

## Jetting Strategies for mBGAs a question of give and take...

Gustaf Mårtensson<sup>1,2</sup>, Petter Svensson<sup>2</sup>, Thomas Kurian<sup>2</sup>

1) BioNano Systems Laboratory, MC2

Göteborg, Sweden

2) Micronic Mydata AB,

Täby, Sweden

### Abstract

The demands on volume delivery and positioning accuracy for solder paste deposits are increasing as the size and complexity of circuits continue to develop in the electronics industry. According to the iNEMI 2013 placement accuracy for these kinds of components will reach 6 sigma placement accuracy in X and Y of 30  $\mu\text{m}$  by 2023 [3]. This study attempts to understand the dependencies on piezo actuation pulse profile on jetting deposit quality, especially focused on positioning, satellites and shape. The correlation of deposit diameter and positioning deviation as a function of piezo actuation profile shows that positioning error for deposits increase almost monotonically with decreasing droplet volume irrespective of the piezo-actuation profile. The trends for shape and satellite levels are not as clear and demand further study.

Key words - jetting, piezo, positioning, solder paste

### Introduction

The demands on volume delivery and positioning accuracy for solder paste deposits are increasing as the size and complexity of circuits continue to develop in the electronics industry. Board designs that include advanced BGAs, CSPs with 0.4 mm and 0.3 mm pitch, as well as simpler 01005 and 008006 components, raise the bar for positioning demands and volume delivery for solder paste deposits. According to the iNEMI 2013 placement accuracy for these kinds of components will reach 6 sigma placement accuracy in X and Y of 30  $\mu\text{m}$  by 2023 [3]. This level of placement accuracy for components must be accompanied by a related accuracy for the deposit of solder paste and related fluids. Among the alternatives for the deposition of solder paste and other fluids on a PCB is jetting, which offers advantages concerning precise volume repeatability, software control and local volume control, see Figure 1.

The ejection of fluid from a jetting head has been studied extensively for low-viscosity fluids. This research has naturally been driven by work related to inkjet printing, see Bogy and Talke (1984) for a classic paper in the area. The jetting of more complex fluids is challenging and the amount of research is limited. An interesting theoretical study on jetting in general was carried out by Clasen et al. (2012).

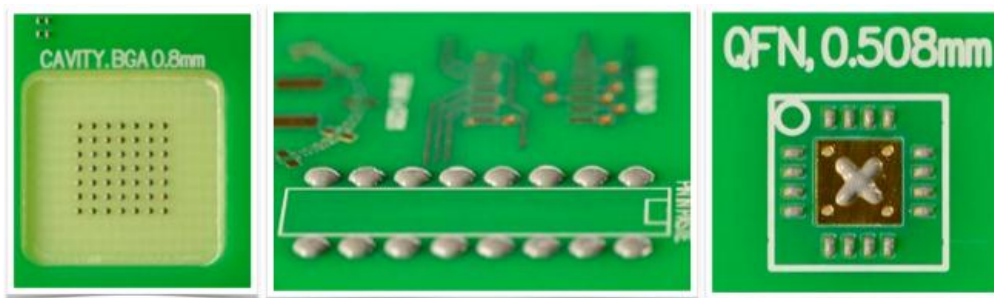


Figure 1 : Example of jetting application of solder paste for various component types, such as BGA, pin-in-paste and QFN.

The goal of this study is to study the effect of piezo actuation profile on deposit quality with respect to positioning, shape and satellite levels in order to achieve adequate deposition quality for applications such as 0.4 mm BGA.

### Methods

The jetting for this study was performed with a MY500 jet printer (Mydata Automation AB, Sweden). The jetting mechanism is based on the increase of pressure in a jetting chamber due to the movement of a piston induced by the expansion of a piezo-lamellae stack. A schematic of the jetting mechanism used in this studied can be found in Figure 2.

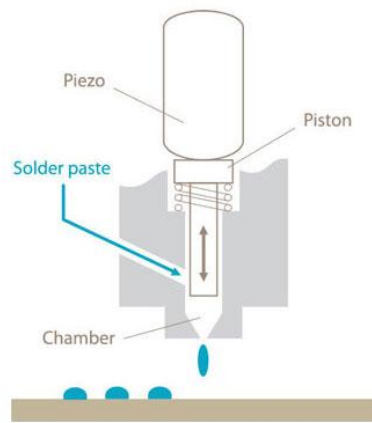


Figure 2 : A schematic of the jetting device used in the test.

