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Is Cu Wire-Bonding for Real?

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The Move to Copper on ICs

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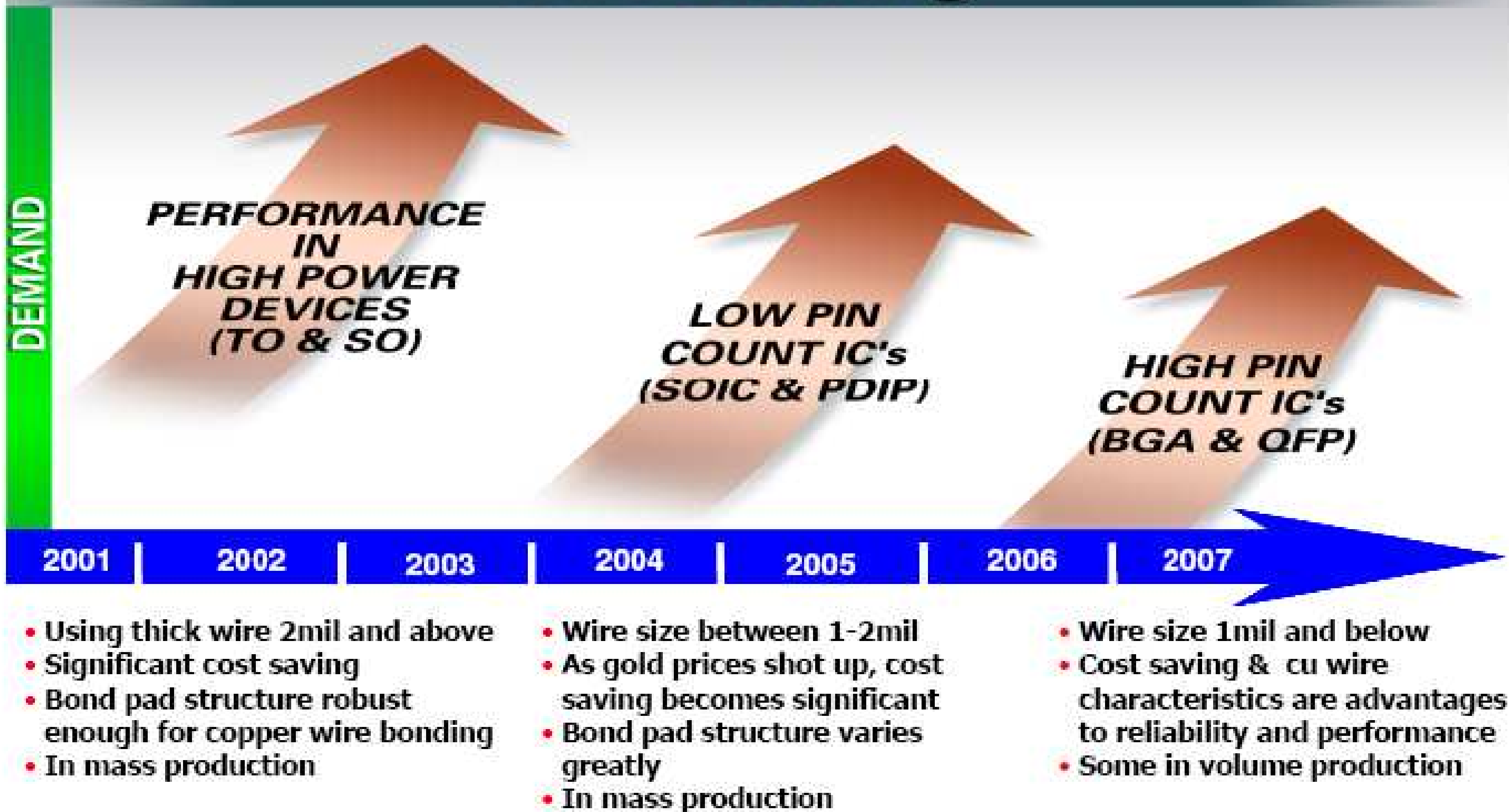

