Soldermasks -

Processes and Properties
Soldermask – what is it for

- Enable mass soldering techniques
- Prevent solder shorts under components
- Prevent corrosion to underlying circuitry
- Plating resist for surface finishes
- Prevent growth of metal whiskers
- Insulate substrate from debris and environment
- Assist with component placement
- And …… and…………
PCB considerations for selection of soldermask

- Feature size
  - Via holes
  - Solder dams
- Registration
- Electrical performance
  - Impedance control
- Cost!!
Soldermask Types

Soldermask

Direct Imaging
- Screen print (UV or Thermal cure)
- Ink jet
- LDI (Laser Direct Imaging)

Indirect Imaging
- LPISM (Liquid Photolimageable SolderMask)
- Dry Film
Registration

Defect: exposed trace
Defect: exposed via
Solder mask misregistration
BGA pad
BGA pad
Via pad
Registration
Material Properties

- Colour
  - Usually green but other colours available
    - Other colours used for revision/function identification or halogen content control
- Finish
  - Gloss, semi-gloss/matte, matte, extra matt
    - Cosmetic
    - Functional
- UL – 94V0
  - Highly dependent on laminate
    - More difficult to achieve with thin laminates and/or thick soldermask layers
- RoHS compliance
  - Restricts the amounts and types of materials which formulations may contain
Material Properties

- **Halogen content**
  - Soldermasks usually contain no bromide (Br\(^{-}\)) but may contain significant amounts of Chloride (Cl\(^{-}\))
  - Halogen free defined by IEC as:-
    - <900ppm Cl\(^{-}\)
    - <900ppm Br\(^{-}\)
    - <1500ppm X\(^{-}\)

- **Ionic contamination**

- **Outgassing**
  - Important for aerospace and space applications

- **Solvent emission**
  - VOC & HAP restrictions may influence choice of mask and/or application method
Compliance

- **SM840D**
  - H - High reliability/military (old Class 3)
  - T - Telecommunication (old Class 2)

- **MilSpec 55110**
  - Soldermask requirements call out SM840

- **Bellcore (Telcordia GR-78-CORE)**

- **NASA Outgassing**

- **Customer specific specifications**
Process compatibility

- **Pb free processing**
  - 10 - 20deg C higher temperatures put more stress on soldermask coating

- **ENIG & Imm Sn/Ag resistant**
  - Highly aggressive processes requiring correct selection of soldermask and good control of application process.

- **Via hole clearing**
  - Smaller vias are harder to clear during development which may influence choice of mask and application method

- **Via hole plugging**
  - Tenting not possible with liquid soldermasks
  - May require separate via-plugging step
  - Via-in-pad requires planarisation and plating. High solids better to avoid shrinkage.
Process compatibility

- **Solder balling**
  - Some assembly processes tend to formation of solderballs on soldering.
  - Use of extra-matte soldermasks can help to eliminate solderballs

- **Assembly materials**
  - Fluxes/cleaners
    - Zero-solids fluxes provide less thermal barrier to soldermask during wave soldering
  - Underfills/adhesives

- **Conformal coating compatibility**
  - Important to evaluate conformal coating/soldermask combination to ensure good coating/adhesion
Application

- Coating methods
  - Influence on soldermask performance
    - Coverage profile
      - Track encapsulation
      - Resolution of fine features
      - Influence on PCB electrical performance
    - Via plugging/cleaning
  - Environmental concerns
    - Solvent emissions
Screen print

- Single side
  - Horizontal orientation
  - Good for thin core/flexible substrate

- Double sided
  - Vertical orientation
  - Good for thin core/flexible substrate
Single side screen print
Double sided screenprint
Curtain coat

- Fast
- Horizontal orientation
- Single side coating
- Not practical for thin core/flexible substrates
Curtain coater
Curtain coat
HPLV Air spray

- Horizontal (usually) orientation
- Single or double sided coating
- Difficult for thin core/flexible substrates
HPLV Air spray system
Electrostatic spray

- Horizontal or vertical
- Single or double sided coating
- Thin core/flexible substrate possible
- Coating affected by circuit layout
Electrostatic spray
Coating profile

- **Screen Print**
  - Uniform coating to the board surface
  - Reasonable track coverage
  - Moderate amount of mask between tracks

- **Curtain coat**
  - Uniform coating on board surface
  - Difficult to coat high/closely spaced tracks
  - Moderate amount of ink between tracks with little on top/edges of high/narrow tracks
Coating profile

- **HPLV Airspray**
  - Single-gun systems have an overlapping spray pattern allowing an even coating.
  - Multi-gun systems can be difficult to set up to achieve even coating
  - Excellent track coverage
  - Minimal ink between tracks
Coating profile

- Electrostatic spray
  - Single or multi gun system
  - Single or double sided coating
  - Track coverage dependent on circuit layout
  - Minimal ink between tracks
## Coating profile
### Wet soldermask thickness

<table>
<thead>
<tr>
<th></th>
<th>SP</th>
<th>CC</th>
<th>ES</th>
<th>AS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Approx. 25 to 50µm over most of PCB. Thickness between tracks can 60-80µm depending on track heights and gap. Thick edges can be &gt;200µm thick.</td>
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</tbody>
</table>
Spray

