Laser Direct Imaging - Application to Liquid Soldermask Products

INTRODUCTION
A previous article dealt with some of the challenges posed by the introduction of a radically different imaging technology for Printed Circuit Board (PCB) fabrication – Laser Direct Imaging (LDI). This system offers the possibility of a fully digital PCB production process, from design to multilayer fabrication, including both mechanical and laser via creation.

So the obvious missing piece in this process is the soldermask; with I/O counts increasing and package sizes getting smaller, the ability to accurately and repeatably place fine solder dams is now seen as a limiting factor for some prototype manufacturers.

Coates Circuit Products anticipated the requirement for a LDI soldermask material, and has been carrying out laboratory and customer trials throughout 2001. This article outlines some of the challenges posed for developing such a product and gives details of the current level of achievement.

BACKGROUND
Laser direct imaging of soldermask represents a novel method of forming circuit features without the need to go through the costly and time-consuming steps involved on preparing a photographic artwork. The laser system, under computer control, is able to ‘write’ a pattern onto a high sensitivity resist at the same time allowing for size changes and deviations in planarity of the substrate. A fiducial recognition system built into the LDI units can also give very precise front-to-back registration, thus minimising scrap due to misalignment. Also, there are no yield losses due to ‘repeat defects’ from dirty or scratched artwork.

The ‘first generation’ LDI units tended to utilise exposure wavelengths in the visible region, mostly because the laser lamps were cheaper. Hence, very specialised dry films (etch resists) were developed for these units but these caused problems during lamination and processing. More recently, however, the laser systems have begun to utilise UV wavelengths for exposure. This has meant that development of a liquid LDI soldermask (LDISM) has become more straightforward.

EXPOSURE SENSITIVITY
In the move to Laser Direct Imaging one of the controlling factors on process speed is the exposure sensitivity of the resist. Although this is between 10mJ and 15mJ/cm² for LDI etch resists, it was felt that a lower sensitivity would be more likely for soldermasks. This was because of the higher performance requirements placed on the cured film in terms of temperature, process and environmental resistance. Therefore the target set by Coates for a useable LDISM was 35mJ – 45mj/cm², which translated to approximately 50sec – 70sec exposure time for a single side of an 18” x 24” panel.

MOVING THE GOALPOSTS
With the new laser direct imaging equipment it’s not only the exposure sensitivity that has to be improved. The boards must also be resilient to the vacuum applied by the flat bed units such as the Orbotech DP-100 or the ETEC DigiRite 2000. In addition, they must resist any possible...
mechanical damage from automated double-sided systems like the Automa-tech DI2700 and the Barco Gemini system. Added to this, the other processing parameters (tack dry, develop, cure) must not deviate from those typically used for liquid soldermasks.

**LDI EQUIPMENT**
With one notable exception, the laser of choice for exposing negative-working resists is a 4kW argon-ion unit. Both Orbotech and ETEC use a single laser in their flat bed machines, and although not without its’ drawbacks it is rapidly becoming an industry workhorse. From the most recent survey of LDI equipment use, the Orbotech DP-100 is clearly the market leader, with around thirty units installed worldwide.

Automa-tech has chosen to use a pair of Ar+ lasers in their double-sided LDI exposure unit, which may lead to a high cost-in-use.

The one unit that currently ‘stands alone’ is the Barco Gemini double-sided LDI, which contains a single solid-state laser. This configuration offers several advantages such as lower power consumption and reduced laser replacement costs. Much will be expected of this unit, which is currently in its’ beta-testing stage.

**NEW LASER DIRECT IMAGING SOLDERMASK (LDISM)**
With the gauntlet thrown down the challenge was to formulate a liquid soldermask product suitable for the range of exposure machines now in the market and those soon to be available. Work started at Coates on initial products in early 2001, with the first trials following soon afterward. These were mostly a ‘proof of concept’, but demonstrated that:

- Manufacture of LDISM materials with exposure sensitivities around 45mJ/cm² was possible with finished properties matching existing ‘traditional’ LPISM products.
- The resist products proved sufficiently durable to withstand the vacuum bed of the flat bed laser exposure system used.
- Line resolutions of ~75µm were achieved in this first trial.

By the end of last year initial beta-site trials had been performed on DP-100 units at a number of PCB production sites and the resist optimised to give:

- Exposure sensitivities of 40mJ – 45mJ/cm².
- Line resolutions down to 35µm (~1.5mil).
- Improved surface hardness to withstand mechanical handling within an automated LDI unit.
- Excellent adhesion of lines through electroless nickel/immersion gold (ENIG), immersion tin, or hot air solder levelling (HASL) processes.

An example of laser exposed 50µm solder dams is shown below:
APPLICATION SYSTEMS AND PROCESSING

The soldermask product has been developed with screen print or curtain coating application in mind, although HVLP spray may also be a possibility. The main consideration to be made in processing these materials is the increased light sensitivity and hence hold times in even 'yellow light' should be minimised.

The following processing parameters have been found to be suitable for these liquid resist materials:

<table>
<thead>
<tr>
<th>Process</th>
<th>SCREEN PRINT</th>
<th>HVLP SPRAY</th>
<th>CURTAIN COAT</th>
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</thead>
<tbody>
<tr>
<td>Product codes</td>
<td>Resist: CKXN0314</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hardener: CKXN0315</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixing ratio</td>
<td>3:2 resist:hardener</td>
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<td></td>
</tr>
<tr>
<td>Thinning</td>
<td>Maximum 3% XZ107</td>
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</tr>
<tr>
<td>Application</td>
<td>32T – 43T/ cm polyester screen</td>
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<td></td>
</tr>
<tr>
<td>Tack dry</td>
<td>Side 1 = 15min @85°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Side 2 = 40min @85°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expose</td>
<td>40mJ – 45mJ/ cm²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develop</td>
<td>1% Na₂CO₃ @35°C, 45 – 55 second dwell</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UV bump</td>
<td>Optional, 1000mJ – 1200mJ/ cm²</td>
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<tr>
<td>Final cure</td>
<td>50 – 70min @140° - 150°C</td>
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CONCLUSIONS

Laser Direct Imaging of PCB materials is a process that is rapidly gaining pace within the industry. The ability to accurately register and define features below 75µm with no effect on yields from the imaging step offers cost savings for prototype and high volume shops alike. The new LDI machines, working in UV wavelengths, have enabled the formulation of liquid soldermask products to meet the requirements of high resolution together with ease of processing.

Coates Circuit products, working with equipment manufacturers and PCB fabricators have developed such a product that offers exposure sensitivity suitable for laser direct imaging with the benefits and processing latitude of their existing Imagecure™ XV501T-4 range.