LED Encapsulation
Integration of lenses and sensors
IMAPS 2014

SHM Kersjes
Content

About Besi - Fico

LED encapsulation

Trend

Transfer molding of primary LED optics

Integration of lenses and sensors
Besi Netherlands.

Corporate Headquarters
Duiven – the Netherlands

Founded: 1956
Employees: 200
Employees ww.: 1400
Surface Area: 26,400 m²

BESI develops and manufactures high-precision equipment for the semiconductor industry, covering the back-end semiconductor assembly process.
## Back-end Semiconductor Assembly Process

<table>
<thead>
<tr>
<th>Dicing</th>
<th>Die Attach</th>
<th>Wire Bond</th>
<th>Packaging</th>
<th>Plating</th>
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<tbody>
<tr>
<td>Die Sort</td>
<td>Die Bond</td>
<td>Wire Bond</td>
<td>Molding</td>
<td>Trim &amp; Form</td>
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<td>Plating</td>
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<td>Leadframe Assembly</td>
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<td>Ball Grid Array</td>
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<td>Ball Grid Array</td>
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</tbody>
</table>

- Leadframe Assembly
- Singulation
- Ball Grid Array
- Wafer Level Packaging
- Flip Chip Assembly
Global organization

- Development activities in Europe and USA
- Increasing production and sales/service activities in Asia

€ Millions as of December 2013

<table>
<thead>
<tr>
<th></th>
<th>Europe/NA</th>
<th>Asia</th>
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</thead>
<tbody>
<tr>
<td>Revenue</td>
<td>€60.5</td>
<td>€191.4</td>
</tr>
<tr>
<td>Headcount</td>
<td>646</td>
<td>812</td>
</tr>
<tr>
<td>R&amp;D expenses</td>
<td>9.7% of revenue</td>
<td></td>
</tr>
</tbody>
</table>

|                  | 24.9%     | 75.1%  |
|                  | 54.3%     | 55.7%  |
# Content

**About Besi - Fico**

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</table>
Trend in LED encapsulation

- **Size** vs. **Time**
- **Integration of sensors**
- **Functionality of primary optics**

Diagram showing the trend in LED encapsulation, focusing on size reduction over time, with integration of sensors and functionality of primary optics.
Transfer molding of primary LED optics

Molding process sequence

Foil index

Board insert
Mold close

Molding
Transfer molding of primary LED optics

Molding process sequence

Cavity

Transfer plunger

Injection film
Transfer molding of primary LED optics

Research subjects

For molding three subjects are investigated:

1. Optical quality > Smooth cavity structure

2. Mold release > Foil stretching

3. Processing silicones > Flow behavior
Transfer molding of primary LED optics

Cavity structure

Three subjects:

1. **Cavity structure**

2. Foil stretching

3. Silicone injections
Transfer molding of primary LED optics

Cavity structure

Impact of cavity roughness on a silicone dome:

- 266 nm Ra
- 25 nm Ra
Transfer molding of primary LED optics

Cavity structure

- Manual polishing is the classical method to obtain smooth surfaces
  
- However, it is operator dependent
  
  - Geometrical deviation
  
  - Costly
  
- P-EDM + Foil gives a good surface quality
Transfer molding of primary LED optics

Foil stretching

Three subjects:

1. Cavity production

2. Foil stretching

3. Silicone injections
Transfer molding of primary LED optics

Foil stretching

Foils need to stretch, while preventing rupture
Measuring height and pressure the stretch-stress curve can be derived, following the steps of Galliot et al.

\[ R = \frac{a^2 + h^2}{2h} \]

\[ \sigma_x = \sigma_y = \frac{PR}{2t_P} \]

\[ \lambda = \ln \left(1 + \frac{h^2}{a^2}\right) + 1. \]


Test results of different materials using bubble inflation.
Using FEA, pressure, stretch and stress inside the foil can be simulated. As input an Ogden hyper-elasticity model is fitted to biaxial and uniaxial stress-stretch data.

![Diagram showing uniaxial and biaxial tensile data with Ogden fits]

<table>
<thead>
<tr>
<th>i</th>
<th>$\alpha_i$ (-)</th>
<th>$\mu_i$ (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.35</td>
<td>$3.14 \times 10^{-6}$</td>
</tr>
<tr>
<td>2</td>
<td>-2.18</td>
<td>-2.38</td>
</tr>
<tr>
<td>3</td>
<td>$1.19 \times 10^{-10}$</td>
<td>$1.83 \times 10^{-12}$</td>
</tr>
<tr>
<td>4</td>
<td>$2.50 \times 10^{-10}$</td>
<td>$1.38 \times 10^{-11}$</td>
</tr>
</tbody>
</table>

Ogden material parameters fitted to uniaxial tensile and bubble-test data.
Transfer molding of primary LED optics
Finite Element Analysis

FEA indicates that the foil needs:

- To be able to stretch a factor 2.1 [-]
- Hold a stress of 6.5 [Mpa]
Transfer molding of primary LED optics
Silicone flow behavior

Three subjects:

1. Cavity production
2. Foil stretching
3. Silicone injection

Cavity Foil
LED Board
Silicone Injection film
Transfer molding of primary LED optics
Silicone flow behavior

Viscosity curve of a methyl silicone.

![Viscosity curve graph](image)

- Heat-up
- Gel time
- Cure
- Slit viscosity [Pa.s]
- Time [s]

Legend:
- 100 c
- 110 c
- 120 c
- 130 c
Integration of lenses and sensors
Silicone flow behavior

Three subjects:

1. Cavity production

2. Foil stretching

3. Silicone injection

Demonstrator product
Integration of lenses and sensors
European development project

Call 2010-1

Integration of electronics and controls in LED modules.
Integration of lenses and sensors

Exposed contacts

Light Sensor

LED’s
Integration of lenses and sensors

Copper wafer carrier
Integration of lenses and sensors

Exposed contacts
Integration of lenses and sensors

Combined large and medium domes
Integration of lenses and sensors

Enlight
Thank you