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Beyond 0402M Placement: Process Considerations for 03015M Microchip Mounting

Brent Fischthal, Sr. Marketing Manager, Products & Solutions
Michael Cieslinski, Engineering Manager
Panasonic Factory Solutions Company of America
Rolling Meadows, Illinois

Abstract
The printed circuit board assembly industry has long embraced the "Smaller, Lighter, Faster" mantra for electronic devices, especially in our ubiquitous mobile devices. As manufacturers increase smart phone functionality and capability, designers must adopt smaller components to facilitate high-density packaging. Measuring over 40% smaller than today's 0402M (0.4mmx0.2mm) microchip, the new 03015M (0.3mm×0.15mm) microchip epitomizes the bleeding-edge of surface mount component miniaturization.

This presentation will explore board and component trends, and then delve into three critical areas for successful 03015M adoption: placement equipment, assembly materials, and process controls. Beyond machine requirements, the importance of taping specifications, component shape, solder fillet, spacing gap, and stencil design are explored. We will also examine how Adaptive Process Control can increase production yields and reduce defects by placing components to solder position rather than pad. Understanding the process considerations for 03015M component mounting today will help designers and manufacturers transition to successful placement tomorrow.

Introduction
The industry's insatiable demand for smaller, lighter, faster devices with more functionality at a lower price is a long-standing driver of the electronics manufacturing industry, especially within the mobile device segment. The increasing use of smaller components has not ceased since the first pin-through-hole devices emerged in the 1960s. Since then, the printed circuit board assembly (PCBA) industry has continually reduced the size and weight of passive components like capacitors and resistors, which continue to shrink from the current 0402M (0.4mmx0.2mm) to the emerging 03015M (0.3mm×0.15mm) microchip component. Figure 1 compares components to demonstrate the continued size reduction by suppliers. By comparison, a human hair is approximately 0.1mm wide.

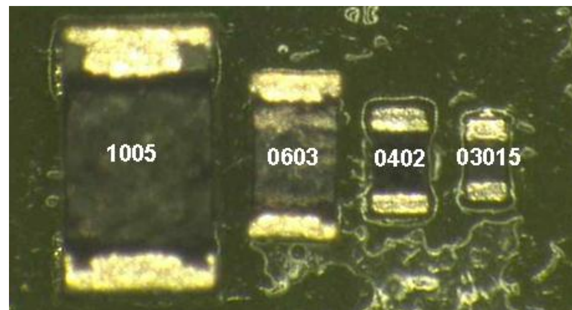

Figure 1: Passive Component Size Comparisons (0402 Metric represents 01005 imperial)

Driven by the increasing usage of modules (e.g. MCM, Hybrid IC, VCO, TCXO, etc) in small communication and consumer equipment like ultra-portable mobile devices and wearable devices, the demand for miniaturization continues. Smartphones, for instance, normally have several hundred resistors per unit. Microchips like the 0402M (01005) and 03015M facilitate high-density packaging to address the increased component count attributed to enhanced functionality demands from consumers.

While the 0402M (01005) component adoption continues, the next wave of microchips is already in development. In general, the new 03015M chip dimensions are about 44 percent smaller in length and width than the 0402M (01005), which helps reduces the board area by about 50 percent and weight by about 58 percent. Figure 2 provides preliminary component dimensions of a 03015M microchip.

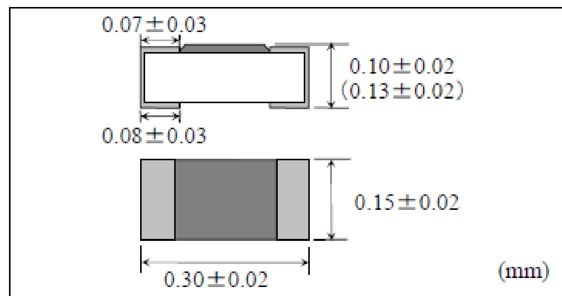

Figure 2: Tentative 03015M Component Dimensions

As 0603M (0201) and 0402M (01005) microchips become established components within the PCBA industry, the 03015M emergence requires delving into three critical areas for successful 03015M adoption: placement equipment, assembly materials, and process controls.

