Two component micro injection moulding for moulded interconnect devices

2k moulding for MIDs

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Publication date:
2008

Citation (APA):
Two component micro injection moulding for moulded interconnect devices (MIDs)

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Polymetal conference
DTU, 26 Nov 2008
Outline

- Introduction to MID
- MID by 2k moulding
  - Polymer-polymer bond strength
  - Polymer-polymer interface
- Selective metallization
- Demonstrator MID
- Summary and conclusion
Moulded Interconnect Device (MID)

The MID is an injection moulded plastic part integrating electrical and mechanical functionalities on a single device.
Pros and cons of MIDs

Pros:
• Three dimensional circuit pattern
• Reduced number of part components
• Less assembly operation
• Reduced production cost

Cons:
• Requires expensive machines and tools
• Not suitable for small production volume
• Shortage of knowhow
Application of MIDs

• **Mobile phone** (antenna, housing, sockets)

• **Automotive applications** (door locking mechanism, dashboard switches, multifunctional steering wheel, turbocharger regulator, seat adjuster and sun hood opener)

• **Air plane industry** (no smoking illumination sign, pressure and flow sensors for air-conditioning, automatic overload detection mechanism)

• **Smart pen, Hearing aid, Flipchip**
### Circuit structuring methods

<table>
<thead>
<tr>
<th>Process Chain</th>
<th>Laser structuring</th>
<th>PVD</th>
<th>Metallization</th>
<th>Hot press</th>
</tr>
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<tbody>
<tr>
<td><strong>1k moulding</strong></td>
<td></td>
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<td>1a</td>
<td><img src="image1" alt="Laser makes the circuit pattern" /></td>
<td><img src="image2" alt="PVD covers the whole surface with metal" /></td>
<td><img src="image3" alt="Electroless deposition of metal" /></td>
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<td><img src="image12" alt="Electroless deposition of metal" /></td>
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<td><img src="image16" alt="3" /></td>
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<td><img src="image21" alt="Electroless deposition of metal" /></td>
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<td><strong>Insert moulding</strong></td>
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</tr>
</tbody>
</table>
Two component injection moulding for MIDs

Plateable plastic

Non-plateable plastic

Two component moulding

Electroless deposition of metal

MID

Metallized tracks
Two component (2k) injection moulding

- Combine two different polymers

- Variant of 2k moulding:
  - Simultaneous
  - Sequential
  - Cavity transfer

Cavity transfer 2k moulding

Source: www.arburg.com

First cavity

Second shot

Second cavity
Challenges of 2k moulding

- Reasonable adhesion between the two polymers
- Well-defined interfaces between the two polymers

More for MIDs…

- Selective metallization
- Micro scale selective metallization
Micro MID

Quality parameter

Bond strength

Interface

Selective metallization

Manufacturing process

2k micro moulding

Electroless metallization

Functional requirement

Material integration

Conductivity

Demonstrator MID
Investigation of the polymer-polymer bond strength

- Suitable polymer pairs for 2k applications
- Factors influencing bond strength
## Material list