Historical Perspective

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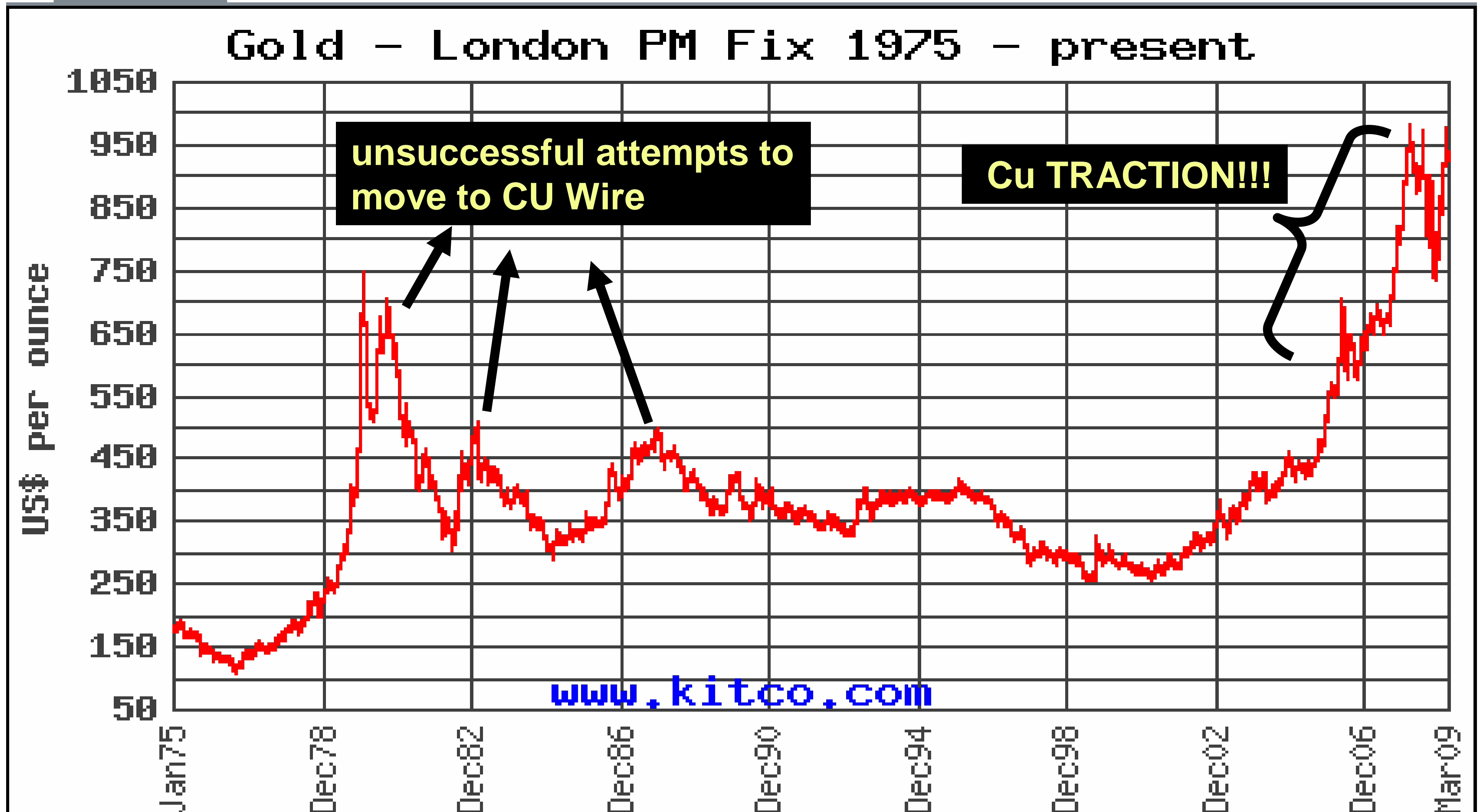

The Opportunity – Savings !!!!

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Wire Diameter (um)	Cost Wire - per KM			
	Gold @$800	Gold @$900	Gold @$1000	Copper
20	186	205	225	40
25	274	304	335	40
30	381	425	469	40
38	593	664	734	40
50	1005	1127	1249	40
75	2224	2498	2772	40

Note:
These savings need to be offset with other expenses such as "forming gas"; equipment modifications, throughput reductions etc.