Placement Equipment

When the 0402M (01005) microchip first entered the market, many pick and place equipment suppliers noted the mounter required several core features for successful placement of the new microchip. With the introduction of the 03015M microchip, many of the same attributes remain critical to successful mounting. For example, the mounter should include a highly stable frame with accurate drive system. The vision system should be able to illuminate the component at various intensities to account for component supplier differences. Integrated flow detection should be part of the pneumatics in the placement head to monitor the component from pickup to placement. Additionally, certain features like adaptive pick control and automatic tape pocket teaching will help the maximize yields. Our testing has determined an additional need for chip thickness inspection using a side view CCD camera, which will further improve 03015M mounting. Figure 3 shows the three basic steps for the 03015M process.

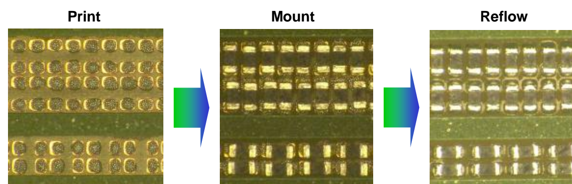

Figure 3: Successfully mounted and reflowed 03015M test vehicle sample

Necessary Options

Using an upward looking or head mounted vision inspection system to align the X, Y, and Theta of a 03015M is an absolute requirement for accurate placement. Yet, the emergence of microchips like the 0603M (0201), 0402M (01005), and especially the latest 03015M microchip, another inspection step of the Z-axis will prove beneficial to the process.

For the tests we conducted as part of this study on the challenges for successful 03015M placement, we used a production mounter outfitted with two 16-nozzle heads and upward looking line scan cameras. Each includes a Board Warp Detection sensor to verify component placement height and a Side View Camera to measure chip thickness/presence.

Board Warp Detection

After the substrate enters the mounter and the fiducial system registers it into place, a head-mounted laser detection system engages to map the topography of the substrate. Once the short machine sequence concludes, the first mounter compiles and shares the data with downstream mounters to improve the placement position of the 03015M and other components. This step ensures the placement head has registered the actual substrate board height, which will adjust placement to accommodate any bow or warp on the substrate. If a substrate bows downward, component placement to the programmed board height may lead to cracked components to displaced solder due to premature board contact. If a substrate is warped downwards, other negative effects, including but not limited to insufficient solder contact or dropped component could occur. Figure 4 provides a representation of a multi-point board mapping system in a pick and place machine.

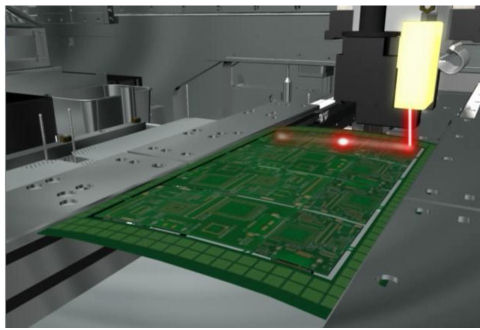

Figure 4: Board Mapping Concept in a Pick and Place Machine

Side View Camera

As the upward camera is inspecting X, Y, and Theta orientation, a Side View Camera is inspecting the end of each spindle to confirm component thickness, presence, absence, and position on the nozzle tip. Once this system confirms a correctly positioned component is available, it verifies the thickness of the component matches the data file in the component database. Figure 5 shows the general concept of a head-mounted side view camera on a pick and place machine.

