Destructive Wire Bond Pull Testing and its Purpose

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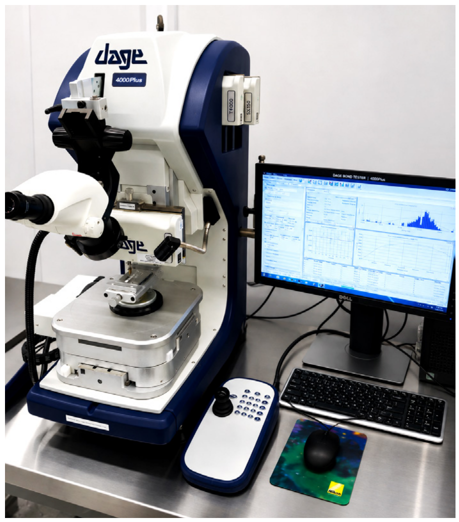
IN A PREVIOUS ARTICLE, DESTRUCTIVE wire bond shear testing was discussed. In this article we will discuss the practice and purpose of the destructive wire bond pull test. The reason that we chose to discuss wire bond pull testing after examining shear testing is that, in concurrence with the development process of a wire bond, we perform pull testing only after shear testing has been performed. The destructive pull test is explicitly what it sounds like. A wire bond loop is pulled until it fails in one of three ways: bond lift, heel break, or midspan break. The pull test measures the force required to break the wire from tensile force, and the remnants of the wire bond are used to determine the failure mode. Typically used to develop the wire bond process, destructive pull testing is also used as a statistical process control in production bonding. The wire bond pull test is not a replacement or substitute for the shear test, but rather a completely different test with a different purpose and intent. Just like the shear test, the pull test has very specific characteristics that it measures. If we assume that shear testing was used to develop a robust weld at the bond foot, a weld that is stronger than the wire itself, then the pull test should never result in a wire bond lift, as this occurrence would be a considered a reject-able condition and cause for immediate action. We don't just focus on the force required for the wire to fail or break; we are also interested in the failure mode. For a robust and well defined process, that failure mode would be a heel break or a mid-span break. Unlike shear testing, pull testing is covered in MILSTD- 883. This standard, however, covers wire bond pull testing at only a most basic level.

The destructive wire bond pull test is performed by a complex instrument. The tool accessories and settings are selected based on the theoretical breaking pull force range of the wire loop. Once selected and calibrated, the process involves placing a hook under the apex of the bond loop and exerting an upward force on the bond loop until it fails. At SMART Microsystems we employ a Dage 4000Plus to perform this testing. The loop



Dage 4000Plus

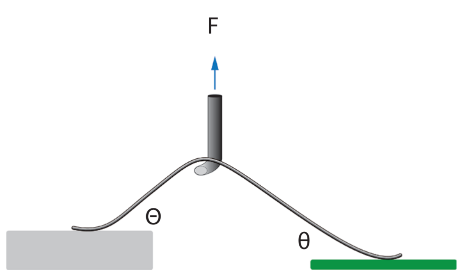


Figure 1

geometry is very important to deciphering the data from the pull test. The tensile force within the bond wire is a function of the pull force and the angle each wire forms with the substrate, see Figure 1. In fact, the resultant tensile force is a trigonometric function of the pull force F and the angle formed by each wire. So, if we assume that the weld formed at the foot of the wire is stronger than the wire itself, as it should be based on rigorous shear testing and development, then in theory, the resultant pull force F can vary from zero to two times the tensile strength of the wire based on wire geometry alone. Just as the shear test is intended to properly develop a robust weld between the bond wire and the bond pad, the pull test is intended to develop the optimum wire formation and loop geometry.

