Metallization options for optimum chip-on-board assembly

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When COB is merged within mainstream SMT, the choice of metallization has to serve both the SMT process and bonding—that choice can be a make or break factor. In the initial migration of die bonding onto organic substrates, the Au/Au and Au/AlSi system was more or less defacto—'inherited' from the packaging back-end. Driven by cost pressures, alternative metallic systems have come under scrutiny, the options refined and made viable. This paper examines and explains to the SMT professional the strengths, limitations, pros and cons and science behind the gold-gold, gold-aluminum, gold-copper, gold-silver, aluminum-aluminum, aluminum-nickel and copper-aluminum systems and examines how each produces different metallurgical interactions with the various die pad and substrate metallizations and how the resulting intermetallic structures and growth impact reliability & cost.

Keywords: Chip On Board, SMT, Metallization

This Paper was published in the proceedings of the SMTA International Conference on Soldering and Reliability, Toronto, May 2009

Technology acquisition

Within the mainstream SMT (surface mount technology) assembly process, wire bonding of bare dies directly on the PCB (printed circuit board) substrate alongside other soldered components has long since been practiced and continues to be deployed across a vast scope and range of COB (chip on board)-SMT applications. These applications range from the very low end, low cost 'throw away' items to high performance, complex assemblies.

The IC (integrated circuit) backend industry, with its decades of maturity and understanding of metallurgy related in particular to wire bonding, finds itself acquiring and adapting SMT know-how to the field of packaging. It is interesting to note that content of leading technical journals aimed at the IC industry now extending into SMT areas with appearance of articles on subjects such as solder paste & printing and reflow ovens.[1-3]

The SMT industry however may find it relatively harder to deal with the complexities of wire bonding associated with the COB-SMT merge—this information has been generally acquired through much 'hands-on' and trial basis.

This paper reviews the metallization options and interactions for COB while considering the needs of the bonding process and soldering. Several real life product examples using COB-SMT are included to illustrate the metallization used covering a diverse range of product positioning. The content is meant to serve the SMT professional familiar with soldering process interactions but requiring an understanding of the COB-SMT merge.

Market environment & trends

A principal factor driving the phenomenal growth of the electronics consumer segment are mobility and hand held products that have been flooding the market, with each successive generation

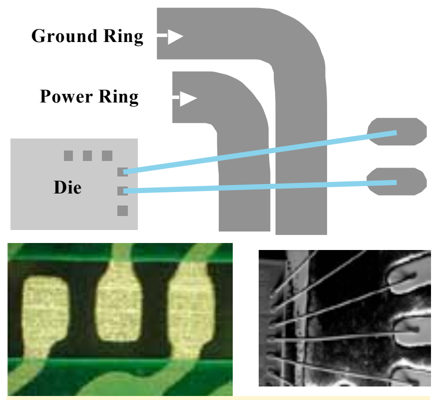


Figure 1. The most common COB layout with bond finger pads arranged in an array around the die.

offering performance and features at prices unimaginably by yesterday's standards. Associated with this growth are short product life cycles and steady price erosion—a trend that has become deeply entrenched in the consumer mind and taken for granted.

This prevailing market 'flavor', in particular as associated with mobility products, is a predominant driver of (and in turn been enabled by) the migration from lead frame based packaging towards organic based interconnection trends. A convergence between IC backend processes and 'traditional' SMT PCB assembly has surfaced, the boundaries of the two becoming diffused.

Apart from the size and footprint advantages, organic based packaging offers a significant spin off—it is a platform readily adaptable by the IC backend towards attaching multiple dies and other active and passive components on a substrate within an IC (ball grid arrays or chip scale packages in the modern context). After over-molding, the resulting assembly creates a highly functional device. SiPs (systems in package) and MCMs (multi chip modules) are examples exploiting this advantage.

Thus after decades of packaging typically a single die on a metal lead frame, the face of IC backend is being permanently transformed and acquiring the flavor of a PCBA (printed circuit board assembly)-like process, albeit one involving dies and SMT all within the package itself. Other than the final over-mould and ball attach if applicable, the process replicates the COB-SMT concept as deployed within the mainstream SMT industry.

COB metallization layout considerations—some basics

In the commonest COB layout (*Figure 1*), bond fingers pads are arranged in an array around the die (fan out only). P (power) and G (ground) rings may be included within the Signal I/O (input/output) bond finger ring. Several P & G rings may be allowable; however when present, rings must be covered by solder mask except of course at the bonding sites. This not only protects the metallization but also prevents any inadvertent shorts.

