TERALINK™

A cross-linked thermoplastic polymer for Optical Components that can withstand SMT processes

Sumitomo Electric Fine Polymer, Inc.
Innovation Core SEI, Inc. (ICS)
Sumitomo Electric Industries, Ltd.

July 2016
SEI’s Five Business Domains

- Automotive
- Electronics
- Information Communications
- Environment & Energy
- Industrial Materials
ICS Role: Creating New Biz. in North America

Phases of Biz. Dev.

- Opportunity Gauging
- Business Model Planning
- R&D • Pilot PJ
- Commercialization
- Business Operation

ICS | R&D | Sales&Biz Unit

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**Company Profile**

**Sumitomo Electric Fine Polymer, Inc.** is a wholly-owned subsidiary of Sumitomo Electric Industries, Ltd. We specialize in electron beam irradiation technology and fluororesin processing technology supplying unique products to a wide range of industries including automobiles, information and communications, home electronics and infrastructure.

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Sumitomo Electric Fine Polymer, Inc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td>1-950, Asashiro nishi, Kumatori-cho, Sennan-gun, Osaka, 590-0458 JAPAN TEL:+81-72-452-1301</td>
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<tr>
<td>Activities</td>
<td>Development and production of products made of fine polymer materials</td>
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<td>Capital</td>
<td>10 billion yen</td>
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<tr>
<td>Number of employees</td>
<td>Approximately 480</td>
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Products

- Irradiated Products
  - Heat-shrinkable tubing and heat resistant tapes
  - Thermoplastic polymer components (*TERALINK*)

- Functional Fluororesin Products
  - Fluororesin- coated aluminum products for cookers
  - Rollers for ink-jet printers
  - Porous materials made of PTFE for microfiltration
What is TERALINK?

- Thermoplastic polymer cross-linked by electron-beam irradiation

**Advantages**
- Structurally stable at temperatures above melting point
- Retains original shape and transmittance under reflow process (260°C)
- Improved resistance to wear
- Improved resistance to chemicals

**Lens for LEDs**

- Reflow (260°C)

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Application example: Lens for SMT LED packages

- **Lens for SMT LED packages**
  - Lens bonded to package by silicone or epoxy

- **Radiation characteristics**
  - **SMT LED with lens-bonded package**
    - \( P_O = 73 \text{mW} \)
    - \( I_E = 350 \text{mW/sr} \)
    - \( I_F = 120 \text{mA} \)
    - \( \Theta_{1/2} = 19^\circ \)
  - **SMT LED without lens**
    - \( P_O = 84 \text{mW} \)
    - \( I_E = 270 \text{mW/sr} \)
    - \( I_F = 120 \text{mA} \)
    - \( \Theta_{1/2} = 122^\circ \)

High power SMT LEDs with view angles < 20° realized by lens-bonded packages
Application example: Optical connectors

- Lens for optical connectors

Features
- Hybrid structure of lens and housing realized in single molding process
- Reflowable (260°C)

No need for adhesives

LED/VCSEL  PD

lens

outer package for supporting lens

Optical connector

<Prod.>
- Optical connectors (POF: 650nm)

<R&D>
- Optical connectors (MMF: 850nm)
- Lens package for LEDs & PDs
Application example: Optical lens module for VCSELs

- **10Gbit/s AOC lens module**

  ![Diagram of optical lens module]

  - *mount and fixed by thermal cure epoxy*

  **Before reflow**
  
  **After reflow**

  **Effective area of lens**

  **Deformation of the lens surface profile after reflow is within 1~2μm**

T. Shimazu et al., Reflowable Thermoplastic Optical Lens Module for 10-Gbit/s Transmission with 850-nm VCSEL, OFC2015
Shift in the lens position after reflow

AOC lens module

Test method
- Reflow performed on 7 samples
- Lens positions measured after reflow

Shift in the L1, L2 positions after reflow is at most 2.1μm
Demonstration of 10Gbits/s transmission

(a) Tx Optical waveform (Before Reflow)  (b) Tx Optical waveform (After Reflow)

10m MM Fiber

Pulse Pattern Generator
10.3125Gbps
PRBS $2^{31}-1$

Evaluation Board

E/O

O/E

Oscilloscope

Bit Error Rate Tester

(C) Output waveform (Before Reflow)  (D) Output waveform (After Reflow)

Error Free!

