Fabrication of miniaturized moulded interconnect devices by means of laser induced selective activation (LISA)

Professor Hans Nørgaard Hansen (hnha@mek.dtu.dk)
Ph.D. Yang Zhang, M.Sc. Ulrik V. Andersen,
Ph.D. Peter T. Tang
Outline

• Background
• LISA process
  – Process description
  – Characteristics
  – Performance of structures
  – Characterisation
  – Modelling
• Summary
Moulded Interconnect Devices (MID)

“.. an injection moulded thermoplastic substrate which incorporates a conductive circuit pattern, and integrates mechanical and electrical functions..”

Polymer components with metal “circuits” made by “hot-stamping”

Source: Krauss-Maffei
Moulded interconnect devices (MIDs)
Industrial examples

MID module
Hearing aid
MID
Overview of MID processes and process chains

- **2k injection moulding**
  - Chemical pre-treatment and activation
  - Electrochemical deposition

- **1k injection moulding**
  - Physical Vapour Deposition (PVD)
  - Laser machining

- **Insert moulding**

**Moulded Interconnet Devices (MID)**
Main Steps of The LISA Process

1. Injection moulding
2. Laser machining
3. Activation and rinsing
4. Electroless plating
Main Steps of The LISA Process

1. Laser machining
2. Activation and rinsing
3. Electroless plating
Laser process characteristics (selected)

- PE, PP, ABS, PET/PBT, PC...
- Sample is submerged in distilled water

<table>
<thead>
<tr>
<th>Laser type</th>
<th>Wavelength</th>
<th>Average power</th>
<th>Pass</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nd:YAG laser</td>
<td>1064 nm</td>
<td>~3 W</td>
<td>15-30</td>
<td>1.2-2KHz</td>
</tr>
<tr>
<td>UV laser</td>
<td>350 nm</td>
<td>~2 W</td>
<td>3-6</td>
<td>30-40KHz</td>
</tr>
<tr>
<td>Fibre laser</td>
<td>1075 nm</td>
<td>~10 W</td>
<td>1-15</td>
<td>1/2 - 3/4 *</td>
</tr>
</tbody>
</table>

Square pulse: Pulse-period ratio
Nd: YAG laser

1 pass

5 pass

20 pass
Activation

Step 1  Wetting

Step 2  PdCl$_2$/SnCl$_2$ Activation

\[ \text{Pd}^{2+} + \text{Sn}^{2+} \rightleftharpoons \text{Pd}^0 + \text{Sn}^{4+} \]

Step 3  Rinsing in distilled water

Step 4  Rinsing in 10% HCl acid

Step 5  Rinsing in distilled water
Metallization

- Auto-catalytic electroless copper bath
- Circuposit 3350 from Rohm Haas
- 45 Degree Celsius
- Rinse and dry the sample after plating
- Optional nickel + gold

\[
\begin{align*}
\text{Cu}^{2+} + 2 \text{H}_2\text{CO} + 4 \text{OH}^- & \rightleftharpoons \text{Cu}^0 + \text{H}_2(\text{g}) + 2 \text{H}_2\text{O} + 2 \text{HCOO}^-
\end{align*}
\]
Metallization
# Plating velocity compared to LDS®

<table>
<thead>
<tr>
<th></th>
<th>LISA</th>
<th>LDS®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plating time*</td>
<td>0.5hour</td>
<td>0.5hour</td>
</tr>
<tr>
<td>Activity of the bath**</td>
<td>1262s</td>
<td>900s-1200s</td>
</tr>
<tr>
<td>Substrate material</td>
<td>Polycarbonate 10% glass fiber</td>
<td>LCP</td>
</tr>
<tr>
<td>Temperature</td>
<td>52° C</td>
<td>52° C</td>
</tr>
<tr>
<td>Average thickness***</td>
<td>4.81µm</td>
<td>~2µm</td>
</tr>
</tbody>
</table>

* Electroless autocatalytic copper bath: Circuposit 4500 from Rohm and Haas
** e-Cu: Check system by HSG-IMAT  Long time -> low activity.
*** The thickness is measured by Fischerscope® X-Ray system
Conventional plating processes
Samples — multiple metal layers

- **Before plating**
  - PC +10% glass fiber

- **Plated by copper**
  - PC +10% glass fiber

- **Nickel+Gold**
  - PC +10% glass fiber
Adhesion test @ HSG-IMAT

PC +10% glass fiber
Adhesion test @ HSG-IMAT

PC +10% glass fiber
## Adhesion test @ HSG-IMAT

<table>
<thead>
<tr>
<th></th>
<th>Average power</th>
<th>Average adhesion strength (MPa)</th>
<th>Standard deviation (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>4.2W</td>
<td>13.2*</td>
<td>2.9</td>
</tr>
<tr>
<td>Group 2</td>
<td>2.7W</td>
<td>13.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Group 3</td>
<td>0.7W</td>
<td>11.7</td>
<td>1.6</td>
</tr>
</tbody>
</table>

![Adhesion strength Mpa](chart.png)

- Group 1
- Group 2
- Group 3
Application – Dipole antenna

LISA

PCB
Application – Dipole antenna

3.67 GHz

3.64 GHz

LISA

PCB
Characterization of structures
Bearing area curve – describing the structure

• Quantitative characterization
• Peak, core and valley
• Core structure determines the plating
Bearing area curve for five cases

- YAG good
- YAG burnt
- YAG low energy
- UV good
- UV high frequency
Normalization

- YAG good
- YAG burnt
- YAG low energy
- UV good
- UV high frequency
Modelling approach

- Estimation of penetration depth as a function of temperature and energy input
Modelling approach

- Validation of mode - temperature
Modelling approach

• Validation of model – penetration depth
## Comparison with alternative processes

<table>
<thead>
<tr>
<th></th>
<th>LDS®</th>
<th>MIPTEC®</th>
<th>Full-Metallization</th>
<th>LISA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Materials</strong></td>
<td>Special filler in materials, only a few materials are available</td>
<td>Thermoplastics and ceramics</td>
<td>Several thermoplastics are available for metallization</td>
<td>Standard polymers that absorb laser energy</td>
</tr>
<tr>
<td><strong>Laser or other equipment</strong></td>
<td>Special wavelength to crack the bonds, special laser head to shape the track</td>
<td>Special wavelength to remove the metal layer</td>
<td>Special wavelength to remove the metal layer</td>
<td>Most industrial lasers</td>
</tr>
<tr>
<td><strong>Wet step</strong></td>
<td>Electroless plating</td>
<td>Electroplating and metal etching after sputtering</td>
<td>Dangerous chemicals for the pre-treatment</td>
<td>Activation and electroless plating</td>
</tr>
</tbody>
</table>
Thank you for your attention!