Bond finger pads must respect PCB design rules for line spacing and width. Solder mask openings in the bond finger are only as to allow bonding in the open areas. (*Figure 1* bottom left). Further information may be found in Reference 10.

Die placement area metallization

If electrical conductivity to die is required—then die placement area metallization is needed. *Figure 2* shows a typical example of pad sizing, wire lengths and layout based on a real example in a pocket dictionary for one of the dies of approximately 9.5 mm by 5 mm with an I/O count of 184. The pad length shown enables a one time re-bond (rework). For reliability reasons, re-bonds are never done over the previously bonded spots on the pads.[4]

In high reliability, industrial applications or areas such as packaging, this metallization must provide a barrier to Cu (copper) migration into Si (silicon) die. Au (gold) over Ni (nickel) is used for high end applications with Ni providing the needed barrier for Cu migration but for the low end spectrum Ni alone (without Au) is used and is adequate for low cost applications.

As a generic rule in COB, dies for power applications are not advised, due to the significant Cte (coefficient of thermal expansion) mismatch between the Si die and organic substrates[4]. Over-molded assemblies such as SiPs or MCM are more robust and tolerant to this aspect. Placement metallization may be designed to improve thermal performance if needed for a specific situation. This would take the form of vias (copper filled) in the placement metallization connected to the bottom and/or inner layers.

If electrical conductivity to the die itself is NOT required, placement areas with solder mask become feasible. The significant variable to consider are the compatibly of the die bonding material to the mask, the mask cure condition, absorbed moisture and contamination all of which can affect the surface activation energy and hence the adhesion of the die to the substrate. With solder mask the coplanarity in the placement area becomes an important variable—even a few mils of die tilt can lead to mis-bonds during wire bonding process.[4]

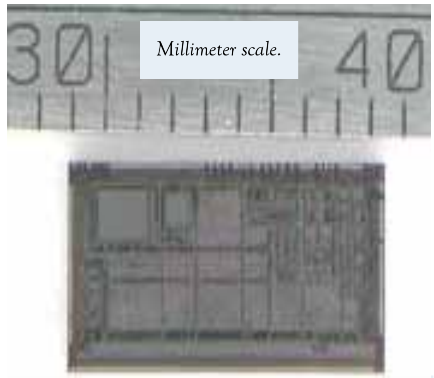
Bonding variables fishbone diagram

Figure 3 shows the variables' fishbone tree. An SMT professional can readily appreciate that the process itself is far more complex and sensitive to any encountered in the mainstream SMT world. When the variables for both the SMT process and COB are combined, the resulting fish bone diagram appears formidable. Solder joint reliability is to the SMT world as bond reliability is to the bonding process—the latter co-related to bond pull strength. Clearly as evident from *Figure 3* the choice of metals and the resulting bond metallurgy play a significant role in attaining this important success parameter. Understanding of both the metallurgical interactions in COB as well as soldering metallurgy is essential in the field of process development and in failure analysis.

Bonding wires options

This section reviews the various bonding wire options in COB applications.

Gold and aluminum bonding wires, the backbone of the IC wire bonding process for several decades, have been (and continue) to be "default" wire bonding choices since the birth of the COB technology. Today other materials such as Cu wire and Ag surface metallization are also coming into focus although currently their use is not as prevalent in COB as discussed further



Die
Size: 200 mils x 270 mils (5 mm x 9.25 mm)
Min bond pad size: 3 mils x 3 mils (75 µm x 75 µm)
Min pad pitch: 4 mil (100 µm)
I/O: 184

PCB
Min PCB pad size: 5 mils x 20 mils (This pad length allows one-time re-bonding in case of rework)
Min PCB pad pitch: 10 mils

Bonding
Max wire length: 200 mills (5 mm)
Wire diameter: 1 mil (25 µm)
Wire loop height: 5-15 mils
Max die to PCB wire angle: 45° (to prevent wires crossing adjacent die pad)

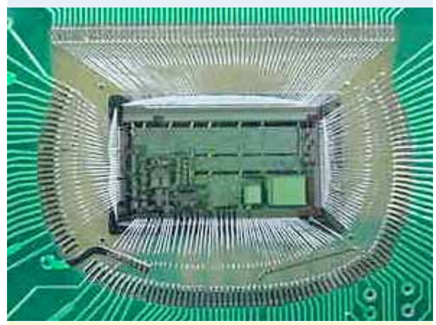


Figure 2. Real-life example of pad sizing, wire lengths and layout.

