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Large Diameter Wire Bonding to Organic Boards

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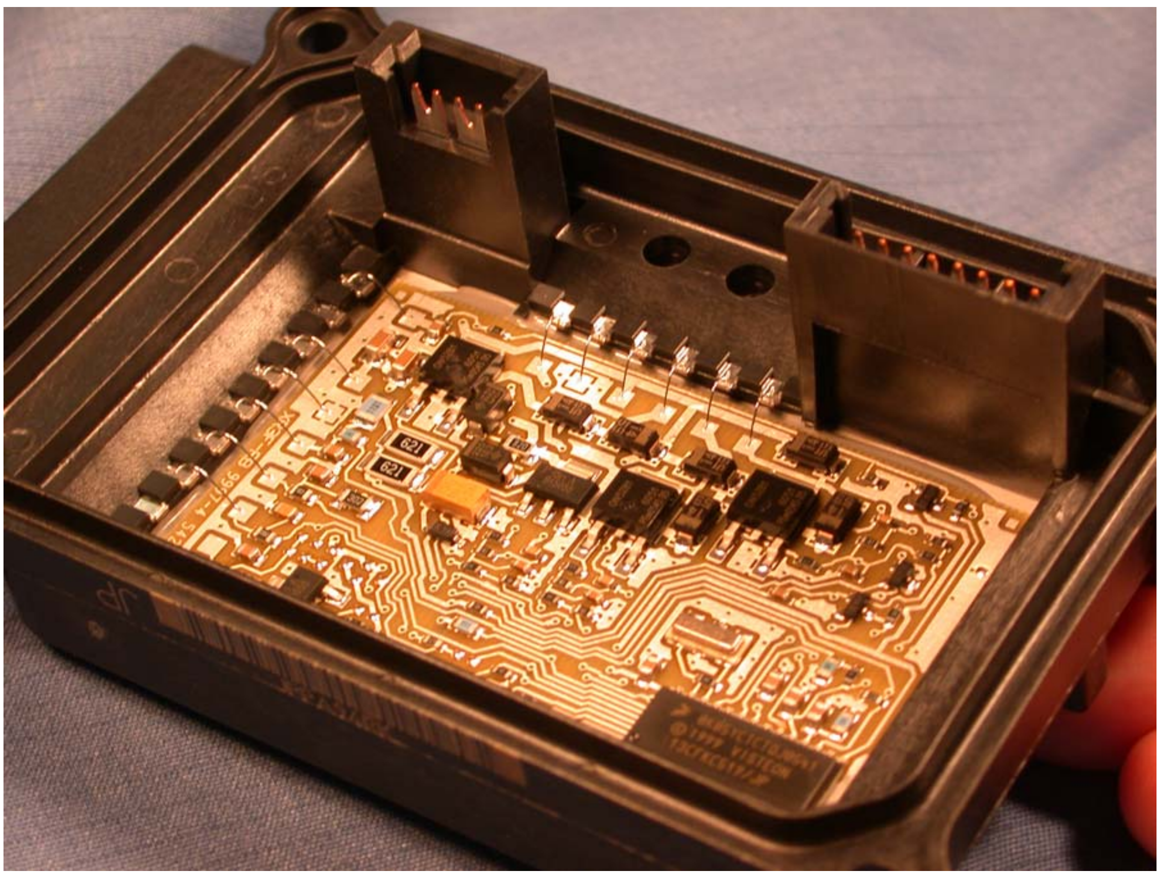
Introduction

Over the past few years, numerous companies in automotive, military, commercial, and other electronic sectors have migrated from using ceramic substrates to printed circuit boards (PCB). They have seen in some instances that the ceramic substrate was over-engineered and that the printed circuit board was capable of handling the application in terms of heat dissipation and temperature exposure. In some cases, there are two substrates within the same module, one PCB and one ceramic.

Chip-On-Board (COB) is broadening its horizons by not just wire bonding from an integrated circuit to the PCB with small diameter aluminum wire, but now also includes large diameter wire for bare die to substrate and interconnecting the housing leadframe to the substrate. Wire diameters from 5 to 20 mils are included in large wire sizes.