Copper TAM Growth

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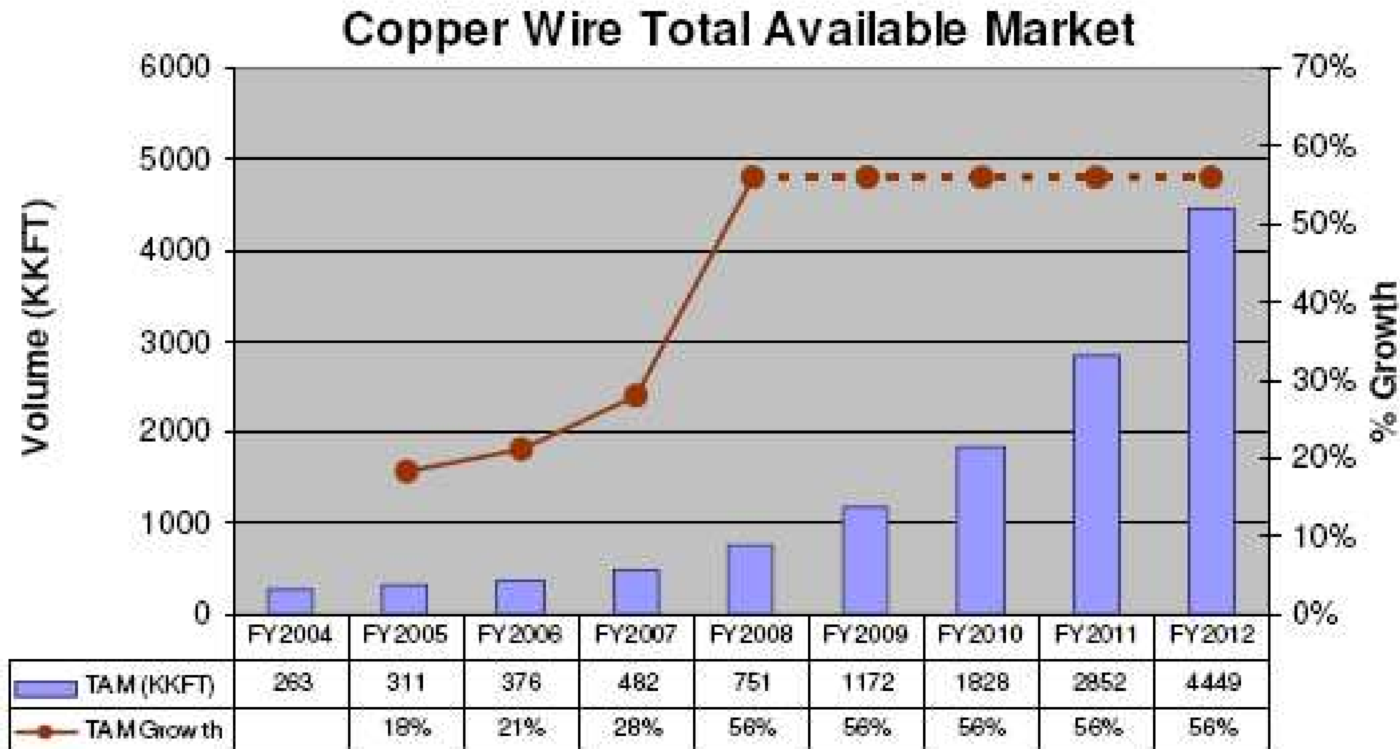

	FY2004	FY2005	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012
TAM (KKFT)	263	311	376	482	751	1172	1828	2852	4449
TAM Growth		18%	21%	28%	56%	56%	56%	56%	56%

- Semi's Global Packaging Outlook Forecasted copper CAGRs ('06-11) ~ 50%
- Growth rates are accelerating
  - Growth so far by larger adoption of Cu-wire in traditional (discretes and power IC) applications
  - Further (even higher) growth expected from adoption of IC fine-wire applications
- Cu TAM currently ~1.7% of Ball-bond wire, Cu in 2012 ~6.7% of Ball-bond wire