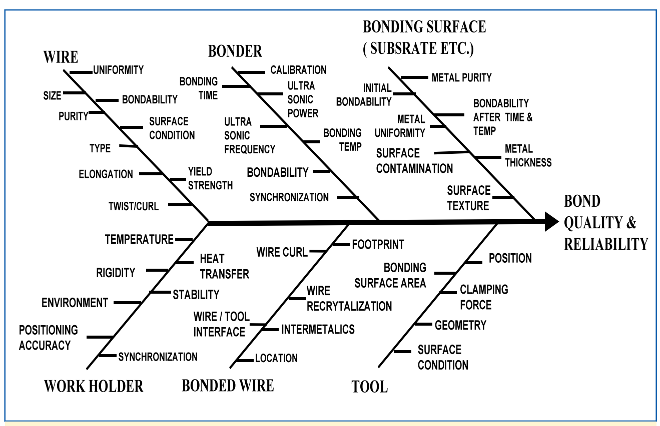


Figure 3. Wire-bonding fishbone diagram.

Property	Units	Gold	Copper	Aluminum
Melting Point	°C	1063	1083	658
Density	g/cm3	19.3	8.92	2.7
Lattice Constant (at 20°C)	10-10m A	4.079	3.615	3.049
Lattice Structure				
Specific Heat (at 20°C)	J/g K	0.126	0.386	0.900
Thermal Conductance	kW/m2K	31.1	39.4	22.2
Coefficient of Linear Thermal Expansion	ppm/K	14.2	16.50	23.10
Electrical Resistivity (at 20°C)	10-8 ohm m	2.2	1.7	2.65
Electrical Conductivity (at 20°C)	10-7 /ohm m	4.55	5.88	3.65
Vickers Hardness	MN/m2	216	369	167
Modulus of Elasticity	GPa	78	123	70.5
Tensile Strength	N/mm2	120-220	210-370	100-200

Table 1. Comparison of Bulk properties. [Source : K&S–Bond Wire Characteristics http://www.kns.com]

Parameter	4N	2N
Micro-dopant[2]	Be, Ca, RE, others	Be, Ca, RE, others
Major dopants	Nil	P, Pt or Cu
Resistivity (μ Ω cm)	2.3	3.0-3.5
Modulus (GPa)	75-100	80-95
Strength (MPa)	140-340	250-340
FAB grain size	Larger	Finer
Neck grain size	Coarse to fine	Fine
Neck strength (% wire)	70-95%	80-90%
Intermetallic growth[3]	Slow	Slower
Low-loop capability	Good	Very good
1st bond	Lower w/larger bonding window	Higher w/smaller bonding window
2nd bond	Large, robust bonding window	Smaller bonding window

Table 2. Comparison of the properties of 4N versus 2N gold.

on. Amongst the important mechanical considerations influencing bonding wire selections are:

1. Tensile Properties
2. Elongation (EL)
3. Break Load (BL)
   [Ref: ASTM (American Society for Testing & Materials) Standard F72]

Electrical properties are application dependent; however it must be borne in mind that each material produces different metallurgical interactions with the die pad metallization and substrate metallization. Since substrate metallization interacts uniquely with different solder alloys it is therefore an important consideration in balancing the needs of wire bonding and soldering. Bulk properties comparison of various materials appears in *Table 1*.

Gold bonding wire

The ductility of gold provides the flexibility needed for good loop formation. Gold has excellent electrical and thermal properties and being inert (gold is a noble metal) makes it well suited to the bonding process. Gold wire is widely used in bonding applications in both ball bonding and wedge bonding applications producing very reliable bonds to both Al (aluminum) and Au (gold) surface metallization.

The needs of flexibility, loop retention and bondability have to be balanced. Pure gold wire is too soft and is usually stabilized with dopants such as Be (Beryllium) of around 5-10 PPM (parts per million) or Cu (copper) around 10-30 PPM. Based on purity, gold wire is classified into various ranges from 99 % (2N gold) to 99.99 % (4N gold). Beryllium doped Au wire is 10-20 % stronger than Cu doped and hence better suited for higher stress applications like high speed automated bonders. Gold wire is typically supplied in an annealed condition to prevent unwanted break offs during initial bond formation.

Table 2 is an example of a comparison of the properties of 4N versus 2N gold as developed by one particular supplier for 'ultra stiff' gold wire bonding applications[3]. It is interesting to note the differences in the minor and the major dopants levels (none in the case of 4N wire).

