

## Product Design for Wire-Bondability

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WIRE BONDING IS A COMMONLY USED process to create low-cost and reliable electrical interconnects between semiconductor components and mechanical assemblies. Wire bonding is generally considered the most cost-effective and flexible interconnect technology for microelectronic assembly. It is used to manufacture the vast majority of fully packaged semiconductor products. In fact, over 15 trillion interconnects are formed by wire bonding each year. Different types of wire bonding processes include gold ball bonding, fine gauge aluminum wedge bonding, heavy gauge aluminum wedge bonding, and ribbon bonding. In order to be successful, wire bonding must be properly designed into the microelectronic assembly from the start. The assembly must be designed to accommodate the wire bond process tooling, the wire bond interconnect pads must be properly sized to accommodate the wire bonds, the metallization of the wire bond pad needs to be designed to be compatible with the chosen interconnect bond wire that can withstand the environmental and mechanical conditions of the end application, and the assembly must be designed to fully support the structure beneath the wire bonds.

Wire bond tooling includes all of the process and assembly tooling as well as the equipment required to perform the wire bonding operation on the device, assembly, or sub-assembly. Process tooling refers to all of the tooling on the wire bond head. This includes the wire bonding end effector tool, cutters, clamps, ultrasonic transducers, etc. (See Figure 1) There must be adequate clearance around the wire bond pad to fit the tool and all of its peripheral parts into the assembly to perform the wire bond. High aspect ratio components, like passive components in close proximity to the wire bond locations, can cause interference with bonding. It is also important not to forget about the tolerance stack in those component locations. If any portion of the bond head, other than the bond tool, comes into contact with any portion of the part, other than the bond pad, the wire bond will be compromised due to the shunting of ultrasonic energy to ground. It may seem simplistic, but it is important to mention that the part being bonded must fit into the wire bonding process



Figure 1. Process tooling – end effector, cutter, and clamp.

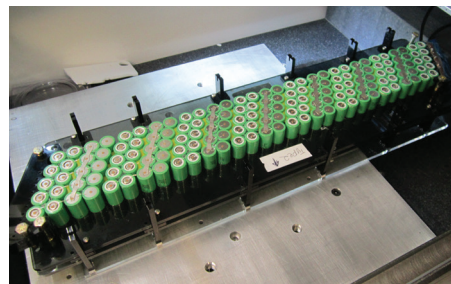


Figure 2. Large battery pack.

equipment. In the case of heavy gauge wire and ribbon bonding, the space inside the assembly is not typically a big issue, but the overall assembly envelope can be large, particularly with battery packs. (See Figure 2) If the assembly design does not fit into standard production bonders, then a custom bonder designed specifically for the assembly may be required. This would add considerable cost.

The wire bond interconnect pads on the part

must be properly sized to accommodate the wire bonds. Because today's production wire bonders have positional tolerances in the sub-micron range, this seems like a fairly simple and straightforward requirement. However, it is often overlooked. Sometimes, in the case of a PCB or flex circuit, the immediate design focus is on layout and assembly envelope. The bond pads are sized to whatever room is left on the board at the very end of the design process. Wire bond pads designed to three times the overall size of the wire bond envelope are preferred. The wire bond envelope includes the bond footprint, the tail, and the transition heel of the bond. (See Figure 3) Creating a pad that is three times the size of the wire bond envelope ensures adequate room with the potential for rework. In cases where the overall dollar value of the assembly is low, and rework is unnecessary or not required, two times the envelope can be an acceptable pad size. Allowing for adequate bond pad size can greatly increase the manufacturability of the



# Product Design

assembly and reduce the cost.

The metallization of the wire bond pad needs to be designed to be compatible with the chosen interconnect bond wire. Not only does the bond pad need to be compatible with the bond wire but it also needs to be compatible with the assembly design for product life. In the case of plating systems, nickel, gold, and aluminum are the most popular bond metals. The most robust wire bonding metal systems are gold wire on a gold pad or aluminum wire on an aluminum pad. (See Figure 4) However, due to product assembly considerations like cost, it is seldom possible to have an ideal metal interconnect system. As an example, soft electroless nickel is a common and well established plating metal. Nickel oxides are particularly difficult to bond through, so for aluminum wire it is common to use a gold flash to protect the nickel plating from oxidation. Conversely, when bonding gold wire on nickel plating, the gold finish needs to be thicker. Also, gold wire bonding requires an elevated temperature of 150°C for the bonding process, so the assembly needs to be designed to withstand this thermal exposure. Since a bond metal compromise is likely to occur somewhere in the design, typically regarding pad metallization, it is best to make that decision sooner rather than later in the design cycle.

The final important consideration for wire bond pad design is structural support for the wire bonding process. Effective and robust wire bonding is accomplished by the application of ultrasonic energy with compressive force over time. There needs to be enough unobstructed support beneath the bond pads to accommodate the compressive forces of the bonding process. Ideally, the space on the back side of the bond pads is free of components and has adequate room for tooling to provide a mechanical support beneath each bond pad. This can be accomplished with an adhesive or mechanical bond to a substructure and/or custom tooling that provides the support. If the mechanical support is provided by an adhesive bond, it is important that the adhesive is void free beneath the bond pads. Air voids in the adhesive layer will absorb the ultrasonic energy and weaken the wire bond due to lack of structural support.

When developing a wire bond interconnect it is important to begin the design with the end in



Figure 3. Close up of wire bond envelope – initiating first bond.



Figure 4. Aluminum wire on aluminum and nickel finishes.

mind. The best outcomes can be achieved when the design team includes the process engineering team in the design reviews and product decisions as early in the cycle as possible. Whether the effort is internal to a single organization or is based on an outsourced supplier relationship, early collaboration in the spirit of concurrent engineering in “product design with the end in mind” can save considerable time and money overall.

*William Boyce is the Engineering Manager at SMART Microsystems. He has served in senior engineering roles over the last 24 years with accomplishments that include manufactured automotive sensors. He is certified in EIT and Six Sigma Green Belt and is an industry recognized expert in Al wire bonding. Additionally, he designed and led the metrology lab and machine shop at Sensata.*