DEVELOPMENT OPPORTUNITIES FOR THERMOPLASTIC OPTICAL INTEGRATION INTO CO-PACKAGED APPLICATIONS

COBO WEBINAR SERIES

November 11, 2020
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WHO WE ARE

SABIC IS A GLOBAL LEADER IN CHEMICALS

From making cars and planes more fuel-efficient, to contributing towards water conservation, and helping enable colorful smartphone cases, we find solutions to the challenges of today to help our customers achieve their ambitions and build a better tomorrow.
SABIC AT-A-GLANCE

1976
Company established

33,000
Employees around the world

50
Countries of operations

3rd
Largest global chemical company*

122nd
Largest public company in the world*

85
US$ bn
Total assets

5.7
US$ bn
Net income

45
US$ bn
Annual revenue

≈ 150
New products each year

12,540
Global patent filings

68
World-class plants worldwide

*Forbes 2018  **Brand Finance, 2019
OUR BUSINESSES

BUSINESS PORTFOLIO

PETROCHEMICALS
- Glycols, Olefins, Oxygenates and Aromatics
- Chemical Intermediates & Industrial Gases
- Polyolefins
- PC/Engineering Thermoplastics (ETP)
- PVC, Polyester and Polystyrene
- Specialty Polymers & Polymer Additives
- Synthetic Rubbers
- Sheet & Film

SPECIALTIES
- Specialty Engineered Thermoplastics
- Specialty Compounds
- Advanced Composites
- Additive Manufacturing
- Thermosets and Additives

AGRI-NUTRIENTS
- Nitrogen
  - Prilled Urea
  - Granular Urea
  - Ammonia
- Phosphate
  - DAP and Dark DAP
  - MAP
- Specialty
  - NPK
  - TGU

METALS*
- Long Steel
  - Rebar
  - Wire Rod
  - Rebar in Coil
- Flat Steel
  - Hot Rolled Coils
  - Cold Rolled Coils
  - Galvanized Rolled Coils
  - Pre-painted Rolled Coils

* Supplied under SABIC brand through Hadeed, a fully-owned SABIC Affiliate
SABIC’S SPECIALTIES BUSINESS - A MATERIAL SUPPLIER

Our materials and resins are sold and converted or integrated into a wide number of products

Electronics  Mobility  Industrial  Healthcare  Consumer

Injection molded thermoplastic lenses made from ULTEM™ 1010 resin were developed in the late 1990s for TOSA and ROSA modules. SABIC resins are also used in other connector components
REQUESTED CAPABILITIES FOR THERMOPLASTIC MATERIALS IN OPTICAL CONNECTORS

ROBUST OPTICAL DESIGN

Reduce dB loss during assembly
• No deformation after solder reflow assembly
• Improved alignment and placement
• Reduced connector size

Maintain optical signal
• Dimensional tolerances for single mode
• Aging standards and part robustness
• Low impact assembly methods

OUR FOCUS IS ON MATERIAL PROPERTIES
• Improve dimensional stability
• Demonstrate design capabilities to maximize flexibility and increase part integration
• Performance evaluation of assembly methods, chemical exposure and aging
High connector reliability is required to reduce breakage from strain or repeated connections

**Status: Multiple Options**

Requested properties:
- High stiffness and strength
- Injection molding of fine features
- Precise alignment

**Amorphous resin (PEI, PES, PC)**
- Higher melt viscosity can require higher processing temperatures
- Stable coefficient of thermal expansion (CTE)

**Semi-Crystalline resin (PPS, LCP, PBT, PEEK)**
- Low melt viscosity
- Dimensional stability requires higher reinforcement loadings
ADVANTAGE OF THERMOPLASTIC OPTICAL ELEMENTS

DESIGN FREEDOM
Thermoplastics can allow complex part designs that are potentially limited in alternative solutions like glass or thermoset resins.

INTEGRATION AND SIMPLIFICATION
Thermoplastics allow the integration of mechanical (such as fixtures) and optical features to simplify design and assembly for potential cost improvement.

ECONOMY OF SCALE
Injection molding of thermoplastics enables high precision manufacturing of complex parts at large build numbers.
CHEMISTRY TO ENABLE IR TRANSPARENT SOLDER REFLOW THERMOPLASTICS

EXTEM™ resins maintain stiffness and dimensional stability through lead-free solder conditions
- Based on ULTEM™ resin polyetherimide chemistry processes
- EXTEM NGE resin series under development could meet 260°C peak reflow solder reflow temperature, validated on test plaques
- Realistic optical designs needed to complete validation

Molded by NALUX Japan for OEM working on multi-mode on board optics/CPO*

Connector designed using EXTEM NGE resin series optical properties
- 4 Rx and 4 Tx lens array on bottom with 250 µm spacing
- Internal reflective mirror to front lenses
- Front MT ferrule connection
- 4.3 x 8.9 x 2.1 mm (W x L x H)


ULTEM™ 1010 Resin
EXTEM™ XH1015 Resin
EXTEM NGE Resin Series

Storage Modulus (MPa)

0°C 200°C 260°C
ULTEM™ 1010 Resin
EXTEM™ XH1015 Resin
EXTEM NGE Resin Series

Transmit laser to fiber
Receive fiber to detector
REPLICATION AND SPACING MAINTAINED BEFORE AND AFTER REFLOW

**SOLDER REFLOW TESTING - DIMENSIONAL STABILITY**

Current dimensional measurements on lenses and alignment spacing after reflow conditions have changed by sub-micrometer distances.