Considerations with gold wire bonding

Surface cleanliness and contamination are both critical to bond strength. Surface finish of the bonding metallization is critical to prevent bond tool capillary clogging. Some of the trade–offs with gold bonding wire are:

a. It is an expensive material
b. Uses expensive bonding tools—ceramic for ball bonding, titanium carbide for wedge bonding
c. High temperature bonding is needed which is a possible source of die stress.
d. Limitations in heating the PCB (organic) substrate metallization

Although gold wire bonds can be made without substrate or wire heating, reliable gold bonding requires heating the bonding metallization and wire to a high temp. Ball bonding requires a temperature in the range of 220-250°C while reliable Au wedge bonding can be accomplished at a lower temp of around 150°C.

Heating a metal lead frame or die pad (for example pre-plated Cu lead frames as used in IC manufacturing) given the form factor, high thermal conductivity and uniform thermal mass is relatively easier compared to organic substrates. Organic PCB substrates variables—lower thermal conductivity, complex thermal mass distribution, size, Cte, and whether the PCB is populated or unpopulated make it non-ideal to create localized heating at the substrate pads. The process may slow down throughput and/or lead to higher stress conditions marginalizing the over-all assembly reliability.

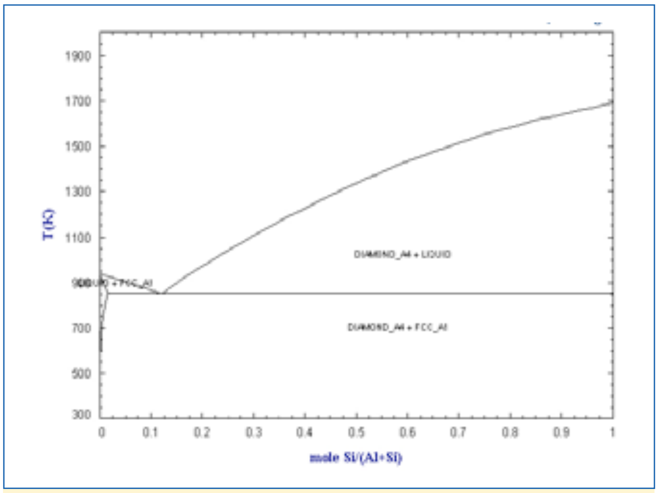


Figure 4. Al-Si phase diagram.

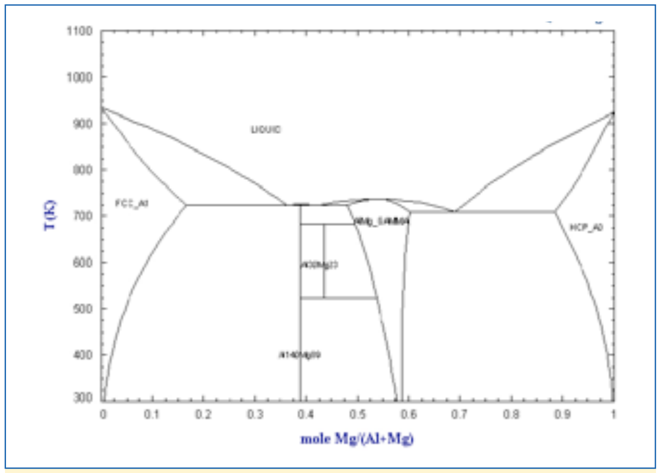


Figure 5. Al-Mg phase diagram.

Al -Si (silcon) bonding wire

Small diameter Al wire is often used for wedge bonding and offers relatively good fatigue resistance. As in the case of gold, pure Al is too soft to draw into small wires so it is alloyed with approx 1% Si (silicon) to provide the desired properties of load and elongation.

Lightweight Al-Si wire is very reliable but is much lower in cost compared to Au. It is used extensively with low cost wedge bonding tools (tungsten carbide) and since Al bonding can be done at room Temp. It is a process well suited to organic substrates and therefore an ideal default choice in a most low to mid cost COB applications.

Figure 4 shows the Al-Si phase diagram. As can be seen, 1 % Si exceeds the solid solubility limits of Si in Al at room temp. Si precipitation can cause stress risers and possible wire fracture and is one of the failure mechanisms associated with heel cracks.

Small diameter Al-Si wires are usually heat treated (partially annealed) to disperse Si uniformly. Large diameter wires are heat treated before and after final drawing.

Al-Mg (aluminum-magnesium) bonding wire

Al alloying with Mg is an alternate to alloying with Si and actually offers certain advantages. *Figure 5* shows the Al-Mg Phase diagram. Mg solid solubility in Al is better than the 1 % maximum of Si dissolved in Al.

Al with 1% Mg can be drawn into fine wire with similar strength as Al with 1% Si. Al-Mg gives satisfactory bonding and is superior to Al with 1% Si in fatigue failures. It also shows superior ultimate strength after high temperature exposure.