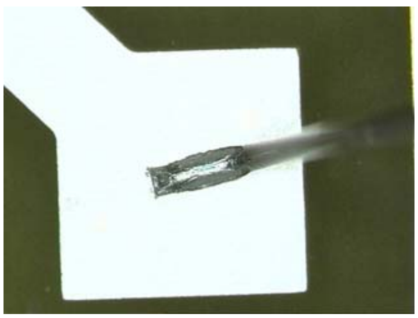
Automotive Module using FR4 and large Al wire bonds *courtesy of Visteon*

PCB & Wire Bonding

The most common printed circuit board available today is FR4. FR4 substrates are significantly less expensive than ceramic substrates. There are more FR4 vendors making circuit boards than there are ceramic substrate suppliers. FR5 is an alternate material to FR4 that is suitable for wire bond applications. FR5 has a higher flexural strength at elevated temperatures as well as having a higher maximum operating temperature compared to FR4. Fine line resolution typically achieved in the ceramic world is available in the organic world with 2-mil line / spaces are not uncommon.

Switching from a stable ceramic substrate to an organic substrate is not without its challenges but the cost savings realized more than make-up for the effort needed. Construction of the base material and for a multiplayer PCB is basically the same. Glass sheets impregnated with epoxy resin is layered on top of other sheets and laminated together under pressure and heat typically in a vacuum to make the final substrate. Compared to co-fired ceramic, the resulting substrate is not that rigid and when the ultrasonics get applied, they may disperse randomly through the PCB structure. This may cause inconsistent bonding quality.

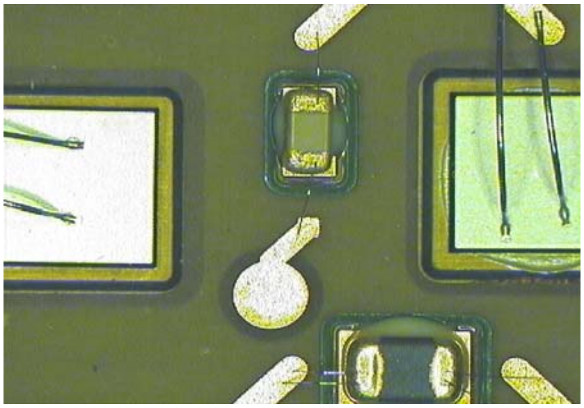
Bonding directly to the base copper of the PCB is typically not possible as the surface becomes heavily oxidized in the process of manufacturing the board. For large wire bonding, it is recommended to put aluminum-clad-copper bond pads on these bond locations or use plating. Since the PCB will also have soldered components in the majority, the use of suitable multifunctional plating is recommended. Electroless Nickel, Immersion Gold (ENIG) is one of the more popular platings used for Al wire bonding. The thickness of ENIG deposit, as specified by IPC-4552 is 2 micro inches minimum at –4 sigma from the process mean for the gold and 120 to 240 micro inches for the nickel. A typical value of 3 to 5 micro inches for the gold should be expected. The phosphorus content of the nickel ranges from 4 to 9% for "mid phos" baths to 10 to 14% for "high phos" baths. Mid phos baths are the most common in use. The function of the gold deposit is sacrificial, used only to prevent the nickel surface from passivating and thus causing both solderability and wire bonding issues. Al wire bonding is made to the nickel and not the gold on the surface. Immersion silver has been shown to be capable of Al wire bonding. However, the bond pad needs to be encapsulated to prevent a metallurgical change due to air exposure that might result in long-term bond failure.


Large Al bond on immersion silver-plating, courtesy of Visteon

When deciding on a FR-type of board to use, there are a few items to consider when wire bonding is required. Choose a glass transition temperature (Tg) that would be safely above your highest operating temperature. This Tg would have a direct impact on the PCB Z-axis expansion. Above the Tg of a material, the expansion rate increases at an exponential rate. Evaluate the Tg of the material by DMA (Dynamic Mechanical Analyzer) as opposed to DSC (Differential Scanning Calorimeter) as it is the mechanical characteristics of the material that has a major impact on wire bonding rather than the heat capacity of the material. The Tg for FR4 & FR5 are similar. There are three separate temperature ranges for these boards: 110 °C; 150 °C; and 175 °C. The use of the lower 110˚C Tg materials in the United States is on the wane, being replaced by the 150˚C minimum. Laminate materials are specified in the IPC document 4101 with each material set assigned a "slash sheet number". FR4 is currently specified by /21, /24 and /26 with increasing Tg minimums of 110˚C, 150˚C, and 175˚C respectively.

