

A Process to Produce Low Cost Solder Balls in Custom Sizes

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Abstract

Use of solder balls as component- and package-to-substrate interconnect media has proliferated with the increasing need for the miniaturization of electronic devices. Solder balls are either manufactured on the pads of devices or packages where they are needed, or pre-manufactured individual solder balls are dispensed on the pads and reflowed to make a bump. Pre-manufactured solder balls require special equipment for manufacture, need tight tolerances, and thus are expensive. They come in standard sizes and are hard to obtain in custom sizes when needed.

A method is described to make custom-size individual solder balls using ordinary SMT equipment without special tooling. Ability to make custom-sized solder balls inexpensively can help expedite research and development projects with savings on total cost of the projects.

Key words: Solder balls, printing, manufacturing, custom sizes, SMT.

Introduction

Solder balls or solder spheres are used as a popular interconnecting media for attaching many types of electronic packages and dice to printed circuit boards and packaging substrates. Solder balls are made from solder powder usually composed of some type of alloy that is melted or “reflowed” into a ball. The solder alloy materials may be in powder form suspended flux to make solder paste. This paste may be printed or applied and then reflowed to form a ball by some means of heat source such as a surface mount technology reflow oven. Plating processes have also been developed for this purpose.

Many types of alloys are available from solder manufacturers. Standard eutectic tin-lead composition has been very popular in the electronics industry for decades. The health concerns of lead have caused a shift towards using lead-free alloys in the electronics industry. Standard tin-lead alloys and lead-free alloys exhibit different properties.

Solder Ball Manufacturing Methods

There are many types of conventional techniques for manufacturing solder balls. A solder wire of uniform diameter can be cut into precise equal sections to produce solder balls of uniform size when melted and allowed to make a sphere. Discs of equal size can be cut out of a uniformly thick solder sheet to make solder balls of equal diameters. Solder balls are also made through pulse atomization of molten solder. These and other techniques subject the raw solder to some sort of heat source, e.g., hot oil, furnace, hot gas, to become molten solder. The liquid phase solder is turned into spheres by surface tension while traveling through the hot media, liquid or gas, inert to the solder. Balls are eventually cooled down after they have achieved a spherical shape. [1-9]

Many different sizes of solder balls are used in the semiconductor industry. Package design, board design and the pad size of the package and that of the die pad dictate the solder ball size along with the needed stand-off height of the chip or package. Higher stand-off leads to improved reliability but the ball pitch and system height

requirements easily becomes a limiting factor.

Many sizes of solder balls are used at the SMT/Packaging lab at NDSU CNSE for chip scale packages and are also found on many off-the-shelf SMT parts used in CNSE SMT builds. Solder ball sizes recently used at CNSE have ranged from 100 to 560 microns in diameter. Most CNSE designed packages use a 250 to 300 micron ball that is purchased already made and ready to attach. A 100-micron ball as a target size for reflowed balls was desired in order to further processing capabilities at CNSE. This target size was also chosen due to a wafer bumping project that needed to use 90-100 micron solder balls reflowed directly on to a wafer to create solder bumps.

Experimental Details

The goal of this study was to determine if solder balls could be manufactured in-house at CNSE with the least amount of outside dependence. This study pushed the development of a solder ball printing process allowing direct paste printing on a suitable non-solder-wetting substrate. Outside

dependant materials needed for the project were defined as a high quality paste that could meet the end solder ball size requirements and a quality designed stencil for solder printing on a non-wetting surface.

The following processing equipment and supplies were used to perform this experiment:

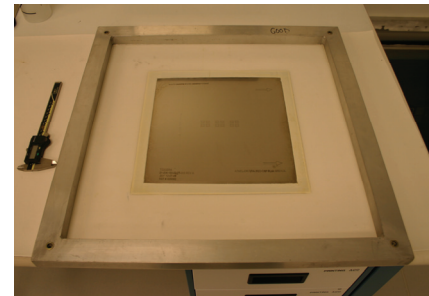
A Milara ST2929 stencil printer using 6" nickel-plated stainless steel squeegee blades, 0.004" 35 mm blank polyimide strips, A type 6 solder paste, and a 1 mil thick stainless steel stencil with calculated apertures to produce desired solder ball diameter, and Electrovert Bravo 4050 reflow oven used for SMT production. Stencil, printer and reflow oven are shown in Figure 1.