The piezo actuation device is activated by an applied time-dependent voltage. This signal was originally controlled only by a rise time,  $t_r$ , and plateau time,  $t_p$ . An example of this actuation voltage can be seen in Figure 3 a). The implementation of a new electronics control system enables an elaborate control of the signal with a choice of control points along the voltage signal. In the described study, a three-step signal with a given rise time,  $t_r$ , plateau time,  $t_p$ , and fall time,  $t_f$ , is used to study the quality of jetting, see Figure 3 b).

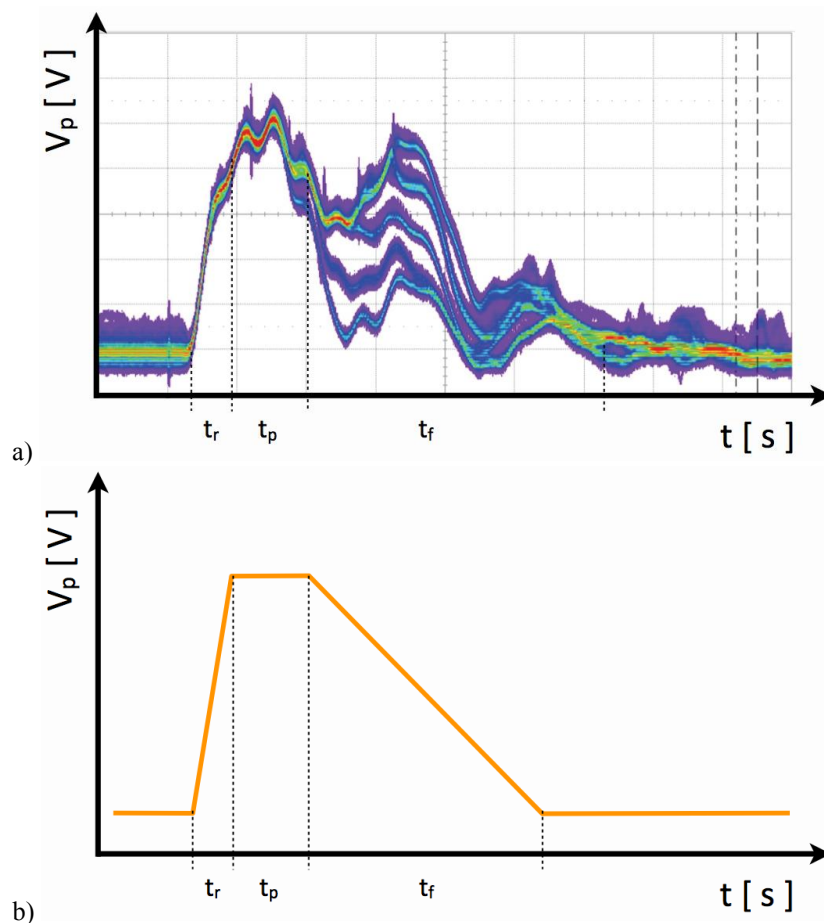


Figure 3 : An example of a) the time-dependent voltage applied to the piezo and b) a three-step signal with a given rise time,  $t_r$ , plateau time,  $t_p$ , and fall time,  $t_f$ , is used in the study.

The quality of jetting is judged using for qualities for each deposit, namely diameter, positioning, shape and satellite level. Figure 4 will be used as the basis for a description of the above-mentioned jetting qualities. In Figure 4, a circle is shown which represents an ideal perfectly circular deposit with diameter  $d$ . The irregular curve in Figure 4 represents an actual deposit. The area of the shaded area is used to extract an equivalent diameter for the deposit by using the equation,

$$d_{eq} = \sqrt{\frac{4A}{\pi}},$$

where A is the area of the deposit. The mass centrum for the area of the deposit is used to calculate the positioning deviation,  $\Delta X$  and  $\Delta Y$ , for the expected position of the deposit on the substrate. The shape of the droplet is calculated by taking the norm of the radial difference of the deposits edge from a circle with the calculated equivalent diameter in accordance with the expression

$$s = \sqrt{\left(\sum_{i=1}^n \left| \Delta \left( r_i - \frac{d_{eq}}{2} \right) \right|^2\right)},$$

where  $r_i$  is the local radius at a point on the periphery of the deposit and n is the number of points used along the periphery. Satellites are defined as free bodies outside the main deposit. The position and diameter of the satellites are registered in the same way as for the main deposit.

