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GAISER TOOL COMPANY
• Inventors of the Ceramic Capillary •

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Copper Wire Bonding

A Low Cost Solution to Gold Wire Bonding?

Part 2: Ball Bonding, Facts, and Issues

Introduction

Part one of this discussion covered aspects of the ball formation; the various ways to achieve size and shape consistency. In this section, the material properties in particular the hardness and the impact on ball bonding will be discussed.

The copper bonding process is not simply about how to make a good free air ball but how to achieve good product quality and reliability.

The Facts

- Copper is a good electrical and thermal conductor, better than gold (see Table 1).
- Copper wire is harder than gold (see Table 1).
- Copper as a raw material is cheaper and more abundant than gold ($0.08/oz vs. $440/oz).
- Copper oxidizes easily, gold does not.
- Copper wire bonding uses a limited number of specially designed capillaries, gold wire does not.
- Copper processing requires special hardware to prevent oxidation, gold does not.
- Copper when bonded to Aluminum pads forms thin inter- metallic layers, Gold forms thick intermetallic layers (see Figure 1).
- Copper works harden easily, gold does not (see Figure 2).

Typical Parameter	Cu	Au
Resistivity (x10^{-6} ohm/cm)	1.6	2.3
Wire Hardness (HK)	> 64	< 60
Ball Hardness (HK)	> 50	< 39
Looping	Excellent	Excellent

(HK) = Knoop Hardness

Table 1

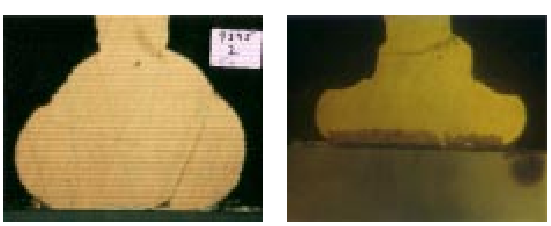

Figure 1

Issues

Some of the most important ones are Cratering, Oxidation, and Long Term Reliability.

The Bonding Process

The copper wire bonding process has to be tailored around the physical properties of the material, the hardness. The significant differences between copper and gold require much higher bonding parameters in order to achieve similar quality factors (Pull and Shear Strength, Ball Size and Shape). The increase in bonding parameters such as Ultrasonic Power and Force signifies a significant increase in capillary wear therefore reducing effective life of the tool. This is the reason Gaiser Tool Company recommends special ceramic material for this application.

The capillary material acoustical properties and wear resistance are key to maximize life and reduce ultrasonic power requirements.

The impact of the Copper hardness is most significant during the ball bond process, when Copper alloys with the Aluminum pad. This can result in bond pad subsurface damage (cratering, chip outs). The most common solution to this problem is either increase bond pad thickness or use a protective under layer (TiW most common). Many times the solution is to implement both, metal thickness and a protective under layer.

It is fact that Copper oxidizes quite rapidly when exposed to Oxygen, therefore special care must be taken to protect it. The use of enclosed containers in the wire bonder are encourage to keep the wire spool free of oxidation as well as to the use of inert gases such as Argon (Ar) or Nitrogen (N).
Copper Oxide is a hard layer that prevents the pure copper from alloying or diffusing with the surfaces in contact.

Long term reliability, especially when devices are exposed to high pressure-high humidity temperature cycling, has yielded mixed results. Some claim no problems while others reported multiple failures beyond 500 cycles.

One of the failure mode associated to copper's work hardening ability is neck breaks, commonly seen during temperature cycling test (see Figure 2).

Figure 2

There are however manufacturing facilities which currently manufacture copper wire products but mostly limited to high power devices where large diameter wire is used.

Small diameter wire (<33 µm) is still a challenge not because of bonding capability but because of reliability concerns as those indicated above.

Conclusion

There is no question Copper is a cheaper material but also one that brings new challenges to the bonding engineers. It may also be a cost effective process in the eyes of a product manager but when the extra care and attention it requires is weighed against the existing gold process then we should ask ourselves, are the net savings worth it?

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