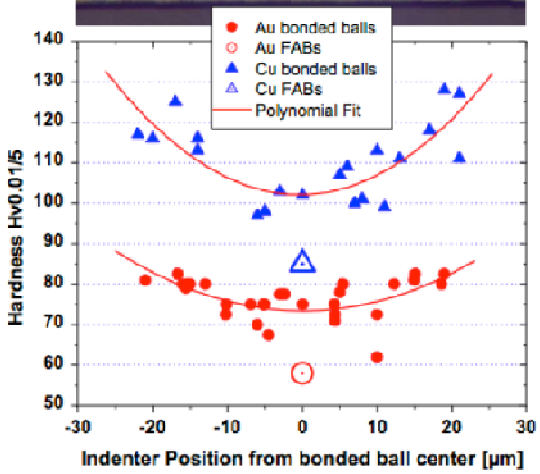
Known Cu Risks

Hardness

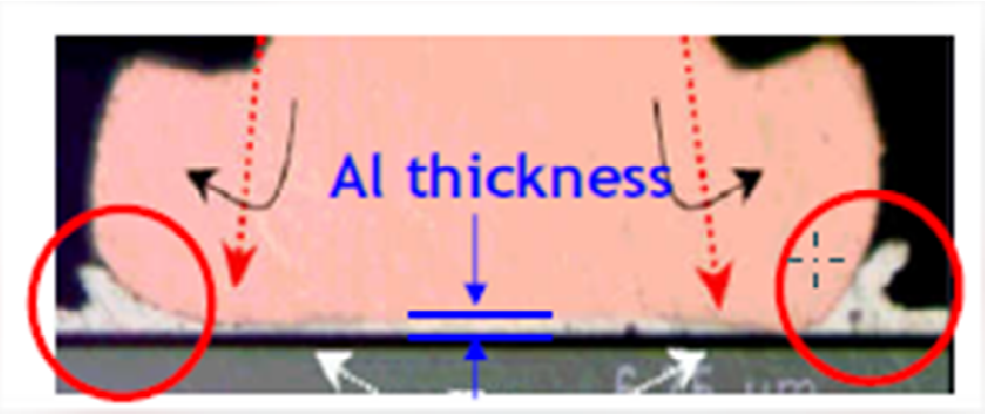
- Pad Crack

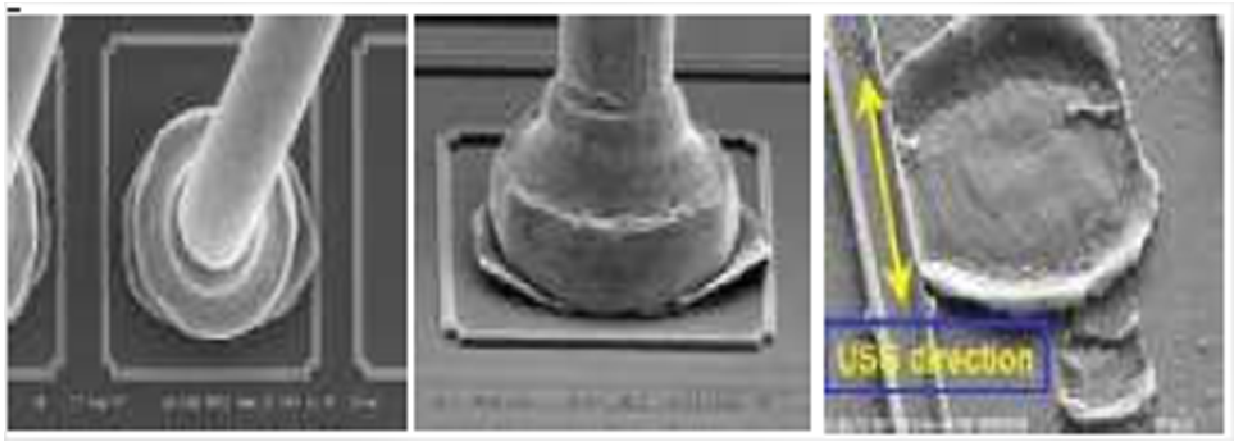






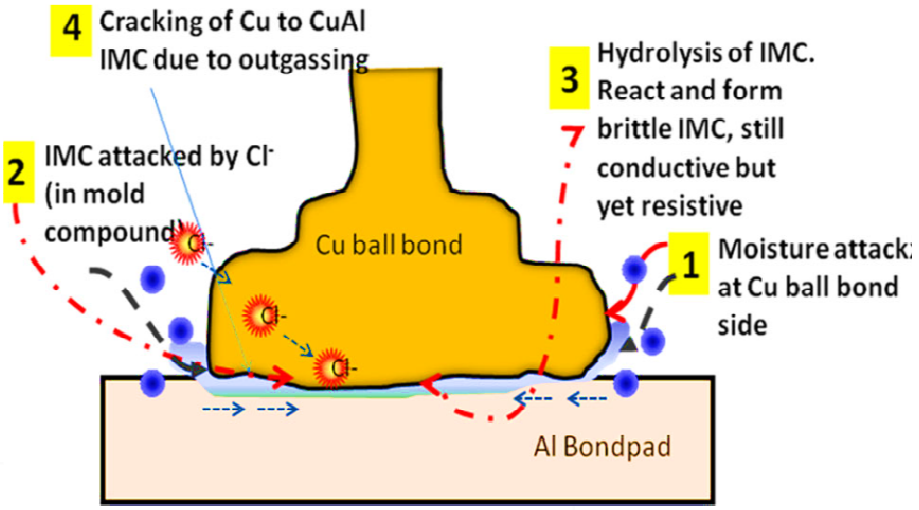