Growth in Cu-Wire by Quarter - Indexed

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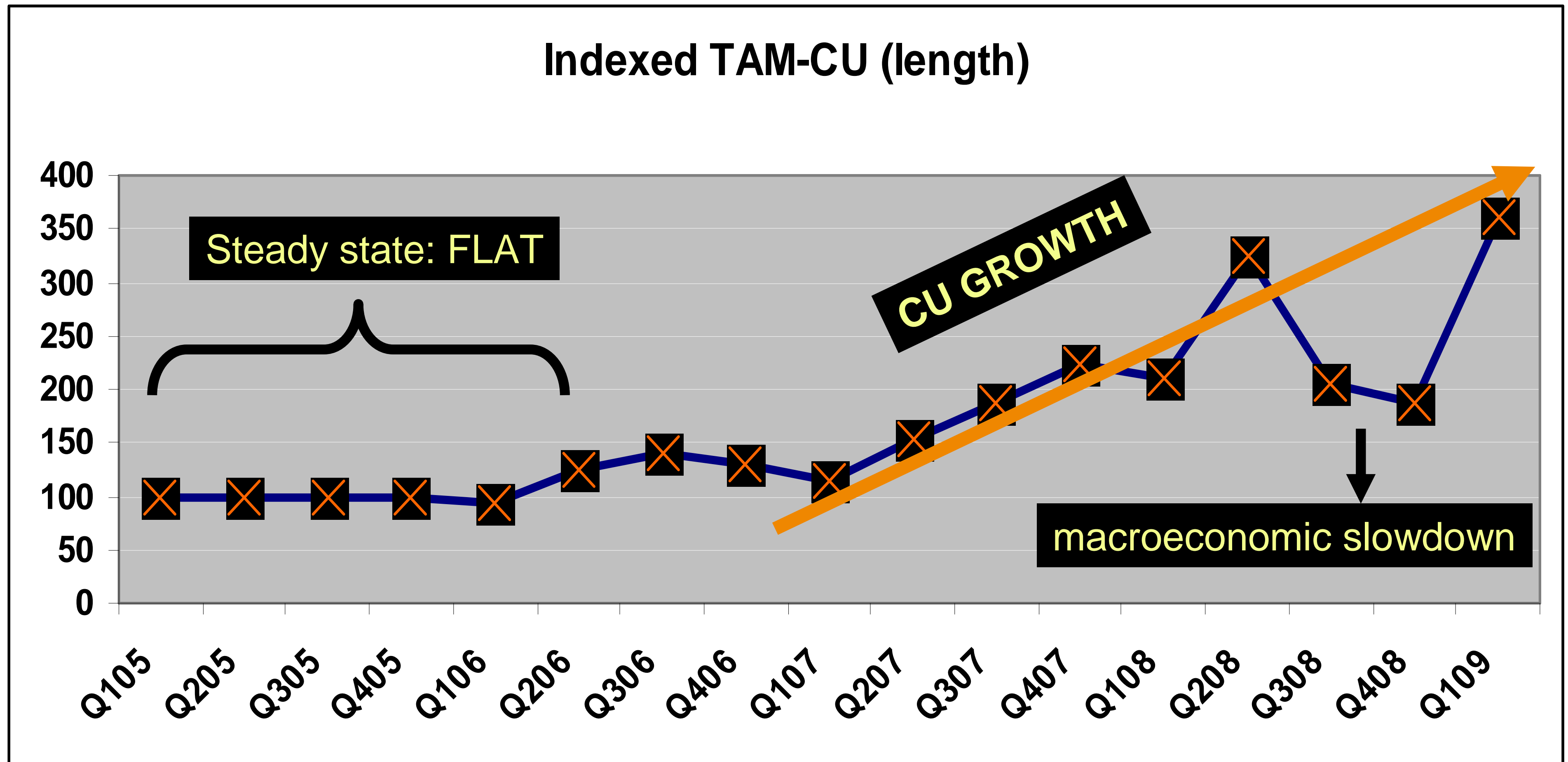

2007 was the onset of the turning point in Copper Consumption

Source: Heraeus

2008 vs 2007 Growth by segment

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	2007	2008	Growth
TAM(KFT)	51,712	159,711	**209%**

	2007	2008	Growth
TAM(KFT)	28,930	91,888	**218%**

IC

TAM Growth **212%**

TAM : 2008

251,599 KFT

	2007	2008	Growth
TAM(KFT)	61,276	130,673	**113%**

	2007	2008	Growth
TAM(KFT)	373,084	466,701	**25%**

DISCRETE

TAM Growth **38%**

TAM : 2008

597,374 KFT

Fine Cu : <=1.3MIL

TAM Growth **157%**

TAM : 2008

290,384 KFT

Heavy Cu : >1.3MIL

TAM Growth **39%**

TAM 2008

558,589 KFT

2008 overall WW copper growth ~ 65%

Note :

- TAM means total available Market World wide

- Data was based from Product Marketing Estimate WW by HMSL

W. C. Heraeus GmbH, Roman Perez, HMSL-BW, Mar. 2009

Recent Trends

- **Cu appears to have now gained significant traction as noted by its recent growth**
- **Fine Cu wire (<1.3 mils) is growing more rapidly than the traditional heavy wire (used in power packages)**
  - **On a run rate basis fine wire consumption has exceeded heavy wire**
- **Cu in IC applications is growing more rapidly than traditional discrete devices**
- **One could conclude that Cu has now achieved critical mass**
  - **At least from the standpoint of qualifications etc.**
  - **Next year is going to be key transition year**
    - If transition is successful, clearly CU will be a significant part of all ICs interconnected

What's Different Now?

