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An Innovative Contactless Technology for High Resolution, High Speed, Solder Paste Deposition

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ABSTRACT
Solder paste balls are being deposited at tighter and tighter resolutions. Various solutions have been proposed, but there is always a trade off somewhere. The tighter resolution can come at expense of custom materials, such as in inkjet, or speed, such as in dispensing. Ideally, we would have a solder ball dispensing solution that had the throughput of the traditional analog solutions, such as screen printing, with the accuracy and flexibility of traditional digital solutions, such as jetting and needle dispensing.

With Continuous Laser Assisted Deposition (C.L.A.D.) there is no longer any trade off between materials and other parameters. This contact-less technology has no nozzle and no mesh. It can deposit drops from materials above 300,000 cPs (300Pa.s) at high speed and high resolution. The high viscosity window allows standard certified solder pastes to be used from Type 4 and above, without any reformulation.

This laser assisted deposition technology can be applied to several applications, but in this paper we will focus on solder paste deposition. In addition to standard solder paste materials, most other materials can be printed too, up to very high viscosities. This includes conductive materials, polymers, ceramics and silicone. The C.L.A.D. solution allows up to 5 different materials to be printed.

In the C.L.A.D. technology, a material, evenly coated on a transparent carrier film, passes under a laser. The laser applies a short burst of energy to it. This releases perfectly consistent drops of material onto the substrate below. The material drops can then be sintered or cured inline, in the same machine. Minimum resolutions are higher than currently achievable resolutions. Multiple component sizes can be handled, as well as component heights. Very high thickness to diameter rations can be achieved, sometimes by multiple passes.

With these multiple benefits, the technology has been widely recognized by industry as well as investors.

Key words: new equipment, solder paste deposition, materials printing, laser assisted deposition, advanced manufacturing, additive manufacturing

INTRODUCTION

Traditionally, solder paste is placed on a bare printed circuit board with digital or non-digital means.

The most common are the non-digital solutions, such as screen printing. In screen printing, the solder paste is transferred through a predefined pattern especially prepared for the desired design. This pattern needs to be prepared beforehand and stored which takes up real estate and during operation, it needs to be regularly cleaned to prevent the mesh openings from getting clogged. Moreover, the stencil size defines the minimum layer thickness and resolution of the applied solder paste.

Digital technologies came on the market, such as jetting and dispensing. Digital technologies offer a lot in terms of flexibility. More control is offered for each individual drop, but this comes at a price in terms of throughput. In addition, because these digital technologies extrude the material through a nozzle, the nozzle size defines the type of solder paste that can be used as well as the speed of printing. The solder paste type defines the average size distribution of the solder balls.

Ideally, we would have a solution that offers the flexibility and accuracy of the digital technologies, while keeping the throughput of the non-digital technologies.

CONTINUOUS LASER ASSISTED DEPOSITION

A new deposition technology was revealed in a paper in 1968(1), which was later named Laser Induced Forward Transfer (LIFT). The LIFT technology can print materials of high viscosities, that until then could not be printed.

LIFT has been further adapted and refined ever since, with one of the later versions dubbed Continuous Laser Assisted Deposition (CLAD). Materials with viscosities higher than 300,000 cPs have been printed. CLAD is a contact-less technology, requiring neither stencil, nor nozzle, giving full flexibility of the material deposition. The lack of any medium between the donor material and the substrate enables full control of the layer thickness. Solder paste is not the only material that can be deposited using CLAD, examples of other materials of extremely high viscosities are, silicone, ceramics, conductive epoxies and metals(2) to name a few.

The technology can print lines down to 30µm, and in the same print, vary the line resolution from 30µm up to 500µm. Aside from solder paste, multiple different materials can be printed in the same production run, such as polymers, metals and ceramics. Being a laser based process, the throughputs are comparable with screen printers, reaching 3 liters/hour, or 2,000 drops/second (7M drops/hour).

CLAD TECHNOLOGY

Any flowable material, up to very high viscosities can be deposited with CLAD technology. The material is initially dosed to the underside of a transparent carrier foil.
The layer thickness of the print is accurately determined when the material passes through two cylindrical rolls. The carrier moves the material under the laser. The laser offers a brief, powerful, controlled energy pulse to the material. This releases a drop of the material from the carrier on to the substrate below. The laser continuous to print the pattern with the material from the carrier, digitally defining material drops in all the required locations to complete the pattern and form factor on the substrate.

