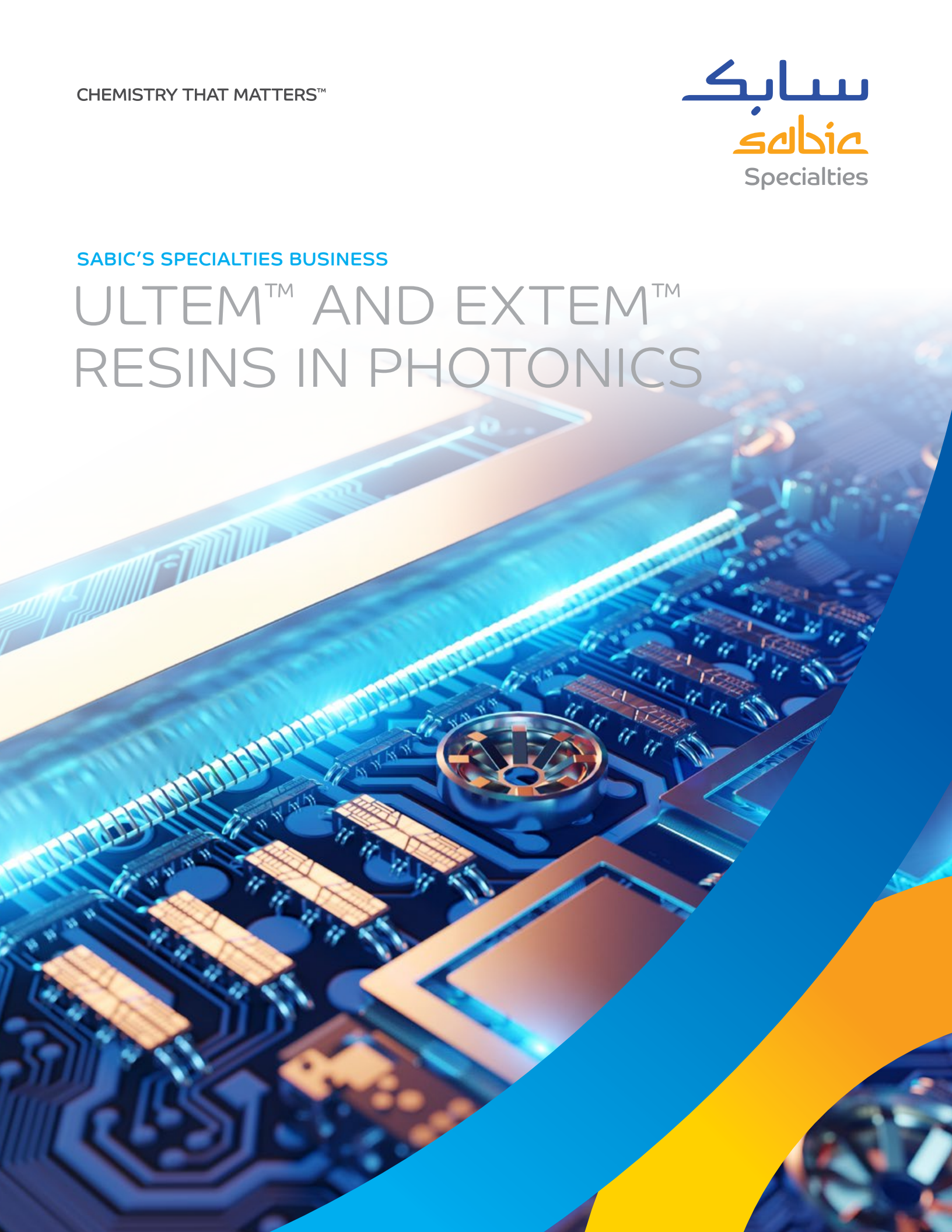
CHEMISTRY THAT MATTERS™

SABIC Specialties

SABIC'S SPECIALTIES BUSINESS

ULTEM™ AND EXTEM™ RESINS IN PHOTONICS



CONTENT

SABIC
A GLOBAL LEADER
IN CHEMICALS

Ranked among the world's largest petrochemicals manufacturers, SABIC is a public company based in Riyadh, Saudi Arabia. For over 40 years, our ambition to define the future of petrochemicals and thermoplastics has yielded solutions for the challenges of today and helped our customers achieve their ambitions for a better tomorrow.

We believe the answer to some of the world's biggest challenges lies in the natural human instinct to collaborate. We're making sure we understand the megatrends that will impact on our lives in the years to come.