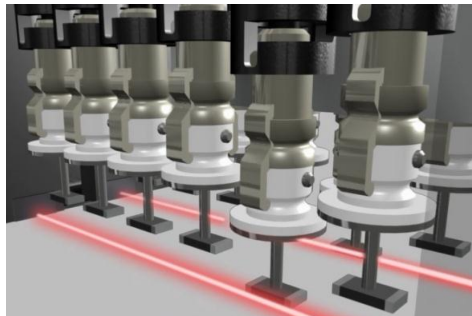

Figure 5: Head-mounted Side View Camera Concept in a Pick and Place Machine

Combined, Board Warp Detection and Side View Camera features help ensure the pick and place machine will properly mount components onto the substrate without dropping components, missing components, solder bridging, or other manufacturing issues mandating either board rework or scrap.

The machine mounting attributes for the 03015M component are only a small subset of the processes involved with successfully manufacturing products with the new component. Let us continue by exploring the assembly materials, including solder paste and stencil, tape packaging, as well as the effects these materials play on the success of 03015M usage.

Assembly Materials

In addition to the core pick and place machine functionality, manufacturers must contemplate the importance of assembly materials, including, but not limited to, solder type, component spacing, and stencil design. For successful production control and durability, board designers must optimize the solder fillet and interspacing gap between components mounted to the substrate (Figure 6).

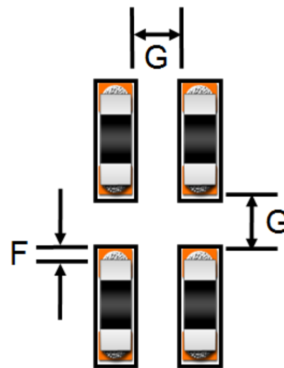

Figure 6: Fillet (F) and Gap (G) need to be optimized

For the solder bridge test, we used a production lead-free paste (Sn 96.5 / Ag 3.0 / Cu 0.5) with a 15-micron to 25-micron powder size . The paste was used in conjunction with an 80-micron thickness stencil, stepped down to 60-micron. The test vehicle included several combinations of fillet (F) at 0-micron, 25-microns, and 50-microns and gap (G) at 45-microns, 60-microns, and 80-microns as shown in Figure 7.

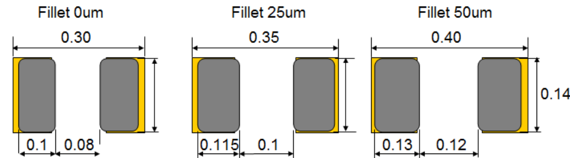

Figure 7: Substrate Pad and Stencil Screen Aperture Conditions

The preliminary results showed 6 to 10 bridges occurred in each test scenario using a 40-micron gap. A significant reduction occurred at 60-micron gap. In fact, the 25- and 50-micron fillets had no issue and the 0-micron fillet had two bridges. There were no solder bridge occurrences for any fillet size with an 80-micron Gap or larger. Figures 8 shows the graphical results and Figure 9 provides images of several test scenarios.

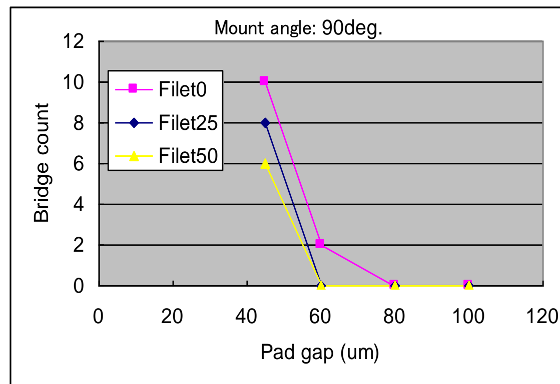

Figure 8: Graphical Results of Solder Bridge Test

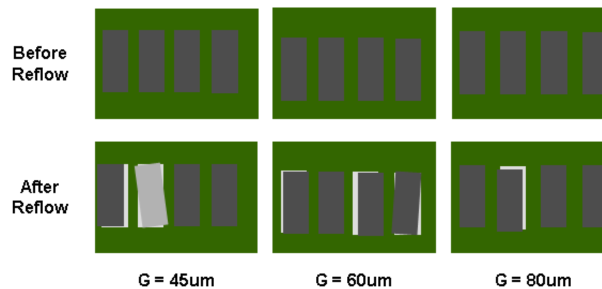

Figure 9: Image of Solder Bridge Test Results

Tape Packaging

Manufacturers must consider the component taping specifications. As stands true for components packaged in tape, the repeatability of the tape pocket plays a critical role in the ability to successful handle 03015M components. When the dimensions of the component compared to the dimensions of the tape are too great, the ability to pick the 03015M component is diminished, as shown in Figure 10.