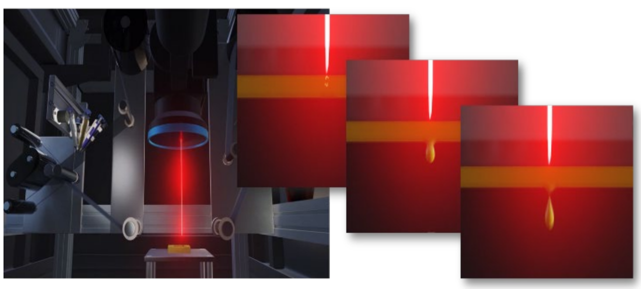


Figure 1: Continuous Laser Assisted Deposition

Post-processing can be taken care of in the same station. There are both UV and thermal curing options, thereby saving time, space and handling costs. The laser from the CLAD can also be used for sintering metals and ablating away any excess material (trimming).

This laser assisted deposition method has all the digital flexibility and accuracy of jet dispensers, with the additional ability to print multiple materials on multiple layers. Throughputs are comparable to screen printers. High resolutions are achieved with standard printing materials. No extensive certification process will be required when changing over to CLAD, since the same qualified materials are being deposited as in traditional methods. CLAD maintenance costs are low due to the fact that there are no nozzles to clean, and no stencils to maintain.

To summarize:

- CLAD prints existing certified materials, no need to source (expensive) reformulated materials for printing.
- The volume of each and every single deposited drop of material can be controlled, giving full flexibility to optimize output for components of different sizes in the same design.
- Multiple materials can be printed in the same machine during the same run e.g. solder paste, surface mount adhesive and epoxy drops.
- Contactless, maskless, and nozzle-free printing, make for a lower cost of ownership
- Being an additive technology, this is an economical and greener process
- The inclusion of post-processing, in terms of curing, sintering and ablation, makes for a faster and simpler production process

APPLICATIONS

In the electronics manufacturing supply chain there are many opportunities to apply Continuous Laser Assisted Deposition. Not only in processes that are currently being done by screen printing and dispensers, but also to replace etching and plating processes. Some applications that would benefit from CLAD are solder paste deposition, die attach and underfill processes. There are many more suitable processes, but in this paper we will focus on the deposition of solder paste.

Solder paste deposition is an ideal application for CLAD. High speeds are required, with fine resolutions and high accuracy. In some cases even a second material can be added, such as an epoxy on the component. Solder paste resolutions have been demonstrated down to 60µm diameter at speeds of 7M dots/hour, which is a comparable output to screen printers. Multiple component sizes can be printed on the same substrate, as well as printed on top of other components, e.g. package on package or multiple chip stack applications.

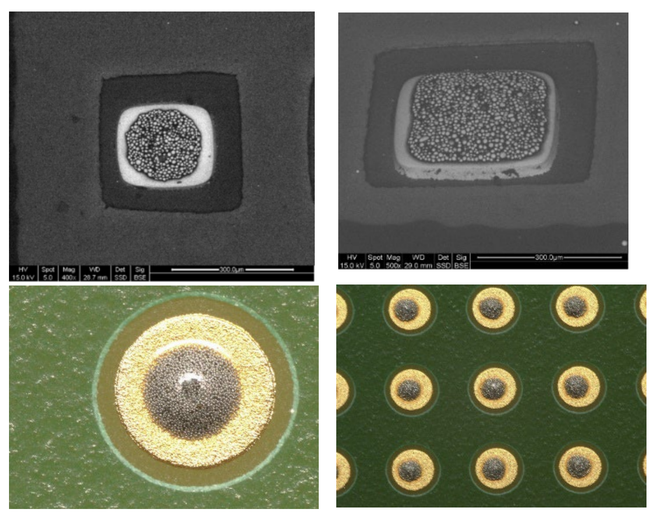


Figure 2: Solder balls deposited with CLAD

Individual drops are smaller than the resulting solder paste ball, giving full dynamic control of the solder paste deposition for both large and small components of all shapes: squares, circles, ovals, etc…

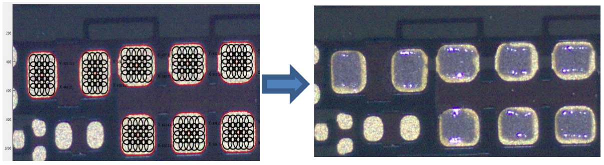


Figure 3: Printing solder balls of varying sizes and shapes

The raster image is taken of the required shape, multiple drops of the solder paste are deposited to create a single solder paste ball of the required form factor.

This tight control of each individual drop volume leads to high uniformity in layer thicknesses and consistent height to width ratios.

