Solder Jet Technology Update

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Abstract

Solder Jet Technology (e.g., piezoelectric demand-mode ink-jet printing technology used to dispense molten solder droplets) has demonstrated the ability to place 25- 125µm diameter bumps onto metallized wafers, circuit boards, and other substrates. Recent developments are discussed, including test vehicle printing, drop size modulation, microbump printing, and print-on-the-fly.

Key Words: wafer bumping, chip-scale-packages, flip-chip

Introduction

MicroFab's Solder Jet development efforts have been described in detail in previous papers and patents [1,2,3,4,5,6]. This paper describes recent results in the areas of test vehicle printing, drop size modulation, microbump printing, and print-on-the-fly.

Background

The goal of our research is the development of advanced solder deposition equipment for the electronics manufacturing industry. Solder Jet Technology is based on piezoelectric demand-mode ink-jet printing technology and is capable of producing and placing molten solder droplets, 25-125µm in diameter, at rates up to 2,000 per second. Solder Jet-based deposition will be low cost (no tooling required), noncontact, flexible & data-driven (no masks or screens are required because the printing information is created directly from CAD information and stored digitally), and environmentally friendly (it is an additive process with no chemical waste).

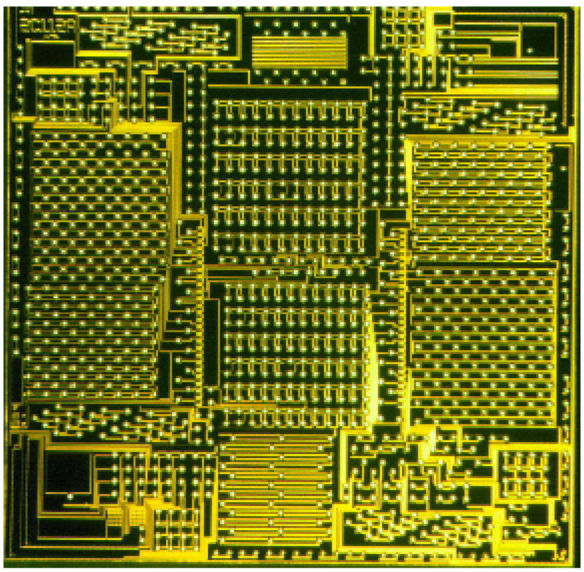

Figure 1: IC test vehicle with 1440 pads, bumped with 63/37 using Solder Jet Technology. Ball size is 70µm.

Test Vehicle Printing

The locations of the pads of an integrated circuit test vehicle with over 1400 pads were programmed into our Solder Jet research platform [5]. Droplets of $Sn_{63}Pb_{37}$, 70µm in diameter, were deposited onto several of these test vehicles. **Figure 1** shows the results from one test vehicles, and **Figure 2** is a detail from the same image.

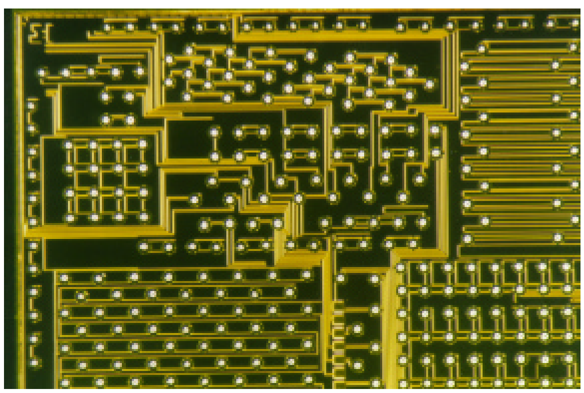

Figure 2: Detail of previous figure.

The solder bump was deposited onto a nickel pad metallization, covered by a flash of gold which promotes adhesion during the droplet impact and freezing process [7].

SEM's were obtained of both the bumps on the substrate and an FIB cross-section of one of the bumps, and these are shown in **Figure 3** and **Figure 4**. The bumps were imaged in the as deposited state. In both SEM's, the lead rich and tin rich phases are apparent. The voids seen in the cross-section are most likely an artifact of the cross-sectioning process, because they are not apparent at the surface of the original bump.

Drop Size Modulation

Solder Jet Technology is inherently flexible because each droplet is dispensed under digital control. To increase the flexibility of the system, we have recently developed novel drive waveform technology that allows the drop size to be modulated over an approximately 2:1 diameter (8:1 volume) range. **Figure 5** shows a Solder Jet device producing 62µm diameter droplets at a rate of 120 Hz. The image on the left in this figure shows the droplet being formed while it is still attached to the orifice of the dispensing device, and the image on the right shows the drop approximately 1ms later, after it has broken free from dispenser.