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- **Immense cost-reduction pressure**
  - **Sustained high gold prices**
- **Physics has not changed**
  - **Improvements in equipment and tools**
    - Better bond control (precision, ultra-sonics etc.)
    - Improved inert gas distribution systems
    - Advanced capillary design knowledge
  - **Improved bonding wires**
    - Tighter tolerances
    - Improved surface consistency
    - Softer Materials
  - **Growth in the use of non-Al pads**
    - Mostly Al pads
    - However higher use of non-AL Pads
  - **Improved encapsulants**
  - **Increased tolerance by users to narrower process windows**
    - driven by overwhelming cost reduction pressures

Cost Reduction Approaches

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Thinner wires

- **Movement to smaller diameter gold wires reduces significant costs**

Alternates to Gold

- **Reduced Gold Content**
  - Example : AU/AG (reliability issues on Al pads)
- **Bare Copper**
  - **This is the mainstream alternate approach**
- **Palladium coated Copper**
  - Higher in cost that copper
  - Issues with 1st bond…inconsistent balls
  - Still needs forming gas
  - improved 2nd bond performance
- **Au coated Copper**
  - Inconsistent balls

If Bare Copper works other alternatives for niche applications only

Copper Technical Challenges

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- **Copper oxidizes rapidly**
  - **Hence the drive for reducing gas (forming gas) atmosphere at ball formation**
- **Spool shelf life**
  - **Unclear how long spools can be left in open environment**
  - **Definitely shelf life is not as long as gold**
  - **However, a week is clearly not a problem (once opened)**
  - **Sealed container (6 months in Dry box or N2 environment)**
  - **New manufacturing discipline required**
- **Copper is "harder" than gold (see next slides)**
  - **1st and 2nd bond characterization required**
  - **Not plug and play like gold**
- **Copper reliability is a function of quality of "as bonded" bond-quality**
  - **Good "as-bonded" bonds result in good long term reliability**

Copper – 1st bond Challenges

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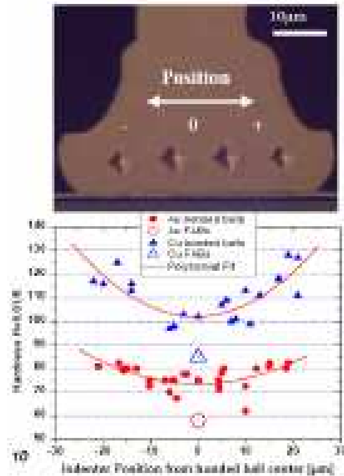
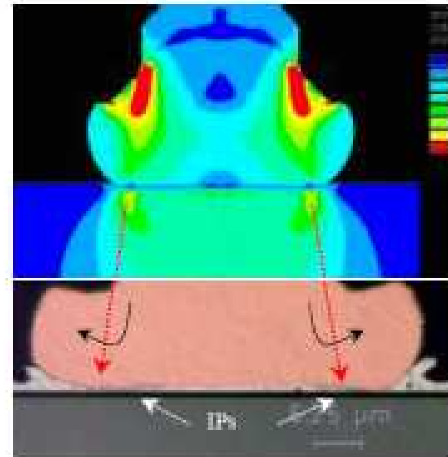
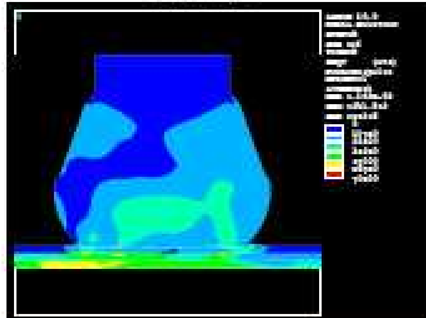
Cu is Harder than Gold

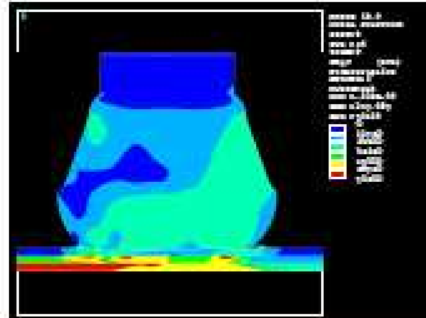




GOLD

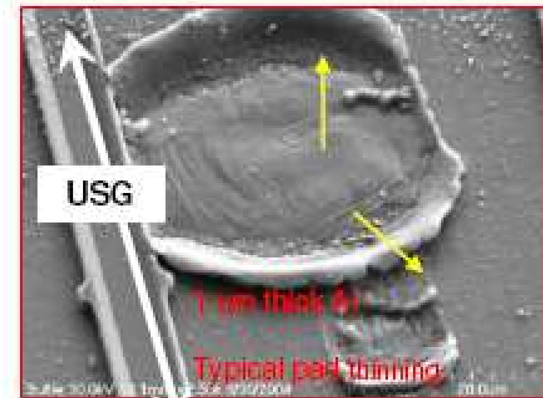


COPPER



Copper process have roughly a 25% increase in the maximum stress compared to an equivalent gold ball bond

