Challenges of Miniaturization

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It is likely that a modern mobile phone has more computing power than all of the computers that NASA used to send men to the moon in the late 1960s. This idea is especially interesting when one considers that the electronics of that era had almost no integrated circuits (ICs) and that many computer circuits were individual transistors, resistors, and capacitors. Today’s PC microprocessors have the equivalent of hundreds of millions of these components, all electrically connected in the IC. Such miniaturization has enabled the electronics revolution.

But what are the challenges of such miniaturization? For the electronics PCB assembler there are many. To enable today’s miniaturization, especially for portable devices like mobile phones and “iPODs,” the size of all components has shrunk dramatically. Most notable are the “passive” components such as resistors and capacitors, which are about 90% of all the components assembled. Not too many years ago, an “0402” (0.04 x0.02 inches) was the smallest passive available. Today, people routinely assemble 0201s and a few have even tackled 01005s. These small passives and other miniaturized components, such as 0.4 and 0.3 mm pitch CSPs, create numerous assembly challenges. For one thing, their small size makes them difficult for placement machines to handle; however, the greatest challenges are in the stencil printing and reflow processes.

It is believed by most pundits in the electronic assembly industry that about 65% of the end-of-the-line defects can be traced back to the stencil printing process. I have not been able to find any data to support this assertion, but I feel it is close to the mark. Stencil printing for 0201, and especially 01005 passives, is especially challenging. The size of the solder paste deposit, for a 01005 passive, is about 6 mils square, which is the approximate size of the aperture of the stencil. It has been shown that for successful printing, the area ratio of an aperture must be greater than 0.66. For successful printing of “normal” size components, a stencil is typically >= 4 mils. A square aperture having 6 mil sides with a 4 mil thick stencil has an area ratio of only 0.375. With an area ratio this small, the consistency of the solder paste volume in the stencil printed “brick” is not acceptable. Even a 3 mil thick stencil only provides an area ratio of 0.50 for a 6 mil square aperture. Solder pastes with finer solder powder sizes, i.e., a type 4 or type 5 solder powder, have recently been shown to help with such fine printing. However, even if you use one of these new pastes with a 3 mil thick stencil and obtain acceptable printing, you will still need to print twice to accommodate the rest of the PCB components that will need a 4 -5 mil thick stencil to obtain enough solder paste for their solder paste deposit.

Of course, once you have obtained successful printing and the placement of these small components, there are other challenges for the solder joints of these small passives because the size of the solder balls in the solder paste is about 1 mil; the printed solder deposit is literally only a handful of solder balls. As the PCB goes through the reflow process, the very small solder deposit has a very high surface area to volume ratio. This means the solder paste flux has more surface area to protect. Many modern lead-free solder pastes do not have an effective enough flux to protect the surface of the solder balls. This lack of protection results in oxidation and incomplete reflow, commonly referred to as graping. Solder joints with graping have unacceptable mechanical properties. Fortunately, there are solder pastes available with fluxes that resist this phenomenon.

Unfortunately, even if the solder joint is acceptably reflowed, it is so small that only one metallurgical grain could form the entire solder joint. If the orientation of the grain is such that its weakest direction is toward the greatest mechanical stress in thermal cycle or shock, the joint could fail. Recent work has shown that small amounts (<0.1%) of some alloying elements, such as titanium, may prevent large grain growth and negate this problem.

These are still only a few of the miniaturization challenges that manufacturers face. Many of these problems can be mitigated by working closely with materials and equipment suppliers, who will often have the experience available to help you understand and meet these miniaturization challenges.

1 The area ratio equals the area of the aperture opening divided by the area of the aperture sidewalls or a \( \frac{a}{4at} = \frac{a}{4t} \), where “a” is the side of a square aperture and “t” is the stencil thickness.

2 The size of the solder paste deposit, for a 01005 passive, is about 6 mils square, which is the approximate size of the aperture of the stencil. It has been shown that for successful printing, the area ratio of an aperture must be greater than 0.66. For successful printing of “normal” size components, a stencil is typically >= 4 mils. A square aperture having 6 mil sides with a 4 mil thick stencil has an area ratio of only 0.375. With an area ratio this small, the consistency of the solder paste volume in the stencil printed “brick” is not acceptable. Even a 3 mil thick stencil only provides an area ratio of 0.50 for a 6 mil square aperture. Solder pastes with finer solder powder sizes, i.e., a type 4 or type 5 solder powder, have recently been shown to help with such fine printing. However, even if you use one of these new pastes with a 3 mil thick stencil and obtain acceptable printing, you will still need to print twice to accommodate the rest of the PCB components that will need a 4 -5 mil thick stencil to obtain enough solder paste for their solder paste deposit.
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