We are making a meaningful impact in the world and sustainability is a vital part of our core business strategy.

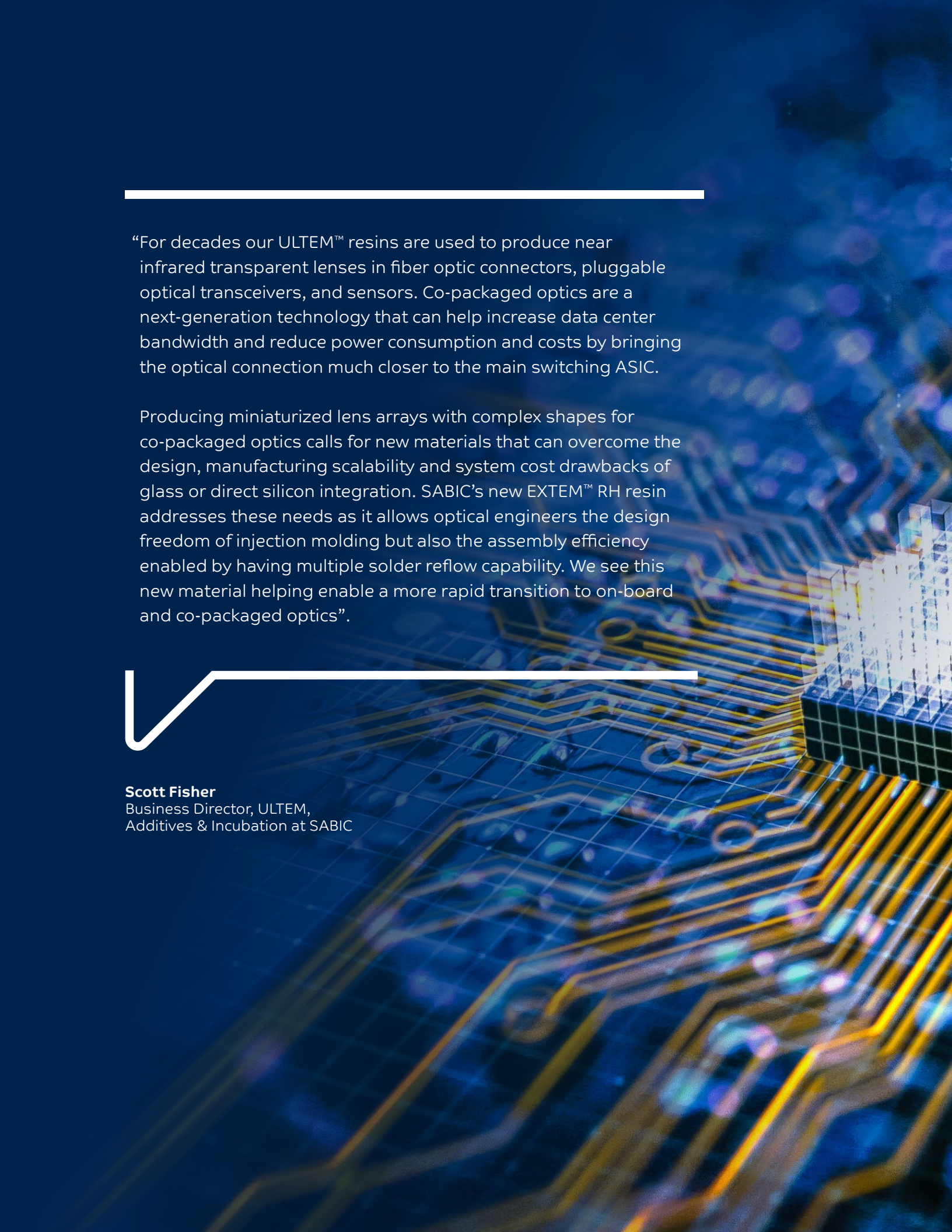
From enabling energy efficient high-bandwidth datacenters, to making cars and planes more fuel-efficient and helping conserve the world's water supply, we find solutions to the challenges of today to help our customers achieve their ambitions and build a better tomorrow.

