The PCB industry is moving aggressively into the age of digital printing. We are now witnessing the fast acceptance by PCB manufacturers of the first such application to emerge: ink-jet based digital legend printing. However, the next obvious application, digital solder mask printing, has the potential for a major impact on the PCB industry.

Indeed, the expected benefits are so numerous and significant that one is forced to reflect and ask the equipment suppliers: “Why is it taking so long to go to the market with this product?”

A traditional solder mask process is shown in the schematic diagram of Figure 1, while the diagram in Figure 2 shows the significant simplification that can be achieved when an inkjet digital printer is used for printing the solder mask. Clearly, this one step process also has the potential to increase final yield, since handling (and handling related defects) are also minimised.

The current process requires, in a way, a plant within a plant. A lot of expensive capital equipment, a significant number of employees, large quantities of chemicals, and photo-tools, all are involved in the solder mask stage. The solder mask process is a major contributor to the total “cost of goods” in the Profit & Loss Statement of PCB companies all over the globe. In addition, the current solder mask process is limited in its performance. The following pair of photographs (Figure 3, left and right) were taken on the same PCB, using the same magnification, and show a remarkable story: on the right hand side the pads of a medium density SMT component can be seen. For this coarse pitch, the PCB manufacturer was able to produce the solder dams between the adjacent pads. The solder dams are required to prevent shorting between adjacent pads during the reflow operation.

The left hand photograph, however, shows the pads of a high density SMT component. In this case the PCB manufacturer could not produce the solder dam. In the case where the solder dam is needed the most, advanced high-pitch components, the industry is forced to raise the white flag. The main limiting factor here is the insufficient registration accuracy of the current solder mask process.

Looking further into the issue, other problems can be noted. For example, with the current process, the first stage is non-selective coating. During coating, holes are partially or completely filled with solder mask. Removing the solder mask from high aspect ratio via
holes is a difficult and sometimes impossible task. These non-cured residues tend to create numerous problems, which become evident especially during the component assembly process. Some experts believe that the black pad phenomenon can also be attributed to this problem. Digital ink-jet printing, on the other hand, is a selective process and can avoid getting solder mask inside the holes.

**The challenges of digital solder mask printing**

Some of the major obstacles faced by Printar during the R&D phase of its digital solder mask printing product are described below. There were a few challenges in the system design area, but the dominant challenge was the material.

**The system challenges**

**Quality and reliability**

Reliability and printing quality requirements for inkjet solder mask printing are very stringent, and call for the use of stationary print heads. In solder mask printing, most of the panel, except for the pads, has to be coated. Even a small “pin-hole” which exposes two adjacent conductors can cause a critical defect, for example during wave soldering. Side firing of ink when printing very close to the pads, for example in the case of solder dams for fine pitch SMT or BGA pads, will cause fatal defects.

**The combination of higher speed and higher resolution**

The IPC solder mask road map specifies solder dams of 50 µm; this requires the use of high-resolution print heads. Industry throughput requirements are commonly 120 – 150 sides per hour. These combined requirements on one hand, and the relative speed limitation imposed on inkjet print heads by the ligament problem on the other, strongly suggest the use of multiple print head printers. Printers with stationary big printing bridge are easily scalable to any required number of print heads.

**Material quantity**

Solder mask printing requires large amounts of material, 50 to 100 kilograms per day. This strongly suggests the use of a stationary printing bridge and a stationary ink supply system designed to support a very high ink flow rate.

**The material challenges**

Solder mask, as a critical element in the final construction phase of PCBs, prevents shorts between adjacent SMT and BGA pads and protects the circuit from any environmental influences. Materials with performance comparable to currently used solder mask materials are necessary in order to meet these requirements; the use of heat-curable epoxy based materials is necessary.

Most advanced solder masks are based on high performance backbone (novolak epoxy, acrylic acid modified epoxy, cyclodifatic or heterocyclic rings based epoxy, phenols, amines or anhydrides). The backbone is usually modified by water-soluble groups (developability) and unsaturated groups (photosensitivity) to make it photodegradable. These modifications always deteriorate the chemical and physical resistance of the cured film.

It is thus an advantage to apply a high crosslink density film of solder mask.

**Figure 3 - The pads of a medium density SMT component (right), and the pads of a high density SMT component (left)**

**Figure 4 - Comparative adhesion test (tape test after cross hatch): a) commercial LPISM; b) competitor – UV curable ink-jettable solder mask; c) Printar – epoxy ink-jettable solder mask**
A New Recirculation And Filtration System

According to US-based JNJ Industries, water, energy and disposal costs in electronics manufacturing can be reduced by using the company’s fully automatic RFS-20 recirculation and filtration system. It is designed to support JNJ’s AQS-3500 Semi-Automatic stencil cleaner and employs a four-stage filtration unit that continuously filters the rinse water and returns it to the stencil cleaner for re-use. In this way, evaporators, haulage, or in-house wastewater treatment facilities are eliminated.

The four-stage filtration system consists of an in-line solder trap, followed by a 10-micron polypropylene filter that filters out coarse particulates, followed by an activated carbon powder filter to eliminate a part of organic substances. Finally a 5-micron polypropylene filter removes fine particulates and organics. This system is also equipped with a three-way valve that allows the rinse tank fluids to be power drained when changing fluids during periodic maintenance of the recycler.

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Figure 5 - Solder mask ink-jet printer manufactured by Printar

Figure 4 - Comparative study of solder mask printing systems

Benefits of the system

The potential benefits introduced by Printar’s digital solder mask printing system (Figure 5) include:

- significant savings in material usage;
- much higher resolution and registration accuracy;
- capital equipment costs savings;
- thinner and stronger solder dams;
- no solder mask residues inside holes;
- selective thickness: thicker on conductors, thinner on laminate areas;
- significant labour cost savings;
- photo-tools cost savings;
- no chemical waste and waste treatment costs;
- better and more resistant solder mask materials with inherent flame retardant capability;
- good adhesion of the ink to the substrate, as shown by comparative tests with other systems.

Solder mask is comprised of high performance polymers, especially aromatic or heterocyclic oligomers that have very high viscosity (10,000-100,000 cp at room temperature) and thus cannot be applied with inkjet technology. Dilution of the material to jettable viscosity leaves too thin a layer with pinholes which cannot function as a solder mask.

The solution requires a massive R&D effort. Without going into the details, a comparative study carried out by Printar is shown (Figure 4).