Can LDI Meet The Needs Of HDI PCB And Packaging?

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Demand and sales of LDI (Laser Direct Imaging) machines continue to increase all over the world and especially in the Pacific area. More and more PCB shops are using LDI today, mainly for sampling, small volume and quick turn jobs. The main question is if the use of LDI will continue to be limited to small volume jobs or if we will see in the near future more use of LDI machines in HDI mass production lines and in the packaging industry. In other words, how high can LDI fly?

The answer to this question should be reviewed from two angles: the needs of each of the market segments (HDI and Packaging) and the ability of LDI vendors to meet these needs.

Figure 1 - NEC 505iS mobile phone

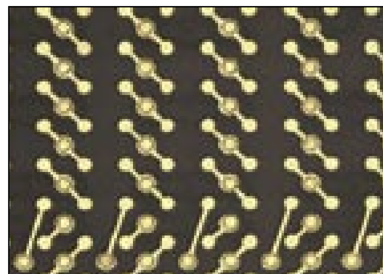


Figure 2 - Sequential build-up board with 35μm annular ring

Figure 3 - 125μm pads over 75μm via holes (25μm annular ring)

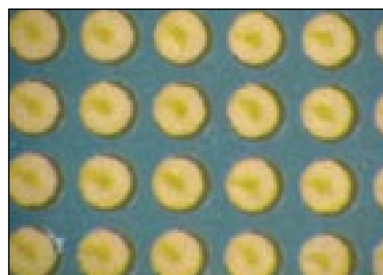


Figure 4 - 37.5μm solder mask clearance, exposed with conventional printer

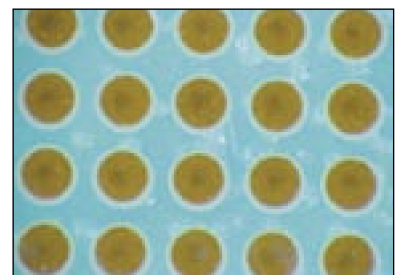


Figure 5 - 37.5μm solder mask clearance, exposed with Orbotech Paragon 8000

End products like cellular phones, digital cameras and IC substrates drive the market and the technology. Cellular phones like the one presented in Figure 1 can clearly show where the technology will be and what will be the demands from PCB and packaging manufacturers in the very near future:

- CSP with 0.4mm pitch - very tight registration tolerances;
- 2+2+2 construction - greater use of build-up layers;
- 0.65mm board thickness - greater use of thin core materials with less dimension stability;
- Pitch below 150μm, driving the registration demands to annular rings of 25μm and below and feature sizes of less than 15μm (and even down to 10μm).

While registration and minimum feature size demands are getting tougher, manufacturers are still trying to achieve the highest possible throughput. But, in order to achieve high yields, in many cases manufacturers are giving up on throughput. A few examples:

- In order to achieve higher yields while exposing L/S designs of less than 75μm, HDI mass production manufacturers have to apply higher vacuum power before starting to expose each panel. Applying more vacuum takes more time and the actual throughput of exposure machines for this kind of job drops to about 90 - 120 panels per hour;
- In order to achieve high quality packaging products with fine lines of less than 30μm, many packaging manufacturers use semi-additive processes, which require thick and non-sensitive dry film, the result, again, is much lower throughput;
- In order to meet the very tight registration demands required for the leading packaging products, manufacturers are using slower imaging solutions like steppers and shutter exposure machines. The result is again, a lower imaging throughput, below 60 panels per hour;
- In order to meet tight registration demands during solder mask exposure, manufacturers are spending more time on set-up before exposure, resulting in low utilisation of the solder mask exposure machine. Figure

2 shows results of a study by CAT of more than 40 PCB manufactures. The study shows that when the solder mask clearance is 37.5µm, only half of the manufacturers recorded first-pass yields above 50%.

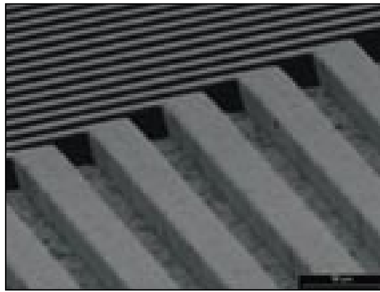
We can summarise the main needs of HDI mass-production and packaging manufacturers as follows:
1. Accuracy - tight registration demands, less than 25µm annular ring;
2. Solder mask exposure - sub set of the need for high accuracy. High density boards presents real registration challenges, especially during the exposure of the solder mask layers;
3. Fine lines - down to 30µm for leading HDI products, down to 15µm for leading packaging products;
4. Throughput - around 60 panels per hour for packaging, 90 - 120 panels per hour for HDI mass production.