Despite the Al-Mg wire alternative with some of its advantages its use has remained less prevalent in the industry compared to Al-Si, which has become widely accepted in the industry.

Copper bonding wire

Cu (copper) ball bonding has seen more recent usage and in particular Cu ribbons have been receiving considerable attention. Cu is economical, has excellent heat and electrical conduction—hence smaller wires possible—and is resistant to sweep during plastic encapsulation.

Cu to Cu bond is possible, but with Cu the major issue remains bondability. Since Cu oxidizes readily, bonding in inert atmosphere is needed, which somewhat negates the cost advantages with Cu bond wire.

Cu-Al intermetallic growth rate is lower than Au-Al, and provided the initial bondablity issue is addressed via inert gas, Cu offers better reliability than Au wires to Al pads with 0.4-4.0 mil wire diameters.

However Cu is harder than Ag and Al (*Table 1*) and risks die cratering or pad metallization damaged—a harder pad metallization is required for Cu wire bonding. Currently Cu usage is limited to mainly high-end usage (CSPs, QFNs)—it has limited usage in COB applications at the moment.

Metallurgical systems

The next section reviews the metallurgical interactions in the bonding process, the substrate metallization options together with soldering considerations in the light of the COB-SMT merge.

Gold wire-gold plated pads

The gold-gold bond being a mono metal system is extremely reliable. It is not subject to interface corrosion—there is no intermetallic formation and no bond degradation. Even a marginal Au-Au bond performs well despite time and temperature.

As mentioned before Au is best bonded with heat. Cold ultrasonic Au-Au bonding is possible but is less reliable. Thermosonic bonding is preferred and is most common, however thermo compression bonding is possible. Bonding is highly affected by surface contamination. Au-Au bonding is used in high-end COB application and within the IC industry for applications such as SiP and MCMs. Use of plasma etching to improve surface activation is extensively used in the high-end process. Au plating thickness for the bond pad metallization is target application (reliability) dependent. For high reliability bonding an ultra pure, soft Au (hardness 60-80 Knoop) in the range of 30-100 micro-inches is typical.

Soldering vs. bonding on gold pads

This subsection examines the Au metallization in its SMT soldering aspects and conflicts and options vis-à-vis wire bonding.

Au offers excellent co-planarity, fine features, and high-density circuits; it is essential in HF (high frequency) applications. Au can withstand multiple reflows, has good corrosion protection and excellent wetting. The main issues with Au are high cost and hard-to-manage plating process.

ENIG: Many segments of the industry have (or are) shying away from the ENIG (electroless nickel immersion gold) process as a surface metallization for fears of 'black pad' defect, an issue which has received considerable attention and continues to be debated. With the prevalent use of the

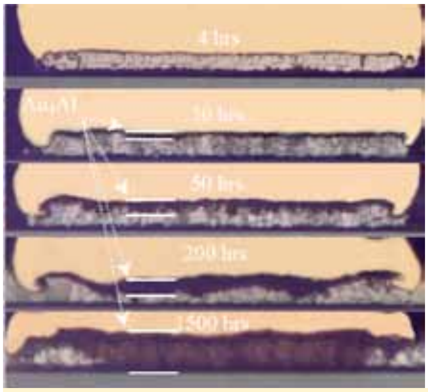


Figure 6. IMC growth sequence. [Source: Semicon Singapore 2005–K&S.]

ENP (electroless nickel phosphor) process, which co-deposits phosphor in the Ni plating, the impact of phosphor content in the ENP plating on bond reliability and solderability has been the subject of several studies.[8] Traditionally 6-8% P content has been used, but some recent studies show otherwise with use up to 10-12% P content producing a more favorable, corrosion resistant Ni surface morphology, an important variable, making it less prone to attack by the subsequent Au plating layer or by the eventual soldering process.[8]

In the author's experience and from a metallurgical standpoint, a well controlled[9] and specified ENIG process offers an excellent surface finish for both soldering (with Sn/Pb and Pb free solders) and wire bonding, but the ideal thickness requirements for the gold film are quite different for the two interconnection methods. For soldering purposes, the Au must be a dense (not porous), thin film whereas for bonding it should be thick, pure 'soft' gold. The general structure favored for soldering applications is a 'dense' gold of around 2-4 micro-inches over an underlying Ni layer of around 200-240 micro-inches[6-9]. The MIL QQ-N-290A Standard specifies 200 micro-inches of Ni between the Cu and Au layer as a Cu diffusion barrier.