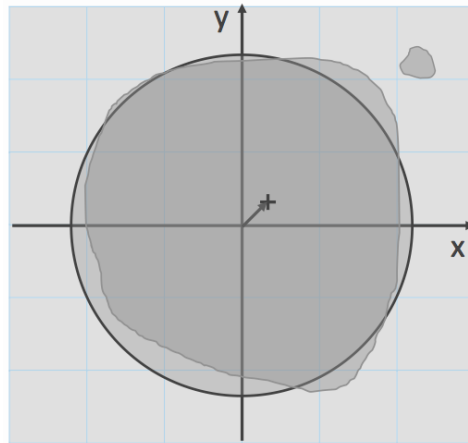


Figure 4 : The quality of jetting is judged using for qualities for each deposit, namely diameter, positioning, shape and satellite level.

A type 5 lead-free SnAgCu 305 Solder paste (Senju Metal Industry Co., Ltd., Japan) was utilized for the tests. For each combination of actuation parameters,  $t_r$ ,  $t_p$  and  $t_f$ , a set of three jobs consisting of X deposits each were jetted for four different deposit volumes. The volume of deposits for the jetting device is controlled by the amount of solder paste transported to the jetting chamber for each individual deposit. The jobs were jetted on a custom 230 mm x 317 mm substrate with spray-mounted photographic paper to enhance contrast for image processing purposes as well as to simplify cleaning.

Data evaluation was carried out using Matlab.

### Results and discussion

Among the most important criteria for any deposition of solder paste on a printed circuit board are positioning, deposit size, volume and volume uniformity. In Figure 5, the correlation of deposit diameter and positioning deviation as a function of piezo actuation profile is presented. Although the absolute values of diameter and positioning vary for the various piezo actuation profiles, the trend is clear in that positioning error increase almost monotonically with decreasing droplet volume.

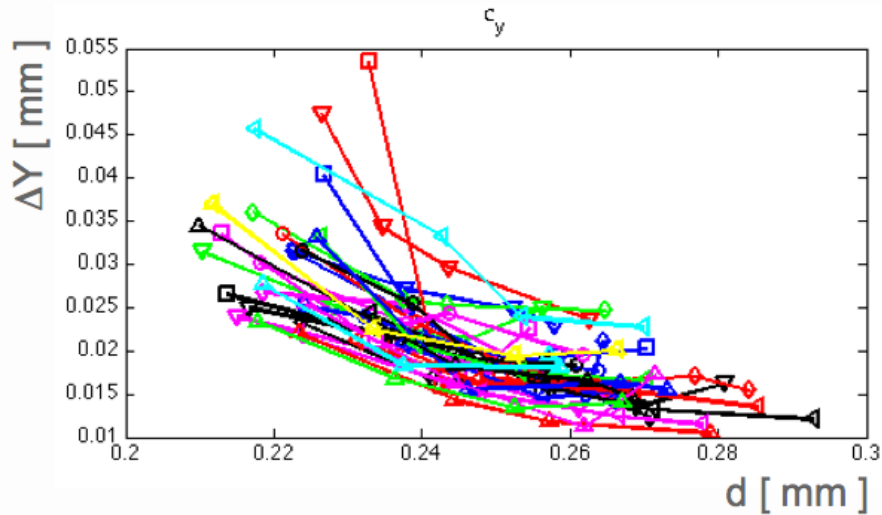


Figure 5 : The correlation of deposit diameter and positioning deviation as a function of piezo actuation profile.

In Figure 6, the correlation of deposit diameter and satellite level as a function of piezo actuation profile is presented. The data here is not as clear as for the positioning deviation, which signals that we have a stronger dependence on the actual form of the actuation profile on the formation of satellites during the filament break-off process.