The ability of LDI to meet market needs

Can Laser Direct Imaging meet the demands as specified above? We shall check each requirement:

Accuracy - less than 25µm annular-ring - one of the main strengths of Laser Direct Imaging is the tight registration capabilities, resulting from the fact that LDI eliminates the use of the non-stable phototools as well as from the dynamic scaling abilities of LDI - the ability to measure the actual dimensions of each panel before exposure and to expose the data while applying the correct X and Y scaling factors per panel. A few samples of very accurate registration results achieved by LDI machines can be seen in Figures 2 and 3.

Solder mask exposure with LDI - The registration capabilities of LDI described above provide the solution for accuracy demands also in the case of solder mask exposure. But, in order to achieve reasonable throughput when exposing solder mask layers with LDI in production, a more sensitive solder resist is required. Solder resist vendors are working on development of such solder resists. Coates (UK) announced fast solder resist XV501T-4 series (Imagecure solder masks) at the last



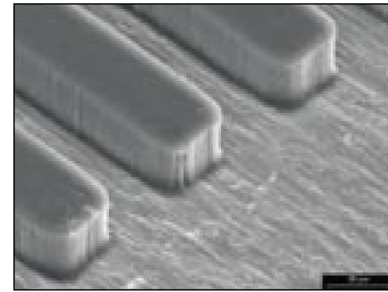


Figure 6 - 25µm L/S, exposed by Orbotech's Paragon-8000 (left)

Figure 7 - 25µm L/S, exposed by Orbotech's Paragon-8000 (right)

EPC2004 show. The new solder resist is a dual-purpose solder mask that can be used with both LDI machines and conventional printers. Resist sensitivity is in the range of 35 - 55 mj/cm^2, allowing high throughput solder mask exposure. Taiyo Ink (Japan) also announced a fast solder resist product, LDI-1000F - a high sensitivity (40 - 60 mj/cm^2) solder resist that allows high throughput solder mask exposure with LDI. Other vendors are currently working on the development of fast LDI solder resists. Figures 4 and 5 show 37.5µm solder mask clearances exposed by conventional printer vs. the same clearances exposed using Orbotech DP-100SL LDI machine.

Fine Lines - Until recently, it was believed that LDI machines could not achieve less than 40µm L/S. The latest developments show that this is no longer true. Figures 6 and 7 show features down to 25µm exposed by LDI, using 20µm thick dry film. Fine features, below 20µm that were exposed by LDI in lab tests showed that there is no real limitation in the ability of LDI machines to meet even the requirements of even the most demanding designs of the leading packaging manufacturers in the very near future.
Throughput - in order to achieve the required throughput (at least 90 panels per hour for HDI production and 50-60 per hour for packaging production) major improvements in LDI machines are required. The latest developments concerning both LDI machines and more powerful lasers show that these requirements will be achievable in the very near future. The latest LDI machine can already achieve 80 panels / hour, using a 4W DPSS laser at 355nm wavelength. The latest models of laser vendors such as Coherent show that 8W DPSS lasers (at 355nm) are already available. The combination of high throughput LDI machine with double laser power (8W instead of 4W) opens the door for 2 major improvements: higher throughput LDI (>80 panels / hour) using sensitive dry films, and a wider working window that will allow acceptable throughput (around 60 panels / hour) while using non-sensitive dry films and liquid resists.

Table 1 summarises the main requirements as we indicated above with LDI abilities. The conclusion from the table is clear: the latest Laser Direct Imaging machines, together with latest laser models, enable wider use of LDI even for applications and market segments that until recently were considered not practical for LDI machines. As further developments materialise, the use of LDI will expand even more, especially in the very demanding segments of HDI and packaging manufacturing.

Table 1 - Summary of market needs and LDI capabilities

	Need	LDI capability
Accuracy	Less than 25µm annular-ring	Available today
Solder Mask exposure	Tight registration demands	2 LDI solder resists available today. Additional models under development by other resist vendors
Fine Lines	Down to 30µm for leading HDI products, down to 15µm for leading packaging products	25µm features available today. Proven ability to achieve less than 20µm
Throughput	90-120 panels per hour for leading HDI. 50-60 panels per hour for leading packaging	80 panels per hour available today. More powerful lasers (8W) opens the door for further improvements