

Critical Barriers Associated with Copper Wire

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Wire bonding is widely used in the microelectronics industry to assemble the vast majority of semiconductor packages, electrically connecting Aluminum (Al) bond pads on the IC chips to the corresponding bond pads on the plastic or lead-frame chip carriers.

The Industry has short listed several common Bond wires which usually consist of good conductor metals such as Gold (Au), Aluminum (Al), or Copper (Cu). Gold has been the most widely used material because of its long successful history and extensive reliability data, resistance to surface corrosion and wire ductility during the bonding process.

Many companies looked at bare Copper wire as a viable replacement option for Gold wire however many shortcomings of conventional Copper wire use in advanced packaging and assembly were encountered. Comparisons of bare Copper wire versus Gold wire can be seen at the following figure.

Copper Wire versus Gold Wire

Advantages

- ◆ **Low Material Cost**
- ◆ **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)**

A breakthrough in the wire industry was the introduction of Palladium Coated Copper (PCC) Wire in 2008. The control of surface oxidation and stability in high volume manufacturing enabled PCC wire as the preferred alternative semiconductor interconnect material of choice to Gold and conventional Copper wire. Comparisons of PCC wire versus conventional Copper wire can be seen at the following figure.

PCC wire versus conventional Copper Wire

Advantages

- ◆ No wire surface oxidation
- ◆ Longer spool lengths & longer shelf life
- ◆ Higher productivity (bonder & looping)
- ◆ Wider 2nd bond process window

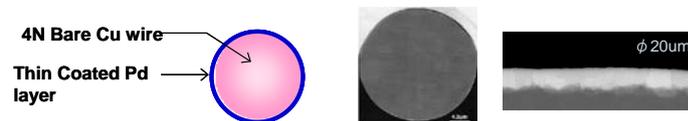
Disadvantages

- ◆ Higher Material Cost
- ◆ Higher Mechanical Strength
- ◆ Harder FAB (free air ball)
- ◆ More Al bond pad splash
- ◆ Need additional qualifications (If bare Cu already qualified)

The critical barriers in fine pad pitch applications associated with bare copper wire such as 2nd bond instability (NSOL), short tails, limited shelf/bonder life (wire oxidation) and high temperature/humidity reliability have been solved with the development of a Palladium coated copper bonding wire. A cross section of PCC wire can be seen at the following figure.

Palladium Coated Wire

Feature: Excellent control of corrosion/oxidation



As a result of the maturity of Palladium copper wire, some process and design limitations have been confirmed such as harder FAB (free air ball), fine pitch process issues, capillary life and advanced bonding techniques. An improvement and solution is a silver bonding wire which has been introduced as an alternative wire to overcome the limitations of the copper wire. FAB wire comparisons can be seen at the following figure.

Wire FAB Compression Test Comparisons

[FAB Making condition]
 •Wire: ϕ 20 μ m
 •FAB: ϕ 38 μ m
 •Bonder : Shinkawa UTC-1000
 •Gas : N₂ , 0.6l/min
 •EFO Time : 0.36 ms
 •EFO Current : 36mA (Ag alloy)
 49mA (Coated Cu)
 46mA (4N-Au)

Ag alloy

**Palladium Coated
Copper**
4N Bare Copper

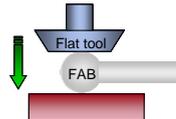
Ag alloy

4N Gold wire

[Measurement Equipment]
 •Compression Tester : MCT-W500
 (SHIMADZU)

[Measurement Conditions]
 •Compression speed : 23.5mN/sec
 •Maximum Load : 400mN

[Outline of Measurement]



Comparison of hardness
with work hardening

Soft Au wire > Ag > PCC wire **Hard**

The advantage of switching from copper wire to silver wire is that silver wire meets ball bonding performance requirements, soft FAB and comparable loop formations while maintaining productivity requirements of other alternative bonding wires.

It is relatively easy to switch from gold wire and copper wire since silver wire only requires safe and inexpensive nitrogen gas. Silver wire shows good potential as it offers several advantages compared to bare copper and palladium coated copper wires; mainly, acceptable bonding performance and reliability. Summary of bonding wires can be seen at the following table.

Summary of Wires

Category	Pd coated Cu	Ag alloy	4N Au	4N Cu
Resistivity	Low	High	Medium	Low
Reliability	High	High	High	Medium
Chip Damage	High	Low	Low	Medium
1st bondability	Good	Best	Best	Good
2nd bondability	Good	Good	Good	Poor
Bonding Environment	N ₂ H ₂ N ₂	N ₂	Air	N ₂ H ₂

Silver may not work for all applications but it can certainly help support many application areas where cost and performance define a product. Silver wire usage is expected to increase in the next few years in both the LED and semiconductor industry.