The IPC 4552 ENIG Standard specifies a minimum Au thickness of 0.05 µm (2 micro-inches) to statistically allow for process variability. It also caution on possible appearance of 'black pad' issues when immersion gold thickness approaches 0.25 µm (10 micro-inches).

The Au layer acts as a sacrificial film, protecting the underlying metal and needs to be thin enough to be 'consumed' by the Sn during soldering, with the resulting AuSn IMCs dispersing into the bulk solder fillet. The bond is thus formed to next layer—Ni or Cu as the case may be—which must be active other wise the Au purpose is defeated.

Soldering to thicker Au films meant for bonding application results in a large percentage of AuSn IMC precipitating at the solder joint to pad interface risking solder joint embrittlement and low cycle life.

So with COB-SMT, the ideal practice with Au would be to follow the structure desirable for soldering combined with selectively plated 'thick' gold at the bonding sites. This process is costly and used mainly in the high end, 'pricey' COB applications (*Figure 12*). If the product positioning does not justify it, a compromise has to be made in which case the 'thin' gold favoring soldering is chosen—it provides a product life cycle commensurate with product expectation.

DIG (direct immersion gold): This is a relatively new process to the industry and plates the Au directly over the Cu[7]. The Au film properties (thickness, porosity, morophology, etc.) apply to the DIG process as in as much as they do to the ENIG; however during soldering the Sn bonds to the Cu forming SnCu IMC which have been documented to have a higher growth rate than the SnNi IMC layer[11], hence a lower reliability may be expected compared to ENIG, but it may well meet the life cycle of many products depending on their price position. DIG field experience is limited at this stage in COB applications but it 'appears' well suited and cost effective.

Gold wire-aluminum die pads

Gold-aluminum is very common in wire bonding process for COB applications. However, there are reliability issues over time. It is easily subject to Au-Al IMC layers and Kirkendahl voids. IMC formation is accelerated with operating time and temp. and 5 IMC layers are formed as listed below (*Figure 6*).

$Au_5 A_{12}$ (tan color) [some studies suggest Au_8A_{13}]
Au_4Al (tan color)
Au_2Al (metallic grey color)
AuAl (white color)
$AuAl_2$ (deep purple color)

It is believed that initially $AuAl_2$ forms at the Au-Al interface then transforms to other IMCs with time & temp.

Gold-aluminum intermetallic growth

In a well control ball bond process, gold aluminide IMC growth shows relatively planar morphology. IMC initial growth rate is believed to be parabolic settling to about 3-4 µm (micrometer) over time. At high temperatures (175°C), the Al pad converts to IMC-Au_5Al_2 (gold side) and Au_4Al (pad side) predominate in the IMC layer. Au_4Al may also grow by consuming Au_5Al_2—see *Figure 6*. Au_4Al is susceptible to corrosion by epoxy molding compounds used in COB and may also oxidize.

Gold wire-copper pcb pads

Gold bonding to Cu copper pads is rarely used in COB but is possible. 3 IMC phases are formed:

Cu_3Au
AuCu
Au_3Cu

Formation of IMC decreases bond strength at high temperatures (200 to 325°C). Kirkendahl voiding can occur due to Cu migration. Bond strength degradation is dependent on micro-structure, bond quality and impurities in the Cu.

Cleanliness is extremely important for bondability and reliability when bonding to Cu. Use of inert gas (argon) shielding improves bondability and reliability, prevents Cu oxidation, and is needed for curing polymer die attach material.

Soldering Aspects: While Cu with OSP (organic solderability preservative) would be a good choice for soldering for products aimed at the low end spectrum, OSP-coated pads are not useable 'as is' for wire bonding. The alternatives of Cu/OSP pads for soldering and selectively plated (Au , Ag or Ni) pads for wire bonding, while feasible, again negates the cost advantage and is hard to justify. Use of inert gas is not justifiable by products at this low price point.

Gold wire-silver pads

The Au-Ag is very reliable for long-term at high temperatures. Au-Ag do not form intermetallic compounds. Au wire bonds to Ag lead frames or Ag-plated pads have been successfully used in high volume production for many years. Ag bondability issues are caused by contaminants like sulphur, which tarnish the silver plating.

Au-Ag high temperature thermosonic bonding is done at approx. 250°C and improves bondability by displacing the tin sulphide films. Use of Ag is currently not prevalent in COB applications for cost reasons and thermosonic bonding requirement.