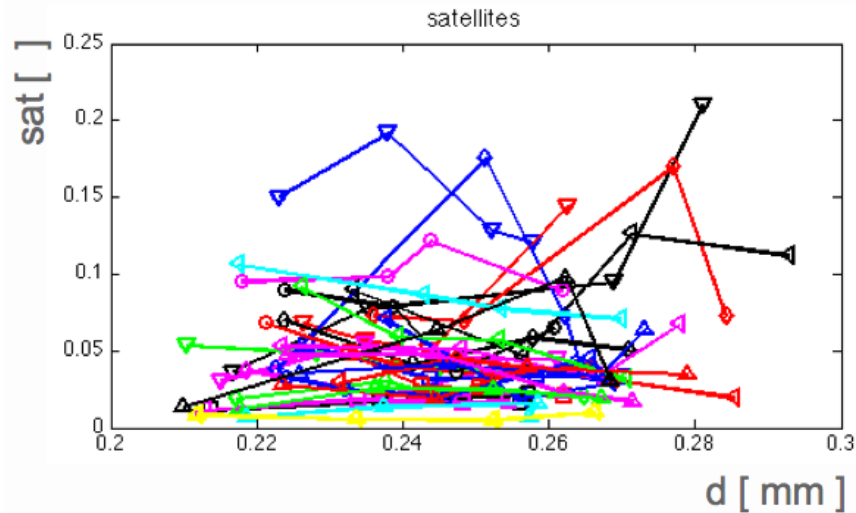


Figure 6 : The correlation of deposit diameter and satellite level as a function of piezo actuation profile.

A number of the piezo-actuation profiles suggest that there is a slight decrease in satellite level for smaller droplet volumes. In the context of these jetting experiments, satellites are primarily formed during the break-off process and not as a result of impact splashing, see Xu et al. (2007). A possible explanation for this behavior ties the increase in positioning deviation with the decreased production of satellites. The speed of the fluid during break-off will scale with the mass of the droplet, such that a smaller droplet will have a lower speed. The lower speed of the mass of fluid during the break-off process will follow a more gradual passage through the three phases of filament break-off for a dense suspension controlled by inertia, viscosity and capillary forces, as described by Bonnoit et al. (2001), and thus decrease the probability of islands of suspension that will develop into satellites.

In the observations above, quantities have been obtained as statistical quantities of a large number of droplets. This is appropriate on one level, since the positioning error of any droplet must be ensured to some level of confidence. At the same time, it is essential to understand that the rheological qualities of jetting fluids are dependent not only on the local shear on the fluid, but also on a relaxation time scale of the fluid. A plot of the viscosity of the solder paste as a function of the local shear on the fluid is presented in Figure 7.

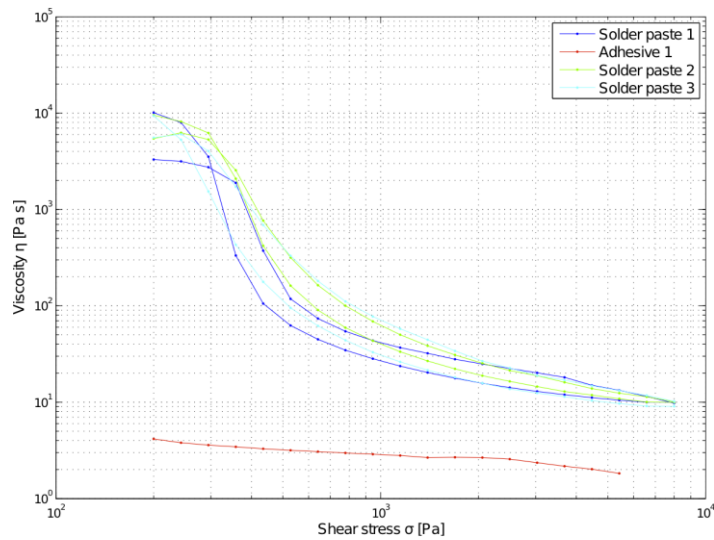


Figure 7 : Viscosity of three solder pastes and an adhesive as a function of the local shear stress on the fluid.

The relaxation time of the paste will primarily affect the first of a series of droplets as can be seen in Figure 8. The plot in Figure 8 shows the effect of various piezo actuation profiles on the evolution of deposit diameter in a number of strips consisting of 20 deposits. For this set of piezo actuation profiles, it is apparent that the behaviour of the diameter of the first deposit is insensitive to the choice of actuation profile. If an adjustment of the actuation profile is inadequate to maintain a constant deposit diameter throughout the entire strip, it is possible that a preferential actuation pattern for the first deposit could be used to attend to this strip property.