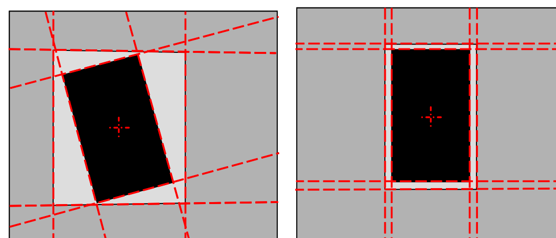

Figure 10: Component size to pocket ratio is critical to control for an accurate pick

We performed two sets of tests using a production tape feeder to determine the pickup rate dependence with regard to material taping. In Test 1, the pocket size was 0.36 x 0.22mm, which represented a 20% oversize in X-axis and 47% oversize in the Y-axis. Following a 5,000 piece test run, we measured the pickup position repeatability in the X-axis at 70 microns (3 sigma) and in the Y-axis at 53.4 microns (3 sigma). The X-Y Distribution is shown in Figure 11. The resulting pickup error was 1.66%.

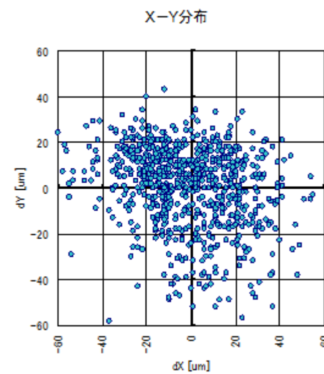

Figure 11: X Y Pickup Position Repeatability Results from Test 1

In the second test, the pocket size was reduced to 0.34 x 0.19mm, which represented a 13% oversize in X-axis and 27% oversize in the Y-axis. Following a comparable 5,000 piece test run with 03015M components and tape from the same supplier, we measured the pickup position repeatability in the X-axis at 46.9 microns (3 sigma) and in the Y-axis at 47.8 microns (3 sigma). The X-Y Distribution is shown in Figure 12. The resulting pickup error was a dramatic improvement to 0.65%.

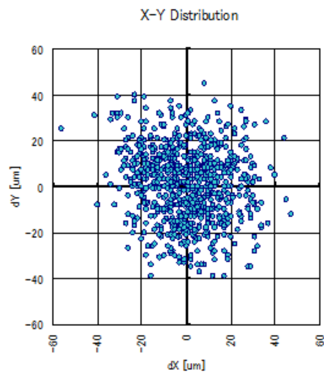

Figure 12: X Y Pickup Position Repeatability Results from Test 2

The results from the tape pocket dimension tests clearly shows a tighter pocket to component ratio will dramatically aid in a producing an appropriate pickup rate, which means fewer mispicks, less component waste, and increased machine utilization.

Adaptive Process Controls

The PCBA industry has numerous studies and documentation detailing how the solder reflow process can help position surface mount components normally on the pads, even if component placement is off pad. However, the trend to shrink components to 0.3mm pitch bumps or 03015M microchips is opening doors to explore how adaptive process controls can improve yields in high-density placements.

Adaptive Process Control (APC) collects solder location data from a Solder Paste Inspection (SPI) system, and then sends the data downstream to pick and place mounters, as shown in Figure 13.