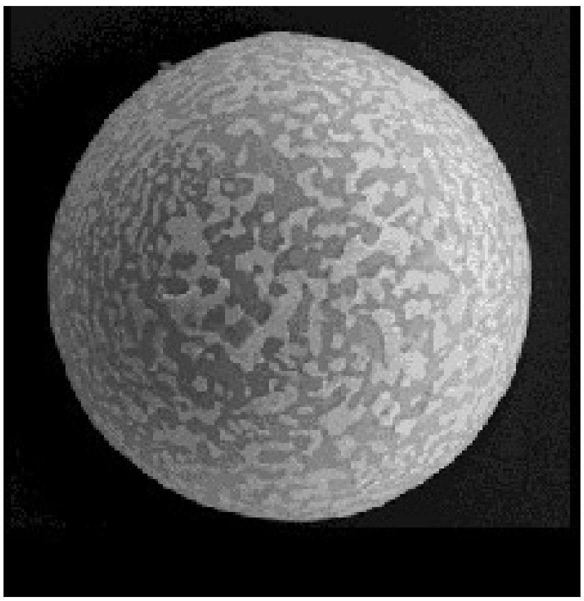

Figure 3: SEM of the top of a 60µm diameter 63/37 bump deposited onto the IC test vehicle.

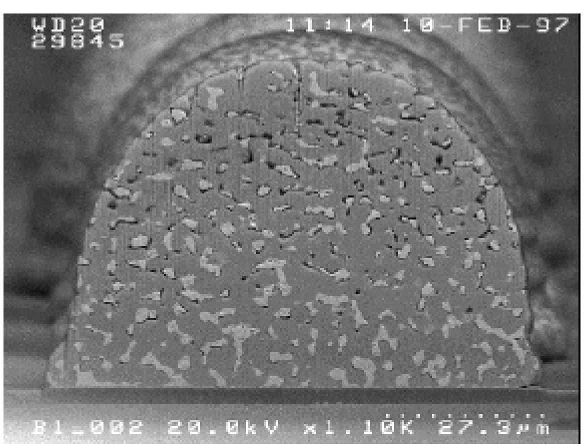

Figure 4: Cross-section of bump shown in previous figure.

Figure 6 shows the same device operating moments later, again at 120 Hz. In this figure, a drive

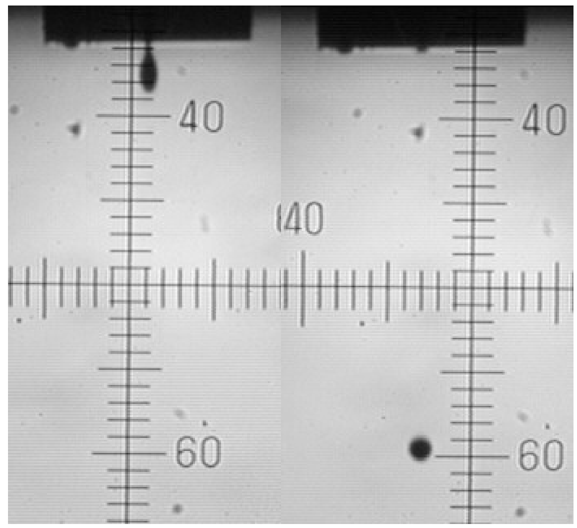

Figure 5: The drop formation process for a Solder Jet device is shown at two times during the process. The drop rate is 120 Hz and drop size is 62µm.

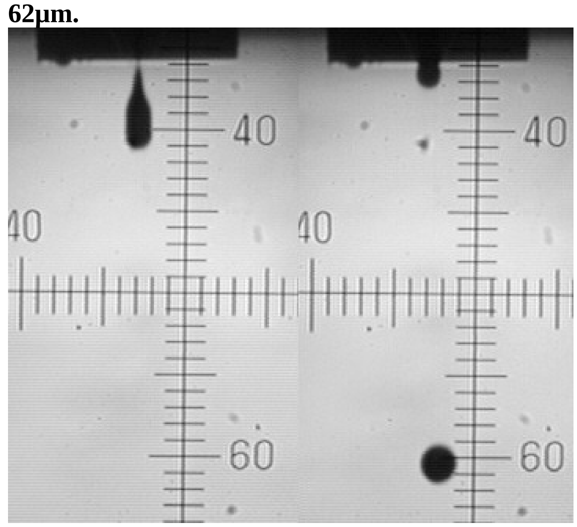

Figure 6: The drop formation process for the same Solder Jet device shown in the previous figure, but using a different drive waveform. The drop rate is 120 Hz and drop size is 106µm.