- Al Splash

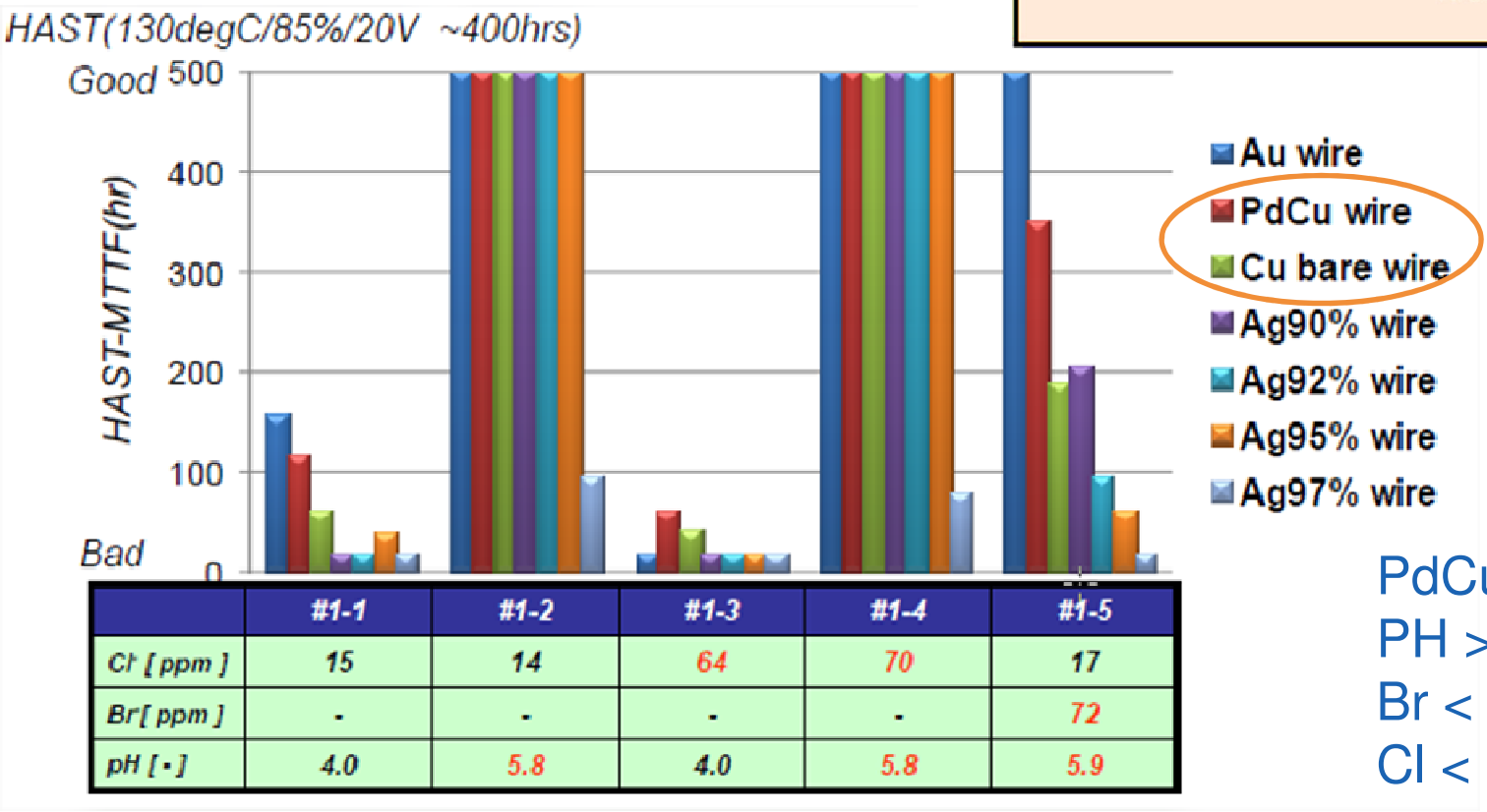




Known Cu Risks

Corrosion – PH/Br/Cl//Moisture





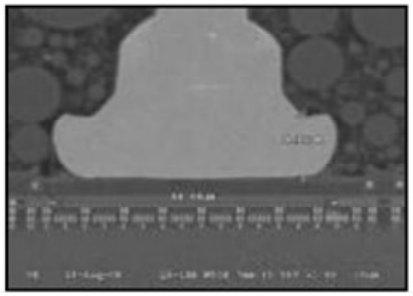
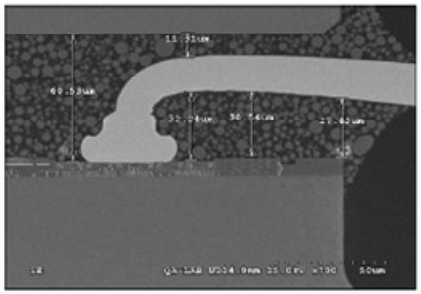
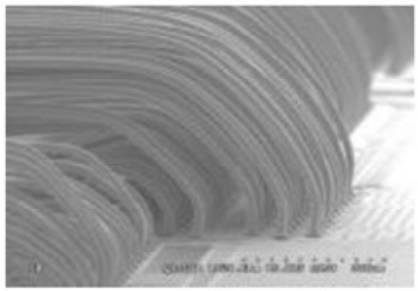
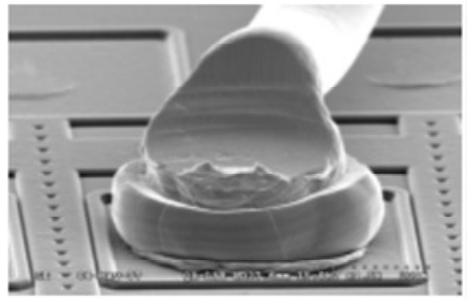
	#1-1	#1-2	#1-3	#1-4	#1-5
Cl [ppm]	15	14	64	70	17
Br[ppm]	-	-	-	-	72
pH [-]	4.0	5.8	4.0	5.8	5.9

