Destructive Wire Bond Testing for Development and Production

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WIRE BONDING IS GENERALLY considered the most cost-effective and flexible interconnect technology and is used to assemble the vast majority of semiconductor packages. In fact over 15 trillion interconnects are formed by wire bonding each year. With that said wire bonding interconnects have also long been the bane of the existence of many process and manufacturing engineers. The process engineering and development takes extensive effort involving destructive pull and shear testing as well as multifactorial design of experiments. Once the process is developed and released to manufacturing, the manufacturing engineering teams are tasked with the responsibility of keeping the process centered in the process window, also requiring some level of destructive testing. And the irony of destructive testing is that every bond we test does not ship to the customer and the only bonds that we ship to our customer are ones we have not tested. So how is it that wire bonding is still such a robust process to create low-cost and reliable electrical interconnects between microelectronic components and mechanical package assemblies? Perhaps one answer is in a rigorous statistical method of process control.

The process of wire bonding is simply the joining of two metals through force and vibration. Thorough wire bond process engineering and development takes extensive effort. Once the design is complete with the wire size, materials, and loop geometry chosen, the next step is to establish a high strength quality weld between the wire and the base metal, commonly referred to as the bond foot. When two metals are joined as is the case with wire bonding, the best way to determine if the weld joint is strong enough and properly formed is through destructive shear testing. In the process of shear testing, a blade is used to shear completely through the wire bond foot to determine the force required to shear through the welded joint. We also carefully examine the failure mode and the remnant left behind after shearing is complete. The maximum shear value can be used to determine if the overall strength is adequate and establishes an objective data point/s for analysis and statistical process methods. The evaluation of the remnant left behind provides evidence of potential weakness in the weld, and ways in which the wire bond weld can be improved. In the wire bond process development effort, destructive wire bond shear testing is still the most valuable tool.

After the wire bond weld has been properly optimized and dialed into the process window with shear testing, the actual wire loop formation needs to be optimized. This is typically accomplished through destructive wire bond pull testing. Bonding wire is typically provided with a tensile ultimate strength test certification on the wire spool. Using the wire tensile strength one can calculate the theoretical pull strength from the bond and loop geometry. In this case the part under test is secured to the base of the pull tester, a hook placed under the bond wire, and a pull force is applied until the wire fails in tensile load. And again we collect the maximum tensile value to be used to determine if the overall strength is adequate and establishes an objective data point/s for analysis and statistical process methods. The failure mode is also collected to insure that we fully understand such things as the heal formation and wire strength. As is the case any time we join metals, the weld joint should always be stronger than the components being joined. So we should never see a wire lift off the bond pad or see the plating (if the pad is plated) separate from the bond pad. Because the wire formation of the heal should always be the weakest element of the interconnect, a heal break should be the highest occurring failure mode. Once the product is released to production, manufacturing engineering would use pull testing as a leading indicator of bond tool wear. Keep in mind that the overall pull strength of the bond loop is a function of the loop geometry, not just the tensile strength of the wire. The bond angle determines the overall pull force required to reach the tensile strength of the wire. This is why in some ways, if the loop formation is not tightly controlled, the pull test results can be confounding.

Once the wire bond process is fully developed, documented and released to
manufacturing, the manufacturing engineering teams are tasked with the responsibility of keeping the process under control. As stated earlier, we cannot destroy every bond with testing, and we cannot develop confidence in the process without testing. So process monitoring and control is typically accomplished through some level of statistical process control (SPC) methods. A testing plan will be established to pull and shear a specific number of wire bonds per lot of material and collect the data in a running chart. This method of statistical process control keeps testing to a minimum, maintains product quality within the process windows, and most importantly alerts the manufacturing engineering team when the process may be wandering out of control.

Some manufacturers like to rely on Mil Std 883 for guidance on wire bond pull strength and testing. At SMART Microsystems, we like to use the published wire strength and analytical data to establish our minimum wire bond tensile and shear strength. Then we use shear testing as the primary objective data for wire bond weld strength, and pull testing for loop formation, loop geometry, and overall formation process health. When products are released to production there is no substitute for rigorous in-process SPC shear and pull testing.

For more about SMART Microsystems services visit smartmicrosystems.com.

William Boyce is the Engineering Manager at SMART Microsystems. He has served in senior engineering roles over the last 19 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. Mr. Boyce earned a Bachelor of Science in Engineering degree from the University of Rhode Island and has been a member of the IMAPS New England Chapter for over 10 years.