Pad Damages During Bonding



Pad Cratering

Metal lift after 1st bond pull

dielectric on bottom of ball

failure mode within aluminum

Copper – 2nd Bond Challenges

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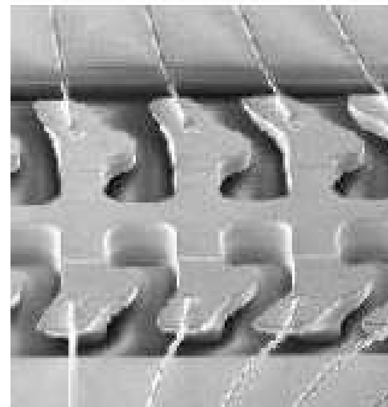
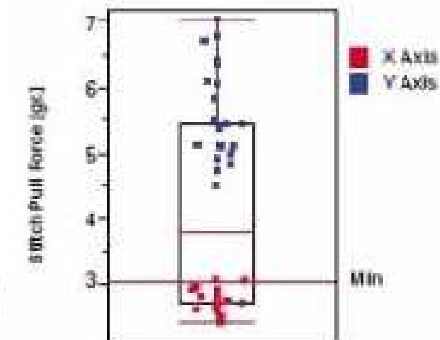
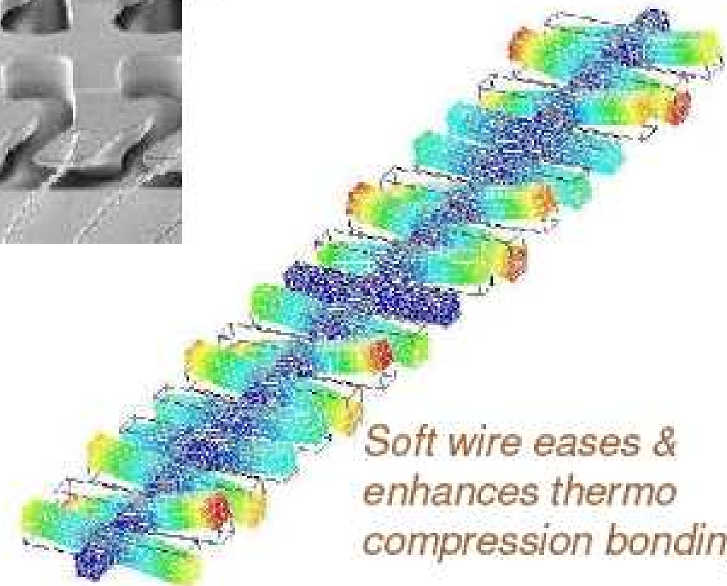
QFN Substrate Characteristics make it more difficult for 2nd bond

- **No Individual Device Clamping**
  - Lead instability during bonding
  - No clamp supporting leads of QFN ribs – limited clamp at perimeter ribs
  - Lead resonance can cause NSOL and SHTL.
- **Tape underneath**
  - Further reduce the contact between the H/B and leads
  - Reduces heat transfer to lead for effective bonding
- **Ni Palladium L/F with Nickel-Gold**
  - Very hard to stick if Nickel-Gold layer is too thin
  - Interdiffusion induced unbondable surface due to long heating in high temperature – if barrier is thin



Stitch Pull variations in Leadframes Packages





Soft wire eases & enhances thermo compression bonding!

Ref. Semicon West 2002, McDivitt, Solving Wire Bond Challenges for QFN Packages

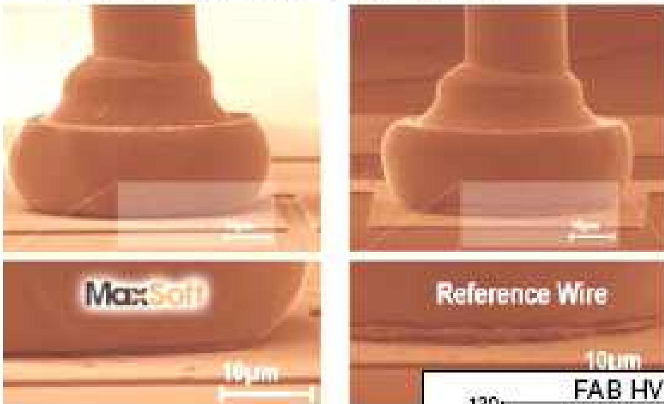
W. C. Heraeus GmbH, Roman Perez, HMSL-BW, Mar. 2009