Screen Print

Curtain coat

Spray
# Single-Gun Air-spray Coating uniformity

## Thickness Uniformity

**Single gun Air-spray at 1.2 m/min**

<table>
<thead>
<tr>
<th>Area</th>
<th>Dry Thickness (thou)</th>
<th>(microns)</th>
<th>Mean dry thickness:</th>
<th>30.4 microns</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.16</td>
<td>29.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.14</td>
<td>29.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.22</td>
<td>31.0</td>
<td>Standard deviation:</td>
<td>0.7 microns</td>
</tr>
<tr>
<td>4</td>
<td>1.19</td>
<td>30.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.17</td>
<td>29.7</td>
<td>UCL</td>
<td>32.6 microns</td>
</tr>
<tr>
<td>6</td>
<td>1.17</td>
<td>29.7</td>
<td>LCL</td>
<td>28.2 microns</td>
</tr>
<tr>
<td>7</td>
<td>1.23</td>
<td>31.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1.21</td>
<td>30.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1.18</td>
<td>30.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1.18</td>
<td>30.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>1.19</td>
<td>30.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1.22</td>
<td>31.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>1.21</td>
<td>30.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>1.26</td>
<td>32.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>1.19</td>
<td>30.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>1.19</td>
<td>30.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>1.22</td>
<td>31.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>1.23</td>
<td>31.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>1.17</td>
<td>29.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>1.19</td>
<td>30.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Track encapsulation

- HPLV spray
  - 400 micron copper
  - Blind via coverage
Rheological Comparison of LPI Formulations

CC v SP v ES/AS

Shear stress vs. Rheology (Log Scale)

- Curtain-coat
- Screen-print
- Air-spray
Via plugging/cleaning

- **Screen print**
  - Tends to put moderate amount of ink in holes
  - Can be used for via plugging

- **Curtain coat**
  - Tends to put ink only in larger tooling holes/slots on board. Via holes not filled
  - Cannot be used for via plugging
Via plugging/cleaning

- HPLV Airspray
  - Very little ink in via holes
  - Cannot be used for via plugging

- Electrostatic spray
  - Very little ink in via holes
  - Cannot be used for via plugging
Via plugging/cleaning

Soldermask in Holes

– Typical developing speed for 2m chamber:

- Screen-print: 1.3 to 2.0 mmin\(^{-1}\)
- Curtain-coat: 2.0 to 2.5 mmin\(^{-1}\)
- Spray: 3.5 to 4.0 mmin\(^{-1}\)
Resolution
Resolution

- Image growth
- Design width
- Undercut
Resolution

Practical Example

- Screen Print versus Air-spray
- Same base soldermask chemistry

Purpose designed test panel - requirements:

- Maintain 10µm on track edges
- Wash clean 0.2mm via-holes
- Maintain 50µm solderdams
# Resolution

<table>
<thead>
<tr>
<th></th>
<th>High Resolution Screen Print SM</th>
<th>Dark Green Air Spray SM</th>
<th>High Resolution Air Spray SM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Developing Speed</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clean <em>0.2mm</em> holes</td>
<td>90s dwell</td>
<td>30s dwell</td>
<td>30s dwell</td>
</tr>
<tr>
<td><strong>Exposure Energy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold <em>50µm</em> dams</td>
<td>583 mJcm⁻²</td>
<td>270 mJcm⁻²</td>
<td>134 mJcm⁻²</td>
</tr>
</tbody>
</table>

*Note:* Holes were plugged after printing.
Resolution

- Elimination of Air
### Air entrainment

<table>
<thead>
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<th>AS</th>
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<tbody>
<tr>
<td></td>
<td><strong>AirBubbles</strong></td>
<td><strong>AirBubbles</strong></td>
<td><strong>AirBubbles</strong></td>
<td><strong>AirBubbles</strong></td>
</tr>
<tr>
<td></td>
<td>Mixing and shearing action during printing induces air into the</td>
<td>Pumping and coating action introduces air into the soldermask.</td>
<td>Both ES and AS applications apply resist via a fine mist.</td>
<td>This application method is not prone to air entrainment.</td>
</tr>
<tr>
<td></td>
<td>soldermask. Viscosity and thixotropic properties impair air-</td>
<td>The low viscosity and thixotropy of CC materials means that the</td>
<td>This allows high levels of thixotropy and faster temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>release. Slow solvents and reduced thixotropy must be introduced</td>
<td>air escapes more readily. However it is important that temperature</td>
<td>ramp during tack-dry leading to improved track-edge coverage.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>for air to escape from between high tracks. This can lead to</td>
<td>ramp-up during drying is such that air has had opportunity to</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>reduced track-edge coverage.</td>
<td>release before the surface skins-over.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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*Diagram showing the effects of air entrainment in different applications.*
Influence on PCB electrical performance
Impedance v LPI coating thickness between traces

Coating thickness

Zdiff
And finally......

Solvent emissions
Solvent emissions

Typical Soldermask Consumption (Min. 10µm over 60-70µm tracks)

<table>
<thead>
<tr>
<th>Application Method</th>
<th>Dry Thickness (µm)</th>
<th>Coverage (m²/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP</td>
<td>≈ 25-30</td>
<td>≈ 17</td>
</tr>
<tr>
<td>CC</td>
<td>≈ 40-45</td>
<td>≈ 12</td>
</tr>
<tr>
<td>ES</td>
<td>≈ 35-40</td>
<td>≈ 4.5 to 14</td>
</tr>
<tr>
<td>AS</td>
<td>≈ 30-35</td>
<td>≈ 16</td>
</tr>
</tbody>
</table>
# Solvent Emission

<table>
<thead>
<tr>
<th>Wet Thickness</th>
<th>SP</th>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Dry Thickness (µm)</th>
<th>25- 30</th>
<th>40 - 45</th>
<th>35 – 40</th>
<th>30 - 35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage (gm⁻²)</td>
<td>≈17</td>
<td>≈12</td>
<td>≈4.5 - 14</td>
<td>≈16</td>
</tr>
<tr>
<td>Solvent content (%w/w)</td>
<td>25</td>
<td>42</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>Solvent Emission (gm⁻²)</td>
<td>16</td>
<td>46</td>
<td>28</td>
<td>28</td>
</tr>
</tbody>
</table>
Thank you