Development Aspects for Single Pass High Reliability Flip Chip Reflow Encapsulants

IMAPS Flip Chip Technology Workshop
June 25, 2002
Background

- **Application**
  - Flip Chip on Flex for disk drive (internal)

- **Goals**
  - Increase productivity
  - Decrease cost
  - Maintain excellent reliability
  - Enable increased product density

- **Strategy**
  - RE (no-flow underfill) was seen as most desirable process path
  - Strong teamwork embedded in a structured approach was the key to eventual success
Multiple “bridges” to build…
- Between organizations
- Between functions
- Between locations
# Project Goals

<table>
<thead>
<tr>
<th>Metric</th>
<th>Target/Rationale</th>
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</thead>
<tbody>
<tr>
<td>Throughput</td>
<td>&gt;30% increase in line throughput</td>
</tr>
<tr>
<td></td>
<td>Product cost reduction</td>
</tr>
<tr>
<td></td>
<td>Fewer steps; higher yield</td>
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<tr>
<td>Product Quality</td>
<td>Equal or better reliability with increased product density</td>
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<tr>
<td>Product Density</td>
<td>Reduce space required for capillary underfill</td>
</tr>
<tr>
<td>Floor Space &amp; Equipment</td>
<td>Eliminate post-cure</td>
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<td>Simplify dispensing process</td>
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Reflow Encapsulant Process

- Dispense performance is critical to process success
  - Material behavior during & after dispense is important
- Placement tailored to optimize compression flow
- Reflow must take place prior to gel, but material must gel prior to cooling
- Cure must exceed 95% after single reflow pass
Project Timeline

- Total timeframe of approx. 3 years
- Initial Material development lacked customer-driven aspect
- Multiple paths on development; some failures
### Material Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Target/Rationale</th>
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</table>
| Dispensing/viscosity                             | Repeatably dispensable; preliminary target $>10000$ cps, ultimately $13000$-20000 cps  
                                                | CV $< 3\%$ @ 2mg shot size                                                        |
| Pot Life                                         | $>8$ hours @ $25^\circ$C                                                          |
| Storage Life                                     | $>6$ months @ $-40^\circ$C                                                        |
| Predictable, Single-pass Reflow and Curing       | $>95\%$ cure after single reflow pass. Repeatable and robust to processing conditions. Excellent solderability to OSP |
Product Reliability Needs

- Internal Hard Drive Requirements
  - No organometallic catalysts
  - No condensable or reactive volatiles
  - Low extractable ionics
  - No particulate shedding
- Temp Cycling, -55°C to +125°C, 300 cycles
- Temp Shock, -55°C to +125°C, 500 cycles
- BTH, 500h @ 85°C, 85%RH
- HTOL, 1000h @ 125°C
Success Through Teamwork

Initially, material development was not efficient due to:

- Poor communication
- Undefined and conflicting expectations
- Tentative trust
Success Through Teamwork

- Redefined Cooperative effort:
  - Corporate technical agreement put in place
    - Defined intellectual property issues (Kester, Seagate)
    - Allowed close working relationship to be established
  - Focused two-day meeting
    - Redefined relationships, goals
    - Defined avenues to deal with communication gaps
      - Cross functional, cross-organizational, geographic
    - Reviewed previous activity/knowledge gained
      - Placed in context of new relationship
Success Through Teamwork

- Six Sigma processes a key to success
  - Improve Time to market for products (increasing DGR)
  - Lead the industry in key objectives (Introducing new and leading technology)
  - Create World class manufacturing Processes
  - Develop Strategic Supplier Relationships
Success Through Teamwork

Six Sigma Steps: RE Development

<table>
<thead>
<tr>
<th>Six Sigma Step</th>
<th>Development</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure</td>
<td>Initial Formulations</td>
<td>Introduce technology to product</td>
</tr>
<tr>
<td>Analyze</td>
<td>Learning through process &amp; test</td>
<td>Qualified at product level</td>
</tr>
<tr>
<td>Improve</td>
<td>Reformulation, improved test structures</td>
<td>Set process keys &amp; WS</td>
</tr>
<tr>
<td>Control</td>
<td>Qualify final formulation</td>
<td>In high volume production</td>
</tr>
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</table>
Success Through Teamwork

Many material formulation attributes not well understood

- Initially, needed to deal with basic things
  - Dispensability was initially very poor
- Once process issues were solved, passing thermal shock was next hurdle
- Final hurdle was thermal cycle performance
  - More difficult than thermal shock
Current Status: 
Dispensability & Pot Life

Dispense Performance

<table>
<thead>
<tr>
<th>Set</th>
<th>1 hour</th>
<th>2 hour</th>
<th>4 hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set A</td>
<td>95.26</td>
<td>95.66</td>
<td>95.76</td>
</tr>
<tr>
<td>Set B</td>
<td>2.12</td>
<td>2.13</td>
<td>2.13</td>
</tr>
<tr>
<td>Set C</td>
<td>95.05</td>
<td>2.11</td>
<td>2.11</td>
</tr>
<tr>
<td>Set D</td>
<td>95.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set E</td>
<td>2.11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Current Status: Reflow/Curing
Material Requirements

Material Properties

- Dispense/viscosity
  - CV of 3% at 2mg achieved
- Pot life
  - Greater than 8 hours
- Storage Life
  - 6 months, -40°C
- Cure
  - >95% cure after reflow
  - Excellent solderability, including to OSP

Reliability Goals

- Passes all Seagate tests for:
  - Organometallic catalysts
  - Condensable volatiles
  - Extractable ionics
  - Particulate shedding
- Passes Temp Cycling, -55°C to +125°C, 300 cycles
- Passes Temp Shock, -55°C to +125°C, 500 cycles
- Passes BTH, 500h @ 85°C, 85%RH
- HTOL >1000h @ 125°C
Future Path

- Complete High Volume Ramp
- Advance Dispense Process
  - 1.0 mg shot size
- General Market Availability
Conclusions

- A unique RE for flip chip on flex has been qualified and is released for production; all key performance goals were met
  - Material will be available to the general market
- A strong OEM-supplier partnership provided path to success
  - Structured, Six-Sigma approach was a key to managing the development process
  - Trust and common viewpoint between organizations took time and significant effort to develop