Copper Wire – Solution: Softer Wire **Heraeus**

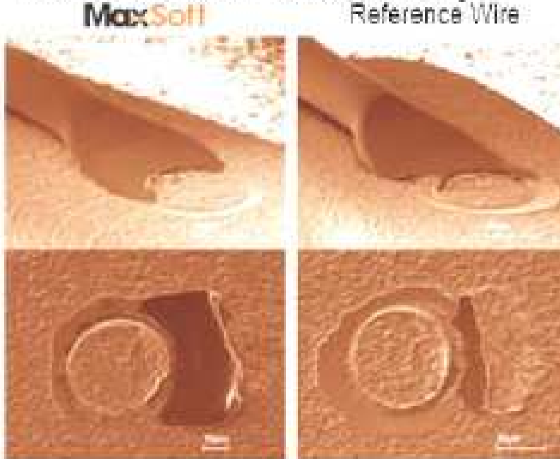
MaxSoft Benefits

- Excellent 1st and 2nd Bond performance
- Reduce pad metal splash
- Wider 2nd Bond Process window

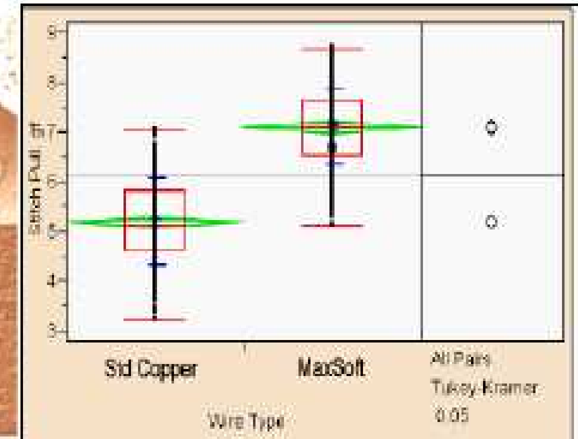
Reduced Pad Metal Splash



Excellent 2nd Bond Quality



Higher Stitch Pull Values

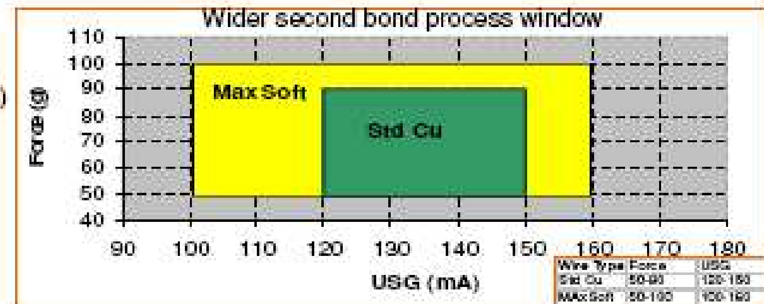


Diameter : 25um

Cap : C8-FC-1-11-R34 (T=4.0mils)

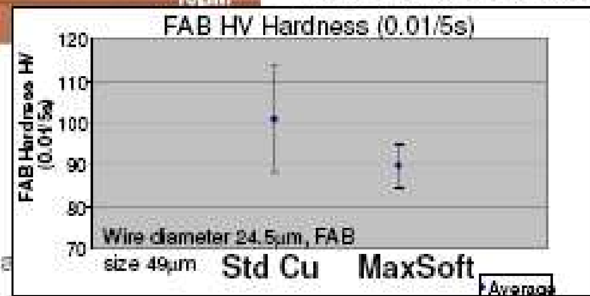
PBGA 2x2 Test Die

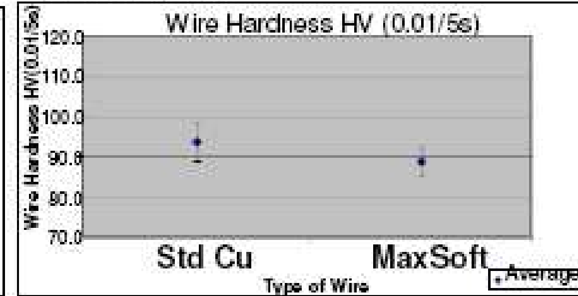
Pad : 1%Si-0.5%Cu 10,000Å



Wire Type	Force	USG
Std Cu	50-90	120-150
MAxSoft	50-100	100-160

Lower Wire and FAB Hardness





Softer Wire - Properties

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MaxSoft vs. Std Cu vs. Other Bonding Wire