The rapid increase in z-expansion as a function of exceeding the material's Tg may result in false touchdowns, cutting problems, over-bonding, faster Al build-up on the bond tool, in addition to other problems. One situation to be mindful of is having the substrate attachment to the backplate or housing exiting the curing oven and being transported to the wire bonder while still hot or warm.

Another critical variable to consider is the camber (also known as the warp & twist specification). Typically, most printed circuit board manufacturers can meet the 7.5 mils per inch/inch. Remember, the bigger the board, the more likely the larger the inherent camber. FR4 board will have a memory, so even if you have an internal process to make the boards flatter, after a temperature excursion it may likely reform back to the natural camber.



Wire bonding to ceramic chip capacitor terminations, courtesy of STI Electronics

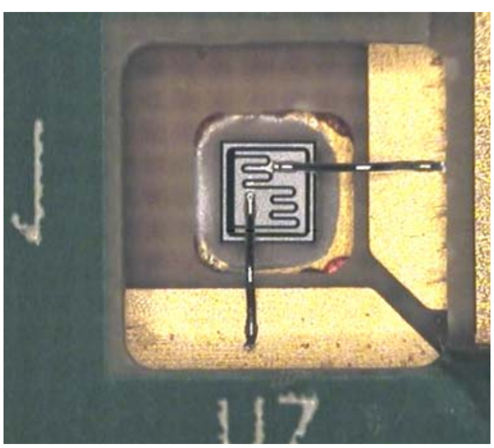
Whenever working with FR4 in wire bonding applications, you should always attach the board to a rigid surface. Ensure that the fixturing is such that the module cannot move in any of the axes during the wire bonding process as this may cause sliding and inhibit the attachment of wire to surface.

The most common wire type used in these applications is 99.99% aluminum (Al). According to Frank Grosso, Wire Manager at SPM in Armonk, NY, he has noticed that wire specifications have changed over the years. Usually this change has been more towards a more ductile (“softer”) wire. Ten-mil diameter Al wire is very common in FR4 applications. A typical elongation could be 10-18% with a tensile strength of 350-450 grams. Years ago, the tensile would have been around 450 grams minimum.

Al Schaller of Visteon in Lansdale, PA has been involved with the conversion of ceramic substrates to FR4 boards for automotive applications. These conversions are done primarily for cost reduction reasons. They have used immersion silver on the bond pads with an FR4 that is .032” thick. Performance and durability of these wire bonded automotive modules has been excellent.

New Trends in PCB & Wire Bonding

Casey Cooper of STI Electronics in Madison, AL states, “Recent R&D efforts at STI have resulted in an emerging assembly and manufacturing technology coined Imbedded Component/Die Technology (IC/DT).” This assembly technology provides the size and weight shrink coupled with increased functionality and reliability that is required across the electronics industry. The size and weight shrink is largely due to the exclusive use of bare die, eliminating the external component packaging as well as high volume, dense solder interconnects. In order to meet the varying current requirements of the electrical system, two wire diameters are often used to eliminate conductor burnout. Overall assembly weight is reduced through the use of a high-temp FR-4 substrate material with electroplated nickel/gold over copper pads. STI has found that the trade-off of flexible wire bonds (small and large diameter) over hard solder joints increases an assembly’s robustness and reliability in harsh environments such as exposure to vibration, shock, and varying thermal environments (CTE movement).



5 mil wires on a bare die mounted on a PCB, courtesy of STI Electronics

Conclusion

Large diameter wire bonding is feasible in printed circuit board applications. This trend will continue as PCB technology advances. The migration from ceramic-based to organic-based substrates has already begun in a few industries, such as automotive and commercial, and will continue to expand into others. It is lead-free process that doesn't require any post-cleaning steps and is done at room temperature. Wire bonding as an interconnection method has proven itself in high-reliability segments since the 1970's and continues to make in-roads into new markets.

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