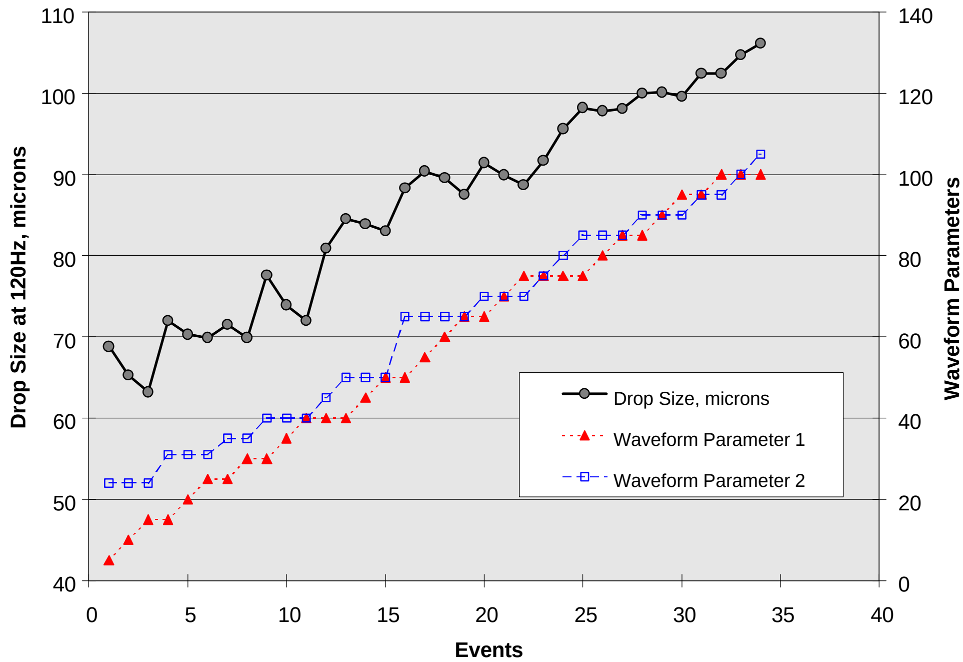

Figure 7: Drop size modulation results.

waveform that extends the drop formation process over a significantly longer time period is being used. By doing this, a considerably larger droplet is produced. In this case, the diameter is increased to 106µm. The volume modulation using this method is continuous over the entire range of achievable volumes, as illustrated by the results presented in **Figure 7**. This capability could be used to allow bump size to be changed under software control, either for product change over, or for application of variable sized bumps onto a single substrate.

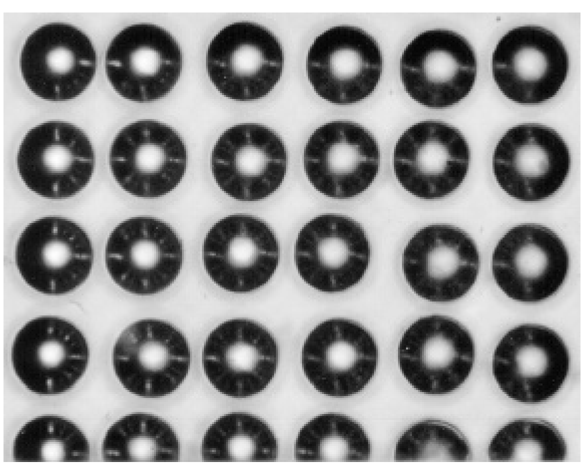

Figure 8: 25µm bumps of 63/37 deposited on 35µm pitch using Solder Jet Technology.

Microbump Printing

Solder bumps currently used in flip-chip processes are typically in the 100-125µm range, although some companies are currently evaluating 75µm bumps. As higher circuit densities and/or greater I/O counts are achieved in integrated circuit devices, there is likely to be a need for smaller bumps for flip-chip processes. Initial experiments were conducted to evaluate the suitability of Solder Jet technology for smaller bump sizes. **Figure 8** shows small section of an array of 25µm 63/37 bumps deposited on a 35µm pitch onto a silicon wafer.

High Rate Deposition

The ability to deposit bumps onto substrate at rates of greater than 200 Hz is critical to the commercial viability of Solder Jet technology. The ability to *form* liquid metal droplets at the rate, and higher rates, was demonstrated several years ago, but platform limitations have prevented us from demonstrating bump rates this high. Two platforms are being completed that have the ability to deposit bumps, using Solder Jet Technology, while the substrate and/or the Solder jet printhead are moving. This operating mode is referred to as “print-on-the-fly”

Because the solder droplet travels at a rate of 1m/s or greater and the velocity of the printhead or substrate would be 5mm/s to place 200 bumps per

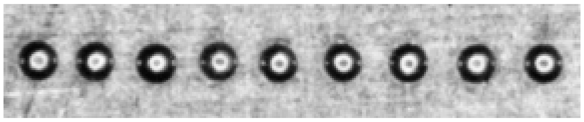

Figure 9: 70µm diameter bumps of 63/37 deposited onto silicon at the rate of 200 bumps per second using Solder Jet Technology.

second on a 250µm pitch , the oblique impact of a drop in print-on-the-fly is not a major concern. However, the locally inert environment near the dispensing device [5] is potentially far more sensitive to translation velocity. Therefore, maintenance of the low oxygen environment was the focus of initial print-on-the-fly experiments.

To qualify the Solder Jet printhead for print-on-the-fly, initial experiments were conducted with the printhead dispensing at a constant rate over an unpatterned substrate at a rate of 200 drops per second and a printhead velocity of 2mm/s., The results are shown in **Figure 9**. The effectiveness of the inert environment is evidenced by the roundness of the deposited bumps: drops that have significant oxide formation during flight and impact are teardrop shape due to the oblique impact. These experiments were repeated with substrate velocities up to 10cm/s with no significant degradation in performance.

Acknowledgments

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