Properties	Units	MaxSoft	Std Cu	Gold	Al
Density	*g/cm^3*	8.92	8.92	19.32	2.7
Thermal Conductivity	*Cal/cm sec°C*	0.94	0.94	0.74	0.21
Elect'l Resistivity (20 °C)	*μΩ-cm*	1.7	1.7	2.3	2.7
CTE (0-100°C)	*ppm/°C*	16.5	16.5	14	24
Young's Modulus	*GPa*	80-90	120	80	70
Tensile Strength	*MPa*	190-210	290	140	150

Softer wire adoption rate

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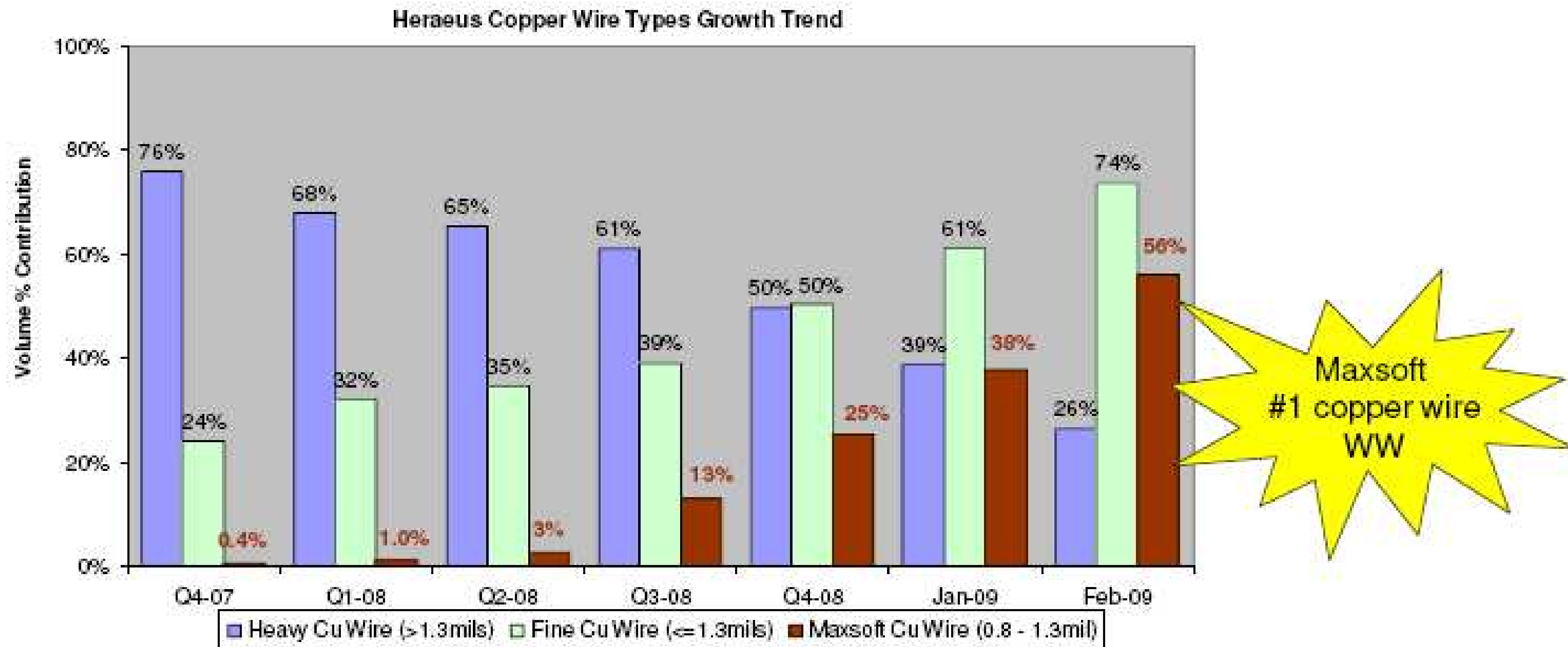

- Maxsoft achieved phenominal growth 2 years after product was launched in Mar 2007.
- Fine pitch IC packages copper bonding gained World wide success with Maxsoft Cu wire
- Fine Copper diameter overtakes Heavy diameter in terms of volume production

Is Cu Wire-Bonding for real?

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If it smells like a duck, looks like a duck and walks like a duck

IT MUST BE A DUCK