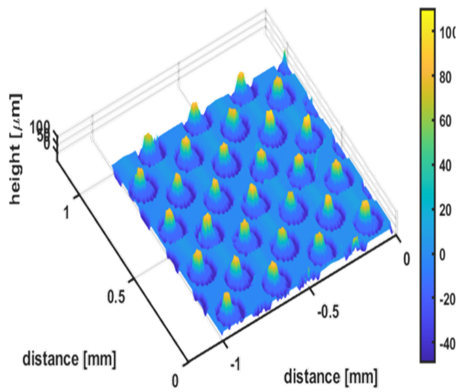
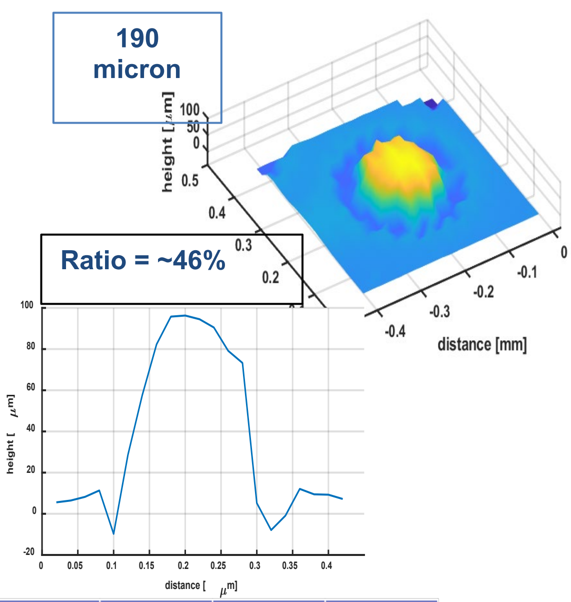


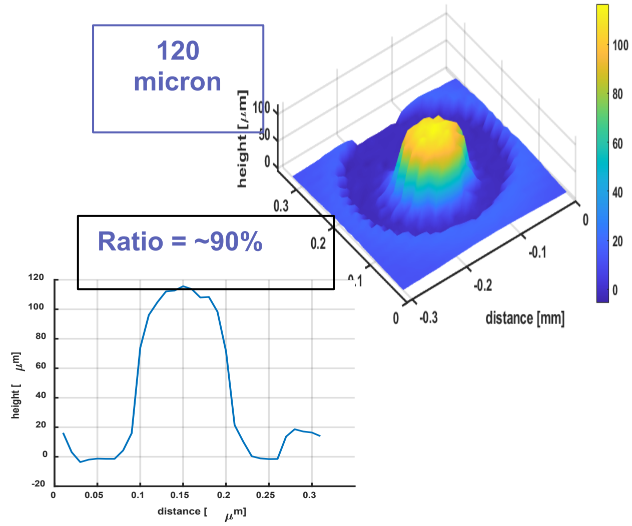
Figure 4: Consistent height to thickness ration



	Average	Pk to Pk	STD
Radius [μm]	96	12.6	4.12
Height [μm]	88	15	5.8

Figure 5: Solder ball with height to diameter ratio of 46%

Up to very high ratios can be achieved using the additive manufacturing aspect of the technology, i.e. printing multiple layers. In Figure 5, a solder ball is printed with an average diameter of 192µm diameter and an average height of 88µm.



	Average	Pk to Pk	STD
Radius [µm]	62	8.1	3.05
Height [µm]	111	11.2	5.1

Figure 6: Solder ball with height to diameter ratio of 90%

To reach a higher ratio, the energy can be adjusted to adjust the form factor of the individual drops to reach the desired height and diameter. This is shown in Figure 6.

The height of the solder ball has increased to 111µm, while decreasing the ball diameter to 124µm, resulting in a height to diameter ratio of almost 90%.

Solder pastes from Type 4 and above have been printed. The smaller particle size of the solder Type allows for smaller ball diameters. For Type 6, solder balls are printed at 100µm diameter. For Type 8, as low as 60µm solder balls have been printed with a standard Heraeus solder paste. No special reformulation of the solder material was required to achieve these results.

As another example for testing multiple layers, e.g. on a Henkel (now Harima) GC50, Type 5; we achieve a very uniform thickness, and an average diameter of 290µm and an average of 34µm height ±10%. An additional solder paste layer can be printed on top, keeping a uniform thickness and increasing the diameter to 310µm. The height is increased to 50µm, increasing the ration from 11% to 16%.