*both Before and After reflow

![BER vs. Input power graph]( BER vs. Input power graph )

Input power [dBm]

-13.0 -11.0 -9.0 -7.0 -5.0 -3.0

BER

- $1 \times 10^{-3}$

- $1 \times 10^{-4}$

- $1 \times 10^{-5}$

- $1 \times 10^{-6}$

- $1 \times 10^{-7}$

- $1 \times 10^{-8}$

- $1 \times 10^{-9}$

- $1 \times 10^{-10}$

- $1 \times 10^{-11}$

- $1 \times 10^{-12}$
Transmittance spectrum

TERALINK: TPN10A
thickness: 2mm

T > 90% @ 650 ~ 850 nm, ~ 90% @ 1300 nm, 75 ~ 80% @ 1550 nm
Effect of reflow on transmittance

Transmittance spectrum remains virtually unchanged above 650nm.
Reliability data on transmittance

Reliability at 100°C

Reliability at 120°C

650nm ⇒ no degradation observed up to 3300h at 100°C
850nm ⇒ no degradation observed up to 3300h at 120°C
<table>
<thead>
<tr>
<th>Material properties</th>
<th>Test method</th>
<th>Unit</th>
<th>TERALINK※1</th>
<th>PEI</th>
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<tr>
<td>Density</td>
<td>ISO1183</td>
<td>g/cm³</td>
<td>1.0</td>
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<td>Refractive index</td>
<td>JISK7142</td>
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<td>1.51</td>
<td>1.64</td>
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<td>Transmittance (2mm)</td>
<td>JISK7361</td>
<td>%</td>
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<tr>
<td>Transmittance (2mm, 650nm)</td>
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<td>%</td>
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<td>89</td>
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<tr>
<td>Transmittance (2mm, 850nm)</td>
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<td>%</td>
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<td>89</td>
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<tr>
<td>Haze</td>
<td>JISK7361</td>
<td>%</td>
<td>1.7</td>
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<td>Glass transition temperature</td>
<td>ISO11357</td>
<td>°C</td>
<td>153※2</td>
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<td>Tensile strength at break</td>
<td>ISO527</td>
<td>MPa</td>
<td>73</td>
<td>110</td>
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<tr>
<td>Elongation at break</td>
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<td>%</td>
<td>29</td>
<td>60</td>
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<tr>
<td>Bending strength</td>
<td>ISO178</td>
<td>MPa</td>
<td>100</td>
<td>165</td>
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<td>Bending elastic modulus</td>
<td>ISO178</td>
<td>GPa</td>
<td>1.8</td>
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<td>Charpy impact strength (notched)</td>
<td>ISO179</td>
<td>KJ/m²</td>
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<td>Water absorption (23°C/sat.)</td>
<td>ISO62</td>
<td>%</td>
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<td>Water absorption (23°C/50%R.H.)</td>
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<td>Thermal expansion coefficient</td>
<td>ISO11359</td>
<td>10⁻⁴/K</td>
<td>0.9</td>
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<td>Flammability</td>
<td>UL94</td>
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<td>Specific volume resistivity</td>
<td>IEC93</td>
<td>Ω・cm</td>
<td>1.00E+11</td>
<td>1.00E+17</td>
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※1 Grade: TPN10A
※2 Teralink does not melt and keeps its original shape above Tg
Summary

- TERALINK is a cross-linked thermoplastic polymer for Optical Components that can withstand SMT processes

Features
- Reflowable (260°C)
- Transmittance is over 90% (600nm~1100nm)
- Injection molding applicable (cost effective, high flexibility in design)
- Hybrid structures of lens & supporting holder realized in a single molding process

Applications include
- Lens for SMT-type LEDs or PDs
- Lens package for optical connectors
- Optical components for multi-mode fiber applications (VCSELs)

We appreciate your feedback!
THANK YOU!

Sumitomo Electric Fine Polymer, Inc.
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June 2016