PdCu > Cu bare
PH > 5
Br < 50ppm
Cl < 10ppm

Cu wire State of the Art

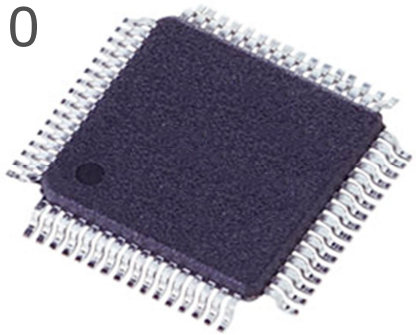
High Volume – Plastic Packages

- Wafer technology: 0.13 Cu/FSG – 90/65/40/28/20nm – LK/ELK
- Bond pad structure: CUP structure
- Bond pad pitch (BPP): ≥ 40µm
- Bond Pad opening (BPO): ≥35µm
- Cu wire diameter: ≥ 15µm/0.6 mils
- Bond pad layout: in line, staggered, up to, 5 tiers, Pad to Pad
- Low loop height: 45µm
- Wire count: > 1500

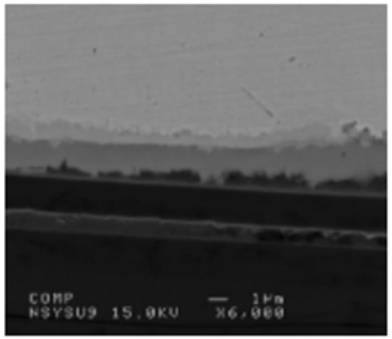
Reliability Results

Example: LQFP176 – Automotive AEC-Q100 Grade 0

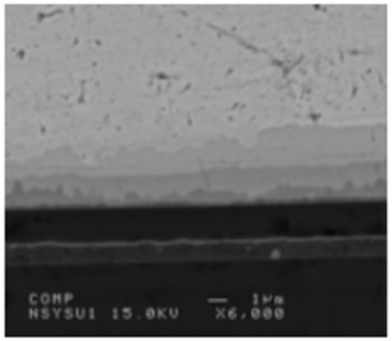


- Body Size: 24x24x1.2mm
- Lead Count: 176
- Wafer process: LowK – 65nm
- Cu wire diameter: 0.8 mils/20µm

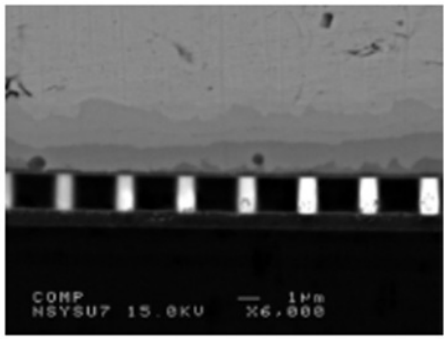
	Result	Requirements	Sample Size	Analysis required
Precon: MSL @ 260°C	Pass L3	L3	0/77	NA
Precon + TC -65/+175°C Precon + TC -50/+150°C	Pass 500x Pass 2000x	500x 2000x	0/45	5 unit wire pull/ball shear after decap
HTS 175°C (no precon) HTS 150°C (no prcon)	Pass 1000hrs Pass 2000hrs	1000hrs 2000hrs	0/77	NA
Precon + uHAST (121/130)	Pass 96hrs	96hrs	0/77	NA
Precon + THB 85/85	Pass 1000hrs	1000hrs	0/77	NA



HTST 300hrs (@225C)



HTST 500hrs (@225C)



HTST 1000hrs (@225C)

Cu Wire Bonding applicable for Space Components?

- Hermetic Ceramic Packages: YES
  - CuPd (PCC)
  - PH > 5
  - Br < 10ppm
  - Cl < 10ppm
  - H_2O < 5000ppm

  Only related to die attach
  - Al Thickness ≥ 1.0µm
  - DOE to each new device (tight parameters window)
  - Cu wire option to allow in MIL or ESCC

A.3.5.5.2 Internal wire size and material. For class level S microcircuits, the internal wire diameter shall be 0.001 inch minimum (0.0254 mm) or of sufficient diameter to meet the minimum fusing requirements and bond pull strength requirements with the approval of qualifying activity. The internal lead wire shall be the same metal as the die metallization.

- Molded Packages: YES but
  - Halogen free materials (BGA substrate – die attach – molding compound) – compliant with ECSS-Q-ST-70-02 outgassing standard
  - Br/Cl lot to lot content stability in materials
  - Sensitivity to moisture (HAST)
  - Dry pack/MSL level to apply?