<table>
<thead>
<tr>
<th>No</th>
<th>Name</th>
<th>Abbreviation</th>
<th>Trade name</th>
<th>Grade</th>
<th>Manufacturer</th>
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<tbody>
<tr>
<td>1</td>
<td>Polyetherimide</td>
<td>PEI</td>
<td>Ultem</td>
<td>1000</td>
<td>GE</td>
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<td>2</td>
<td>Polyetherimide</td>
<td>PEI</td>
<td>Ultem</td>
<td>2312EPR</td>
<td>GE</td>
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<td>Polyetheretherketone</td>
<td>PEEK</td>
<td>Victrex</td>
<td>150GL30</td>
<td>Victrex</td>
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<td>Polyoxymethylene</td>
<td>POM</td>
<td>Hostaform</td>
<td>C27021</td>
<td>Ticona</td>
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<td>5</td>
<td>Liquid crystal polymer</td>
<td>LCP</td>
<td>Vectra</td>
<td>E820i</td>
<td>Ticona</td>
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<td>6</td>
<td>Liquid crystal polymer</td>
<td>LCP(Pd)</td>
<td>Vectra</td>
<td>E820i Pd</td>
<td>Ticona</td>
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<td>7</td>
<td>Liquid crystal polymer</td>
<td>LCP(LDS)</td>
<td>Vectra</td>
<td>E820i LDS</td>
<td>Ticona</td>
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<td>Polybutylen terephthalate</td>
<td>PBT</td>
<td>Pocan</td>
<td>DP7102</td>
<td>Lanxess</td>
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<tr>
<td>9</td>
<td>Polybutylen terephthalate</td>
<td>PBT</td>
<td>Vestodur</td>
<td>GF30FR LDS</td>
<td>Degussa</td>
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<tr>
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<td>Polyphenyleneether blends</td>
<td>(PPE+PA+GF)</td>
<td>Noryl</td>
<td>GTX810</td>
<td>GE</td>
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<td>(PPE+PA)</td>
<td>Noryl</td>
<td>GTX964</td>
<td>GE</td>
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<tr>
<td>12</td>
<td>Polyphenyleneether blends</td>
<td>(PPE+HIPS)</td>
<td>Noryl</td>
<td>GFN1520V</td>
<td>GE</td>
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<tr>
<td>13</td>
<td>Polystyrene</td>
<td>PS</td>
<td>Polystyril</td>
<td>143E</td>
<td>BASF</td>
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<tr>
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<td>Polystyril</td>
<td>158K</td>
<td>BASF</td>
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<td>Polystyril</td>
<td>158KGF30</td>
<td>BASF</td>
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<td>Terluran</td>
<td>997VE</td>
<td>BASF</td>
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<tr>
<td>17</td>
<td>Polycarbonate</td>
<td>PC</td>
<td>Lexan</td>
<td>500R</td>
<td>GE</td>
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</tbody>
</table>
Polymer-polymer bond strength investigation

2k tensile bar
2k Disc

First shot part (small part)  Second shot part (big part)
Pull test results

Machine limit

Bond strength (MPa)

Pair with LCPs

Pair with POM
Tensile test results (2k tensile bar)

- Bond strength was not consistent in opposite shot sequence
Comparative bond strength

- 2k Discs
- 2k Tensile bar

Maximum of the adhesion tester
Bond strength as a function of shot sequences

Bond strength (MPa)

Shot sequence in the list

Reverse shot sequence

ABS-PC  PC-PEI2312  PC-PEI1000  ABS-PEI2312  PEEK-ABS  PC-PEEK  PEI1000-PEEK  ABS-PEI1000  PC-PS143E
**Bond strength as a function of shot sequences**

<table>
<thead>
<tr>
<th>First shot</th>
<th>Second shot</th>
<th>Bond strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEEK</td>
<td>PEI1000</td>
<td>4</td>
</tr>
<tr>
<td>PEI1000</td>
<td>PEEK</td>
<td>37</td>
</tr>
</tbody>
</table>

**Bond strength (MPa)**

\[
T_i = b_1 T_1 + b_2 T_2
\]

- Good bonding \( T_i > T_{\text{melting 1}} \)
- PEI 282°C
- PEEK 297°C

**PEEK-PEI1000**

**PEI1000-PEEK**
Effects of interface temperature

\[ \frac{T_{\text{interface}}}{T_{\text{melting}}} \leq 1 \quad \text{(For good bonding)} \]
## Suitable polymer pairs for 2k applications

<table>
<thead>
<tr>
<th>NO</th>
<th>Material pairs (first shot-second shot)</th>
<th>Bond strength with 2k tensile bar (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PEI1000-PEEK</td>
<td>38</td>
</tr>
<tr>
<td>2</td>
<td>PC-PEI1000</td>
<td>37</td>
</tr>
<tr>
<td>3</td>
<td>ABS-PEEK</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>ABS-PEI1000</td>
<td>27</td>
</tr>
<tr>
<td>5</td>
<td>PC-PEEK</td>
<td>26</td>
</tr>
<tr>
<td>6</td>
<td>ABS-PC</td>
<td>19</td>
</tr>
<tr>
<td>7</td>
<td>PEI2312-PEEK</td>
<td>18</td>
</tr>
<tr>
<td>8</td>
<td>PC-PEI2312</td>
<td>18</td>
</tr>
<tr>
<td>9</td>
<td>ABS-PEI2312</td>
<td>17</td>
</tr>
<tr>
<td>10</td>
<td>PS-PEI2312</td>
<td>13</td>
</tr>
<tr>
<td>11</td>
<td>PS-(PPE+HIPS)</td>
<td>12</td>
</tr>
</tbody>
</table>
Investigations of the factors affecting polymer-polymer bond strength