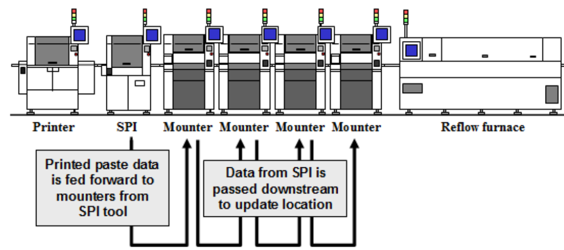

Figure 13: Theoretical SMT Line utilizing Adaptive Process Control

The mounters use the received data to update the placement program; thereby, ensuring the components are placed onto the solder deposits rather than onto the substrate pads. This approach to placing components on the printed solder uses the self-alignment principle to increase production yields and reduce defects.

As shown, when solder is off pad due to myriad reasons and components are placed to the pre-defined placement location in the program, self-alignment is not effective. During reflow, components will shift off pad or bridge with other pads; thereby, causing rework or scrap. (Figure 14)

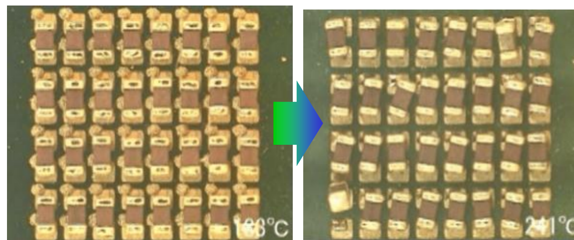

Figure 14: Traditional Placements with Chips Located on Pads (before and after reflow)

Alternatively, Adaptive Process Control(APC) controlled placements will maximize the self-alignment principle. Using APC to mount microchips onto the solder instead of the pad will increase yields and quality. Figure 15 shows a set of test results.

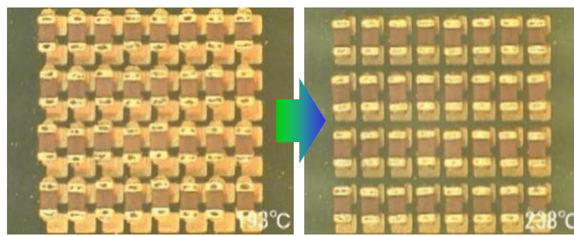

Figure 15: APC-controlled Placements with Chips Located on Solder Deposit (before and after reflow)

In general, communication between a printer and mounter will improve process repeatability by automatically adjusting component placement to the solder deposition, rather than to the pad location. This advanced process further improves microchip mounting reliability. Figure 16 charts dramatic improvement across five different defect types when a manufacturer uses adaptive process control in production compared to a conventional placement approach with no communication between printer and mounter.

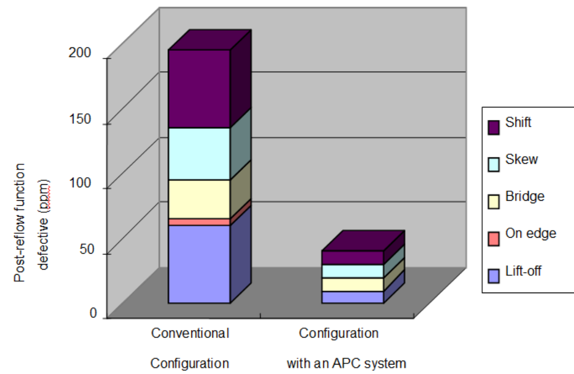

Figure 16: Post-reflow Defect Reduction Effects with Adaptive Process Control

Summary

With the upsurge in miniature, lightweight, advanced-function electronic devices, demand will drive an increase in microchip adoption that will necessarily result in improved practices in manufacturing. The mounting technology for 03015M components requires some of the same principles as the larger 0603M (0201) and 0402M (01005) microchips; yet, certain machine features are becoming necessary to ensure high quality production. Even with a capable machine, component placement is only part of the process. Manufactures must give additional, special consideration to board design, tape standards, solder materials, and stencil design. Certain manufacturing enhancements like Adaptive Process Control can help manufacturers improve yields for microchip. For its part, the company intends to continue evaluating these and other new products to ensure manufactures have the solutions to address mounting challenges likely to arise as the microchip trend progresses. After all, the 0201M chip component is already in the design phase.