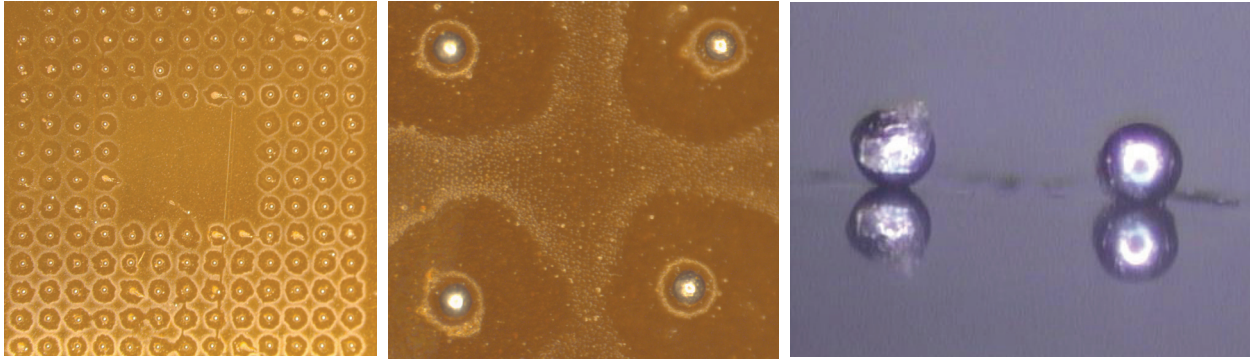
Solder paste selection was critical and was based on the following criteria:

- 1) Paste type and
- 2) Desired reflowed ball size needed.

Eutectic tin lead alloy was chosen due to its slightly more forgiving aspects of reflow. A lead-free alloy could also have been used. Further experiments using lead-free solder paste will be undertaken in the future to study and compare any

Figure 1. Stencil (right) had appropriately designed apertures to produce 100-micron solder balls. Printer (below left) was used to print the solder paste which was reflowed in the reflow-oven (below right) to make solder balls.



**Figure 2.**

Left: 100-micron solder balls printed on a polyimide strip before their removal off the strip.

Middle: A close-up of the solder balls on the polyimide strip.

Right: A side view of the solder balls before cleaning.

differences that may occur in the process due to the different paste types.

The stencil had an array of twelve sites. Each site had 148 apertures. Spacing between apertures was 450 microns and stencil thickness was 1 mil. It had a very good design for testing and evaluating the printing process. Paste could be printed through the apertures with the standard stencil printer on a polyimide sheet and reflowed.

Results

Solder paste was printed on the polyimide tapes. The tapes were passed through the reflow oven set at appropriate reflow profile for the solder. The solder balls thus made are shown in Figure 2. Note that the flux adhered to the substrate and the solder balls were kept in place during the process by the flux. No bridging was seen. It was not necessary

to keep the stencil on the substrate to keep the solder balls from bridging.

The solder balls were then collected. Their diameters were measured both in x and y directions. Both measurements were found to be similar. The z-height was measured on a sample to assure complete roundness, and was found to match the x and y measurements.

Next, six sizes/batches of industry standard pre-manufactured off-the-shelf solder balls were measured for comparison. Thirty solder balls of each size were measured. Data are given in Table 1. Data represent 60 measurements on each batch.

At CNSE, five preliminary evaluation runs were undertaken to make the solder balls using in-house equipment. The solder balls from these five runs were measured. During these evaluation runs, the average diameter varied between 96.8 and 97.8 microns. The standard deviation as a percent of the

Table 1.
Nominal and measured diameters in microns of off-the-shelf solder balls

Nominal Diameter	Measured Average	Standard Deviation	Standard Deviation as % of Average
600	601.2	12.8	2.1
540	536.5	5.8	1.1
450	457.9	7.3	1.6
305 Batch A	302.1	8.3	2.7
305 Batch B	297.8	7	2.3
250	243.8	7.2	2.9

average varied from 3 to 4.6. These results are the outcome of the very first runs without making an effort to improve the stencil design, selection of the solder paste or optimization of the printing process parameters.

Discussion

Solder paste consists of solder spheres. When this paste is used to make solder balls, granularity effect can be expected. Smaller the size of the particles in the paste, lower the effect of granularity, resulting in more uniform spheres. Decreasing ball sizes will require decreasing particle sizes in the solder paste.

The stencil design and the paste make-up will determine the average solder ball size, but its uniformity will be affected by the uniformity of the stencil printing operation, uniformity of the stencil apertures and the size of the spheres in the paste relative to the desired solder ball size.

With proper experimental design, various parameters affecting the uniformity of the solder balls thus produced can be greatly enhanced to match or surpass the off-the-shelf product.

Conclusions

Using commercially available equipment, solder balls could be manufactured without the need of special tooling or manufacture and set-up of special equipment.

The process described in this evaluation can be used in SMT labs to produce custom sized solder balls for research and development efforts.

This process has the potential for high volume application. Stencil can be designed to sport a large number of apertures to make large numbers of solder balls in each stroke.

This process provides a cost effective alternative to the off-the-shelf product.

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