- Mould temperature
- Melt temperature
- Injection speed
- Injection pressure
- Holding pressure
- Holding time
- Environmental factors
- Surface energy
- Surface tension
- Solubility parameters
- Thermal effusivity
- Glass fibres
- Part geometry
- Surface roughness
- Surface roughness
- Part geometry
Effects of injection moulding parameters on bond strength

Comparative influence of injection moulding parameters on the bond strength

- Cooling time
- Holding time
- Holding pressure
- Injection speed
- Injection pressure
- Mould temperature
- Melt temperature
Effects of surface roughness

Bond strength vs. surface roughness

Bond strength (MPa) vs. Surface roughness ($S_a$ in µm)

[Graph showing the relationship between bond strength and surface roughness]
Effects of surface roughness

- Mechanical locking
- Increased area
- Localized melting (high surface area to volume ratio)
Effect of solubility parameters on the bond strength

- Characteristic of a polymer used in predicting the solubility of that polymer in a solvent
Micro MID

- Functional requirement
  - Material integration
  - Conductivity

- Manufacturing process
  - 2k micro moulding
  - Electroless metallization

- Quality parameter
  - Bond strength
  - Interface
  - Selective metallization

Demonstrator MID

Interface of two polymers

500µm
Polymer-polymer bond strength and interface dilemma

<table>
<thead>
<tr>
<th>Shot sequence</th>
<th>Bond strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEEK-PC</td>
<td>0</td>
</tr>
<tr>
<td>PC-PEEK</td>
<td>26</td>
</tr>
</tbody>
</table>

PEEK-PC shot sequence (bond strength 0 MPa)

PC-PEEK shot sequence (bond strength 26 MPa)
Selective metallization

<table>
<thead>
<tr>
<th>Polymer pair</th>
<th>Metallized polymer</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS-PC</td>
<td>ABS</td>
</tr>
<tr>
<td>PEI1000-Noryl GTX810</td>
<td>Noryl GTX810</td>
</tr>
<tr>
<td>PEEK- Noryl GTX810</td>
<td>Noryl GTX810</td>
</tr>
</tbody>
</table>

Before metallization

After metallization
PEI1000-Noryl GTX810
PEEK- Noryl GTX810

Before metallization

After metallization
Selective metallization

Noryl GTX810

Deposited metal layer
Difficulties in selective micro metallization

ABS-PC part after metallization

2k channel

PC

ABS

5 mm

ABS-PC part after metallization

2k tensile bar

ABS (metallized)

PC
Intermediate zone of metallization

Metallized ABS

Non-metallized PC

Mixing zone (partially metallized)
Interface quality and selective metallization

- Polymer not mixing at the interface (bond strength 3 MPa)
- Selective metallization
- Polymer mixing at the interface (bond strength 19 MPa)
- Non-selective metallization

PEI1000-GTX 810

ABS-PC
Demonstrator MID

• On-off button used in hearing aid by Pulse ApS

Hearing aid  On-off button

3.5 mm

2.54 mm
New concept of push button

Dome
Core
House
Push
Connector holes
Dome

pressed
Selected demonstrator geometry (push button core)

First shot part

Second shot

4mm

First shot insert

Second shot insert

Part after second shot

- Design
- Tooling
- Injection moulding
Injection moulding

- Ultem PEI 1000
- Noryl GTX 810
- GTX 810-PEI1000
- PEI1000-GTX810

1st shot part with Ultem PEI 1000
1st shot part with Noryl GTX 810
Metallization

Through hole plating
- Trapped air and chemicals
- Length/diameter ratio (L/D) is critical
- Optimization is required for higher L/D ratio

Noryl GTX810 1k part (Metallized)
Selective metallization

Ultem PEI 1000
Noryl GTX 810

Gate location

Noryl
GTX 810
After metallization

Metal-polymer adhesion 7 MPa

Noryl
GTX 810
Ultem PEI 1000
Electrical testing
Summary and conclusion

1. New material pairs for 2k applications and also for MID applications. LCP, POM proved unsuitable for 2k micro moulding and micro MIDs

2. Important factors for bond strength: Injection parameters, interface temperature, material shot sequence, substrate surface roughness, environmental conditions

3. Polymer-polymer interface study, effects of various parameters on the interface, relation between the bond strength and interface of two polymers
Summary and conclusion

4. Several new material pairs for selective metallization were identified. Factors affecting the metallization quality of plastic parts investigated

5. Demonstrator MID fabricated with the knowledge gained from the project proved its feasibility for industrial applications
Thank you for your attention