The destructive wire bond pull test is intended to measure the force required to break the bonded wire using tensile force. It is also possible to perform a non-destructive pull test, but without the results from the wire break, the usefulness of the data collected is drastically decreased. The non-destructive pull test should be used only after a defined and rigorously tested wire bond process has been developed. In destructive pull testing for wire bond development and process control, we record the actual force required to break the bond many times over, but as you may begin to notice it is important to know how that data can be assessed. This developed measurement method specifically relates to the tensile strength of the wire being bonded. We typically explicate our destructive pull data with the use of non-destructive pull force. By placing a small non-destructive pull force on a wire loop to straighten it, we can then measure the geometry, calculate the angles, and with the known tensile strength, calculate the theoretical pull force required for wire breaks.

In addition to actual and theoretical breaking force, we are also interested in the failure mode. Figure 2 indicates how we at SMART Microsystems generally categorize the different failure modes. A wire bond lift is considered a reject-able condition, but with a properly formed wire heel and a roughly 30-degree angle at the wire-substrate interface, we expect the failure mode to be primarily heel breaks with some mid-span breaks. The reason that heel breaks are most common is simply that the heel is the part of the wire that gets deformed the most, and the wire will always break at the weakest point. There are five distinct modes of failure depicted in figure 2. Each one of the failure modes has a group of potential causes associate with them. A bond lift on either bond foot is considered an immediate cause for concern and is a reject-able condition, but nonetheless provides valuable information. A mid-span break near to either the first or second bond is considered to be the most desirable outcome but can be difficult to achieve with many loop geometries. Heel breaks are the most common failure

WIRE BOND TESTING

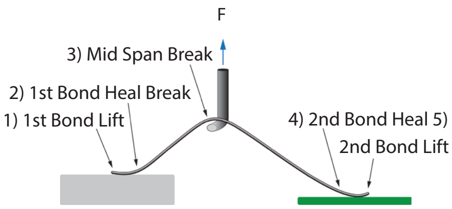


Figure 2

mode by far, but this could easily indicate an incorrectly formed wire bond foot or improper loop geometry, so although common, this type of failure should never be overlooked.

MIL-STD-883 includes a section on destructive wire bond pull testing that includes the minimum pull strength of different wire diameters. At SMART Microsystems we use MIL-STD-883 as a general guide only. Our upper and lower pull strength limits are developed internally and are derived from the wire manufacturer's tensile strength for the specific wire being used and the wire geometry. As you'll know from the previous article (MEPTEC Report Summer 2019, Volume 23, Issue 2), we also derive the upper and lower shear limits from the wire tensile strength. Using the wire bond pull test as a process control can be very useful, and each of the failure modes can be a leading process indicator. A pull test breaking strength that is too low or too high can indicate a wide variety of root causes, including change in loop geometry, or even the wrong wire installed in the bonder. A low pull test breaking strength with poor heal formation could indicate a change in settings or a fowled tool, among many other possible root causes. Pull strength should never be considered a single sided limit, it should have defined upper and lower limits.

Destructive wire bond pull test in process

Wire bond destructive pull testing has a valued and indispensable place in the world of wire bonding. It can provide real actionable data to improve, develop, and regulate the wire bond process. Simply stated, pull testing speaks to the quality of the formation of the wire bond loop. The data that it does not speak to is the quality of the weld between the wire and the substrate, which is derived from shear testing. If I could only choose one test for process development it would be the shear test, and if I had only one test to choose for process control it would be the wire bond pull test.

For more information visit our website at www.spiritelectronics.com.

William Boyce is the Engineering Manager at SMART Microsystems. Mr. Boyce earned a Bachelor of Science in Engineering degree from the University of Rhode Island and has served in the field for over 20 years as a mechanical design engineer, process engineer, team leader, engineering Manager, and Global Engineering Director. In addition to his current role at SMART, he has held positions at General Dynamics, Texas Instruments, Sensata Technologies and TT Electronics. Mr. Boyce has also been a member of the IMAPS New England Chapter for over 10 years as a session chair. He is EIT certified, a Six Sigma Green Belt, and an industry recognized expert in Al wire bonding.