Soldering Aspects: The IAg (immersion silver) process is similar to ISn (immersion tin) except it uses electroless silver deposits. IAg is being promoted as an alternative to

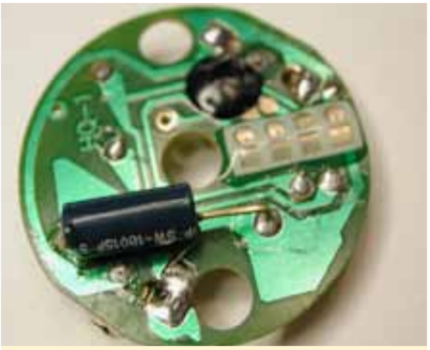


Figure 7. COB in a toy fan with motion-activated LED lights.

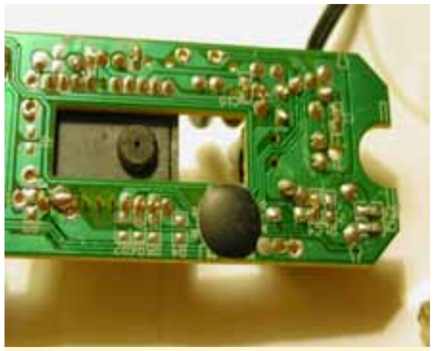


Figure 8. COB in a PC mouse.

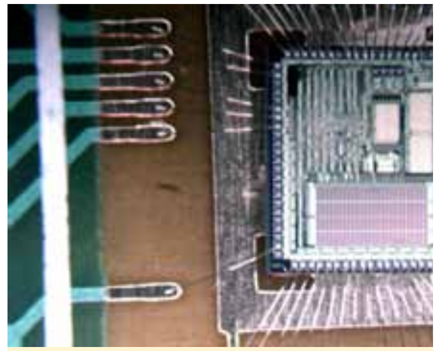


Figure 9. COB in a PDA.

Figure 10. COB devices in a microwave oven modules.

Figure 11. COB in mini-disk player and its remote control.

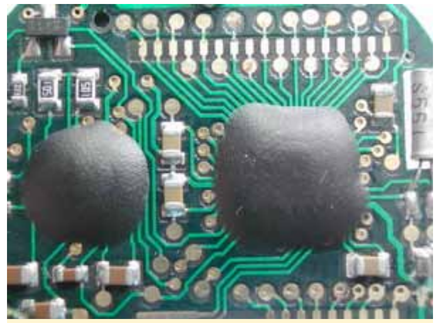


Figure 12. COB devices in a heart-rate monitor.

Au (due to 'black pad' fears with ENIG—see the relevant section further on)—and it can be adopted into COB applications. However, Ag metallization on solder pads is not free of solder joint reliability issues. Microporosity at the Ag-Cu interface occurring from the silver plating process (corrosion of the Cu surface) is being reported and deemed as a reliability threat to solder joints. Ag solderability can easily degrade in contact with Sulphur compounds. Thickness depends on two types chemistry for I-Ag:

"Thin" silver, minimum 0.05 microns [2 micro-inches]

"Thick" silver, minimum 0.12 microns [5 micro-inches]

These thickness values are expected to guarantee a minimum one-year shelf life. Upper thickness limits for both types I-Ag were not established in the initial release of the IPC-4553 Immersion Silver Standard. However I-Ag is not an allowable finish for Class 3 acceptance.

Another reason why Ag is being promoted is to eliminate tin whisker issues. Costs are similar or marginally more than immersion tin. Use of Ag is relatively new and not common in the high volume, cost sensitive COB segment. It needs further field experience & volume usage to understand the long term impacts.

Aluminum wire-aluminum die pads

Al-Al bonding is an extremely reliable system. Being a mono metal bond, it is not prone to IMC formation and it is not prone to corrosion. Al-Al bond is best done ultrasonically. Al-Al thermo-compression bond is possible by high deformation. Al-Al wedge bonding is very predominant in COB applications—it is the mainstay of the low cost, "throwaway" product range and also often used in the mid-end products.[4]

Aluminum wire-nickel pcb pads

Al-Ni bonds are typically made with large diameter wires greater than 75 mm (3 mils).

Large wires bonds are less prone to Kirkendahl voids and galvanic corrosion. Ni provides bonds that are more reliable than Al-Ag or Al-Au. Electroless Ni on pads from boride or sulfamate base systems gives reliable bonds

Al to Ni pad bonding remains very popular in COB applications-it is low-cost yet reliable.

Bondability is affected by Ni surface oxidation and measures to improve Ni pad bondability include:

a. Short time between plating and bonding
b. PCB storage in an inert atmosphere
c. Chemical cleaning before bonding.