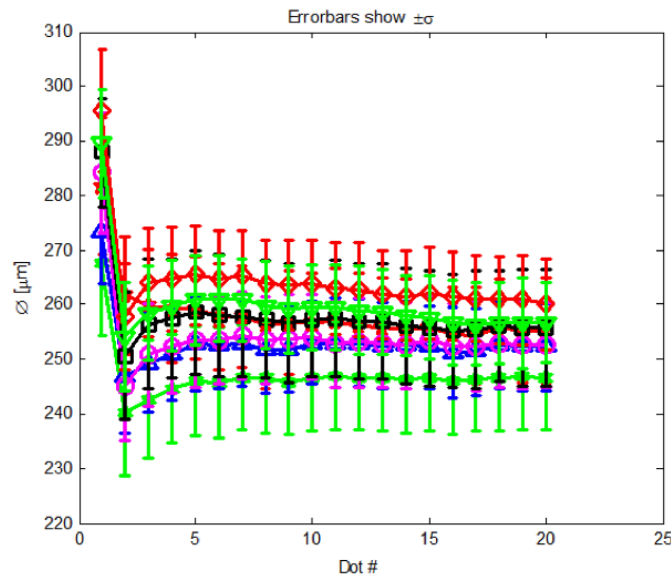


Figure 8 : The effect of various piezo actuation profiles on the evolution of deposit diameter,  $\varnothing$ , as a function of deposit number,  $n$ .

An example of jetting results for a 0.4 mm pitch uBGA can be seen in Figure 9. Although the photograph in Figure 9 only provides an aesthetic test of the jetting quality, a number of the quantified quantities described above can be observed. Slight deviations in size for a number of the droplets can be observed and would result in a poor shape factor.

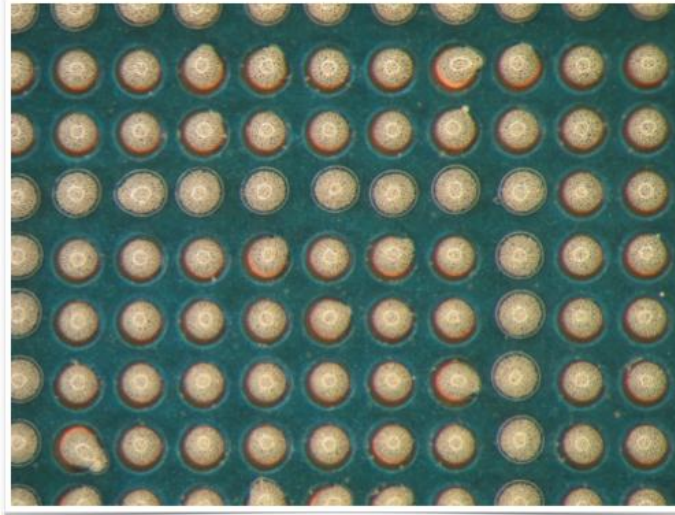


Figure 9 : Example of jetting deposits on 0.4 mm BGA with 250  $\mu\text{m}$  pad size

### Summary

The demands on volume delivery and positioning accuracy for solder paste deposits are increasing as the size and complexity of circuits continue to develop in the electronics industry. This study attempts to understand the dependencies on piezo actuation pulse profile on jetting deposit quality, especially focused on positioning, satellites and shape. The correlation of deposit diameter and positioning deviation as a function of piezo actuation profile shows that positioning error for deposits increase almost monotonically with decreasing droplet volume irrespective of the piezo-actuation profile. The trends for shape and satellite levels are not as clear and demand further study. The insights gained above indicate that reaching deposit specifications becomes a game of give and take; smaller deposits introduce slightly larger positioning uncertainty, while increased positioning accuracy demands slightly larger deposits. The game will be won by the combination that ensures process quality.

### References

- [1] Bogy, D.B. and Talke, F.E. 1984 "Experimental and theoretical study of wave propagation phenomena in drop-on-demand ink jet devices", *IBM journal of research and development*, 28, pp. 314–321.
- [2] Bonnoit, C., Clément, E. and Lindner, A. 2013 "Accelerated drop detachment in dense granular suspensions", *Phys. Fluids* 24, 043304.
- [3] Clasen, C., Phillips, P.M., Palangetic, L. and Wermant, J. 2012 "Dispensing of Rheologically Complex Fluids : The Map of Misery", *AICHE*, 58, pp. 3242–3255.
- [4] iNEMI Roadmap 2013 Advanced Manufacturing Technology, January 2013, iNEMI.
- [5] IPC-7351B Generic Requirements for Surface Mount Design and Land Pattern Standard.
- [6] Xu, L. 2007 "Liquid drop splashing on smooth, rough, and textured surfaces", *Phys. Rev. E*, 75, 056316, pp. 1–8.