**SOLDER REFLOW TESTING – OPTICAL PERFORMANCE**

JEDEC reflow testing completed
- Current test results show maximum change of 0.2 dB after 3 passes of 260°C peak temperature reflow
- No visual defects or blistering
- Aging and long-term performance studies will occur after further optimization of design

RESIN SOLUTIONS FOR SINGLE MODE THERMOPLASTIC OPTICS

Dimensional stability for single mode transmit and receive optics requires glass-like properties.

**Status: Experimental**

Requested properties:
- IR transparent
- Low coefficient of thermal expansion (CTE) 10-20 ppm/°C

Option A: New Polymers
- Long development time
- Accessible chemistry for low CTE performance
- Current research is focused on films market for foldable electronics or OLED

Option B: New Blends
- Speed to market
- Requested CTE is difficult to meet while maintaining optics and surface quality
- Blends can be tailored to specific optical targets or design requirements

23°C 85°C
DESIGN CAPABILITIES IN THERMOPLASTICS
Zemax Optical Studio parameters are available for modeling design, including:

- \( \frac{dn}{dT} \)
- Stress optical coefficient
- Internal transmission, different thickness, standard plaques for external validation
MOLD DESIGN CAPABILITIES FOR MANUFACTURABILITY

Part Capability and Fill Design

Flow and Stress Optimization to Reduce Birefringence

Part Production and Lens Analysis

4 x 3 lens test array using EXTEM™ XH1015 resin to validate optical prescription and dimensional positioning

3D surface of 250 µm diameter lens
4.7 x 5.0 x 0.3 mm
COMPLEX LIGHT MANIPULATION CAPABILITIES DURING OR POST MOLDING

DIFFRACTIVE OPTICS

Used DVD replication capabilities to produce structural diffractive patterns
• Injection molded 0.60 µm high diffractive optics

REFLECTIVE OR ANTI-REFLECTIVE (AR) COATINGS

• Metallization can integrate reflective optics with transmissive optics
• Anti-reflective coatings for higher %T and improved scratch resistance
ASSEMBLY OF COMPONENTS WITH MIXED MATERIALS

OVERMOLDING
Integration of multiple components can be accomplished with two-shot injection molding
- Optical + light blocking
- Optical + rigid alignment / mounting

PCB ASSEMBLY TECHNIQUES
Glues and other assembly methods can be used to assemble thermoplastic components prior or post solder reflow dependent on design needs

<table>
<thead>
<tr>
<th>Adhesive</th>
<th>%T</th>
<th>Shear Test Before / After SMT</th>
<th>Dispensing</th>
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<tr>
<td>Epoxy A</td>
<td>■</td>
<td>● / ●</td>
<td>●</td>
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<tr>
<td>Epoxy B</td>
<td>●</td>
<td>▲ / ●</td>
<td>●</td>
</tr>
<tr>
<td>Epoxy C</td>
<td>●</td>
<td>● / ●</td>
<td>●</td>
</tr>
<tr>
<td>Silicone A</td>
<td>●</td>
<td>■ / ■</td>
<td>●</td>
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</tbody>
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Source: Soprod SA
5 x 2.5 x 1.6 mm
Internal 2-shot part
25 mm diameter x 1 mm

Recommended ▲ Marginal ■ Not Recommended
LONG TERM OPTICAL PERFORMANCE AND SOLDER REFLOW ASSEMBLY

Based on current testing, optical and aging stability of EXTEM™ NGE resin series is comparable to ULTEM™ resins

No significant change in near infrared light transmission or visual color change, haze, or void formation
- Telcordia heat and moisture aging
- Water immersion
- Heat aging 150°C

In-house solder reflow for proof of concept testing
- Moisture sensitivity levels (MSL)
- Solder reflow profiles (240 – 270°C peak temperature)
- Re-bake / re-work simulation profiles

Aging dB loss data is based on 1 mm pathlength %T
EXPANDING THERMOPLASTIC CONNECTOR DESIGN CAPABILITIES

NEW MATERIALS
• New resins for thermoplastic optics can allow optical components to be assembled prior to lead-free solder reflow
• Materials with lower CTE for single-mode optics are being developed

NEW DESIGN CAPABILITIES
• Increased design complexity can be possible with diffractive optics, metallization, and overmolding
• Improved validation tools and datasets are available for reliability testing

FUTURE DEVELOPMENTS
• Increased activity for dimensionally stable thermoplastic single mode optics and connectors
• Continuing integration of assembly and design to fulfill datacenter scaling requirements
THANK YOU FOR YOUR ATTENTION

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Case studies
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