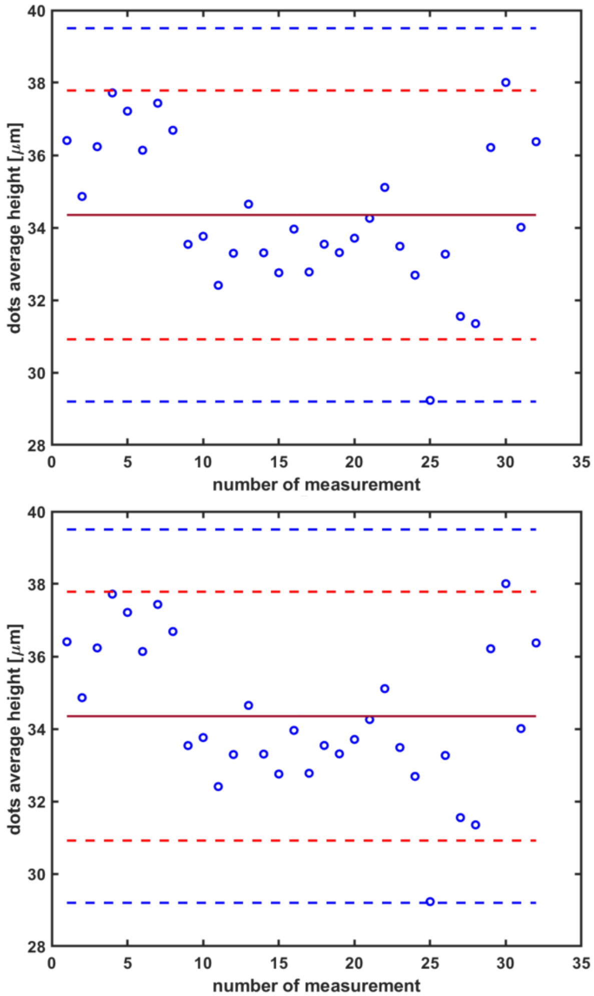


Figure 7: Diameter and height for a one layer solder paste deposition

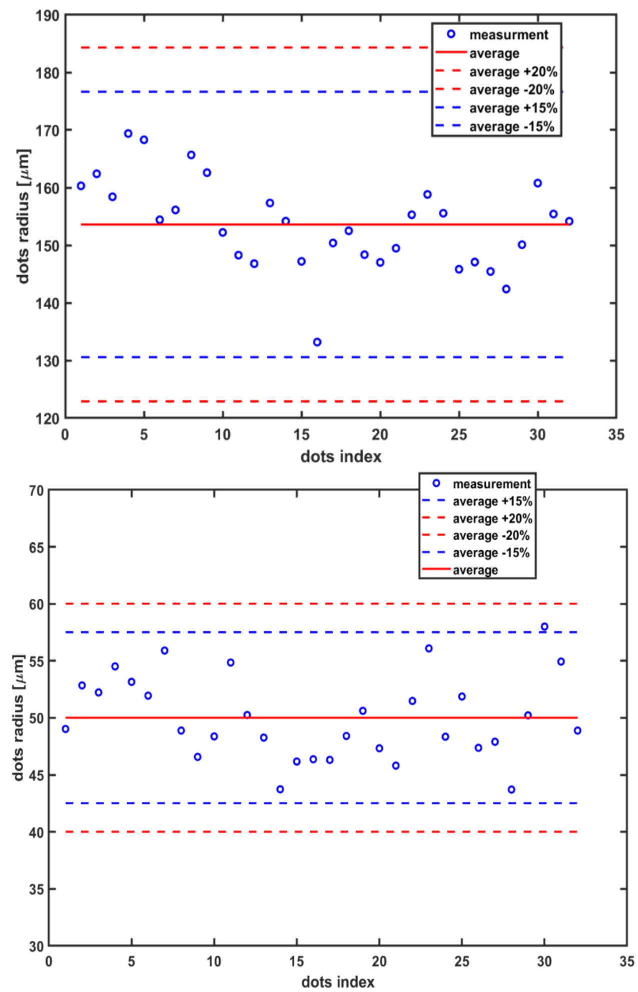


Figure 8: Diameter and height for a two layer solder paste deposition

SUMMARY AND BENEFITS

There are many benefits of using the CLAD technology for depositing one material upon another. This paper has focused on printing solder paste balls on a substrate, for which there are several benefits:

- Standard certified solder paste of Types 4 through Type 8 can be used. No reformulation of the solder paste required.
- Throughputs are comparable to screen printing (up to 7M dots/hour), but with the accuracy and flexibility of digital technologies.
- Resolutions are finer than with traditional techniques, e.g. solder balls of 100µm with a standard Type 6 solder paste.
- Contactless means there are no masks to prepare, clean and store, nor nozzles that get clogged.
- Supports complex designs with landing pads of varying shapes and sizes.
- Very high diameter to height aspect ratios.
- High repeatability: Uniform layer height
- Multiple materials: in addition to solder paste, epoxy dots can be printed as well SMA's

The CLAD technology enables new designs to break through old design limitations, with higher density of solder balls, and greater aspect ratios. This is all done without sacrificing throughput, and without requiring any special solder pastes.
Overhead and maintenance is kept to a minimum by removing the need to prepare masks, or to clean clogged nozzles. The high throughput enables the potential to replace several machines in some cases, saving on floor space, labour and handling costs.

REFERENCES

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