Soldering aspects with Ni Pads: Measures mentioned above to improve bondability also apply to improve solderability. electroless nickel coated components have a short shelf-life (less than 24 hrs to meet solderability to Mil 893C specs!) unless protected over by gold. Issues also relate to the P content in EnP plating (Ref ENIG subsection). Storage conditions are important as is FIFO (first in/first out). Use within six months from date of manufacture remains a related concern with Ni.

Copper bond wire-aluminum die pads

The Cu-Al system is prone to various IMC failures similar to Au-Al system

IMC growth in Cu-Al is lower than in the Au-Al system, and no Kirkendahl voiding is seen in Cu-Al IMC.

Brittle $CuAl_2$ in IMC layer lowers shear strength at 150-200˚C at 300-500˚C excessive IMC growth significantly reduces bond strength. Cu-Al IMC is impacted by atmospheric composition. Presence of O_2 creates Cu oxides which inhibit bondability by growth of void like grooves under bond. Cl (chlorine) contamination and H_2O (moisture) can produce corrosion of the Al and Cu-Al IMC layer.

Metallization and product positioning—real life examples

Several diverse applications of COB-SMT are show in *Figures 7* to *12*. The *Figure 7* PCBA is from a hand-held toy fan with motion activated flashing lights that sells for under US $4.

Figure 8 shows the PCBA from a computer mouse selling around US $10. Both *Figures 1* and *2*, the products use a single-sided BT PCB with Cu OSP solder Pads and Ni over Cu COB pad metallization. Both products are low cost and low profile and made possible by COB-SMT with appropriate materials and metallization typical of products in this low end product category.

At the next higher level of product hierarchy, a mid-priced product example, *Figure 9*, shows the COB in a personal digital assistant (PDA) using a multilayer FR 4 PCB with uniform Ni metallization at both soldering and wire bond sites with AlSi wire bonding process.

Moving further up the ladder, *Figure 10* is the display and control module from a microwave oven (with a US $100 product sales tag), and *Figure 11* shows the main and remote control PCBAs from a mini -disk player. Both products use ENIG pads for both soldering and wire bonding.

At the highest level, *Figure 12* is the PCBA from a high-end heart rate monitor (a US $150 product) using ENIG at the solder sites and selectively plated soft pure gold at the COB sites.

So far the author hasn't encountered any real life examples using ENEPIG (electroless nickel, palladium, immersion gold)[5] or DIG metallization, but that may be because both are relatively new.

The common factor in each of the shown products is COB; however, metallization choices in each are dictated by product positioning, product life, reliability expectation and price point. The low end of the spectrum is very cost sensitive and uses metallization that leans in favor of the soldering process.

Other examples (not shown here) relate to the IC industry, such as SiPs and MCMs.

Common goals in integration.

In the denouement, the goal for both IC packaging and the PCB assembler remains the same, that is, the ability to address the market demand with greater value add, increased performance & functionality while lowering cost.

Whichever way it is approached, attaching dies alongside SMT short cuts the final interconnection enabling functional integration with shorter time to market, PCB real estate savings and a slimmer form factor. Most COB applications involve (proprietary) ASICs (application specific integrated circuits), and the COB route provides a much shorter time to market and greater intellectual property protection so the 'first to market' can retain market leadership for a longer period.

Conclusion

COB merged with SMT is a very versatile process deployed currently across the very wide range of applications. That millions of products are being profitably produced and sold using COB is testimony of its robustness. Wire bonding is certainly not out of steam yet given the improvements seen in latest generation of bonders.[6]

The choice of metallization can help provide the right balance between wire bond reliability, soldering yields, and solder joint reliability. At the mid to low cost spectrum there is tendency to lean towards metallization aligned towards soldering process. Despite this compromise, the wire bonding process, for this product class, proves robust enough for the application.

The required metallization for reliable wire bonding is not necessarily the same as that needed for high quality solder joints. In the case of ENIG (and its evolution, the ENEPIC (electroless nickel, palladium, immersion gold) process but limited to SAC alloy soldering) provided the nickel and gold plating control has been carefully maintained[7-9] when combined with selective pure thick gold on the wire bond sites provides the highest reliability for both soldering and wire bonding but also incurs the highest cost.

At the next lower level, ENIG is an option for both soldering and wire bonding without selective plating on the wire bonding sites. The ENIG metallization yields an excellent solder joint quality and while not 'the' best for wire bonding, it proves adequate for mid end product needs.

At the low end where cost sensitivity is acute, either OSP over Cu for solderability with selective Ni or Au plating on the bond sites or simply a uniform Ni as a common soldering and bond site finish together with aluminum wedge bonding provides the lowest cost alternative. The target application, its reliability, life cycle, cost and price positioning must all be considered to obtain the optimum balance.

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