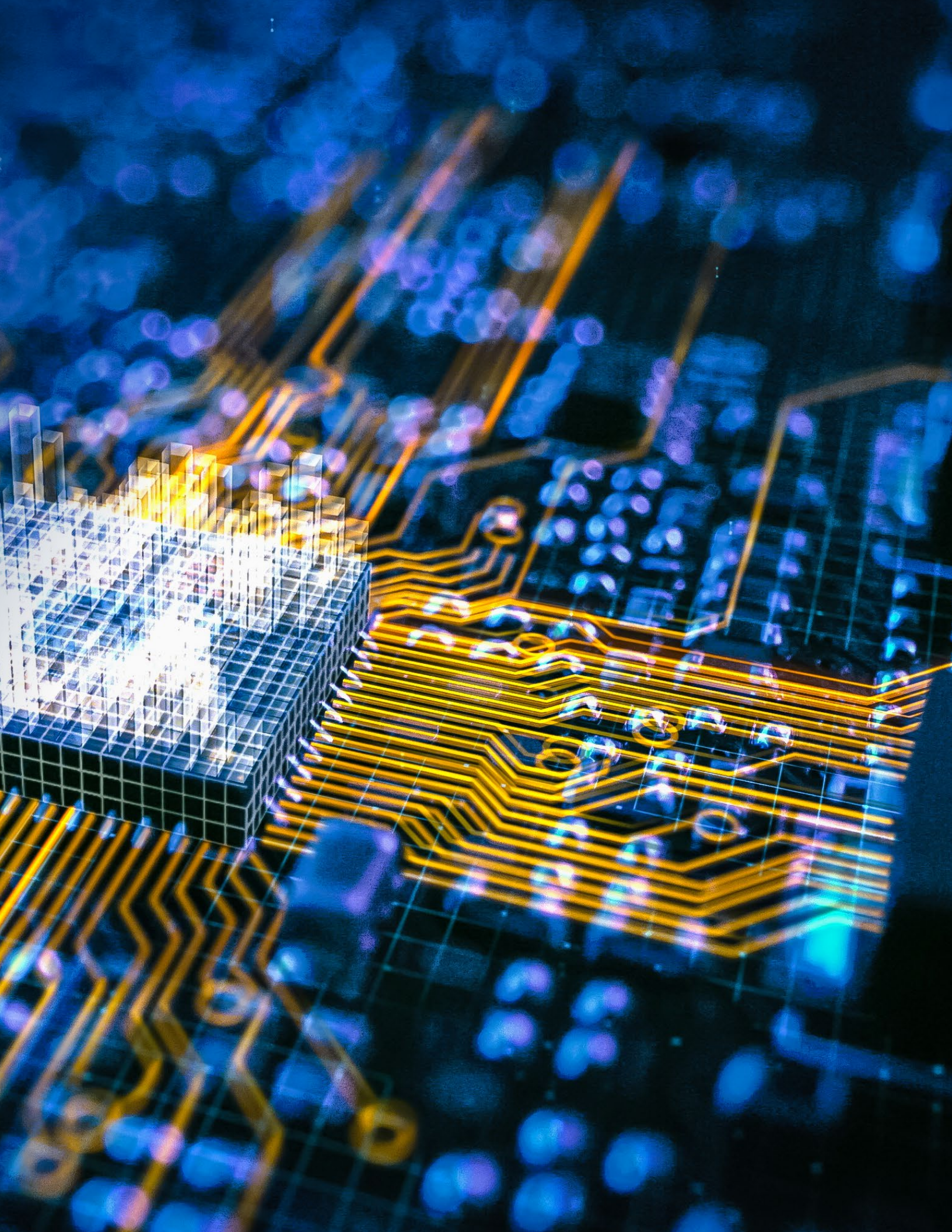
Together we're making Chemistry that Matters™.

“For decades our ULTEM™ resins are used to produce near infrared transparent lenses in fiber optic connectors, pluggable optical transceivers, and sensors. Co-packaged optics are a next-generation technology that can help increase data center bandwidth and reduce power consumption and costs by bringing the optical connection much closer to the main switching ASIC.

Producing miniaturized lens arrays with complex shapes for co-packaged optics calls for new materials that can overcome the design, manufacturing scalability and system cost drawbacks of glass or direct silicon integration. SABIC’s new EXTEM™ RH resin addresses these needs as it allows optical engineers the design freedom of injection molding but also the assembly efficiency enabled by having multiple solder reflow capability. We see this new material helping enable a more rapid transition to on-board and co-packaged optics”.

Scott Fisher
Business Director, ULTEM,
Additives & Incubation at SABIC





POTENTIAL BENEFITS OF SABIC'S ADVANCED OPTICAL THERMOPLASTIC RESINS

SABIC has several decades of history in supplying thermoplastic polymers in the opto-electronics industry. Optical elements in data communication and mobile applications play a critical role for seamless connectivity of electronic devices and back-end infrastructures.

Design Freedom & Miniaturization

Complex optical components that can be micro-molded with thermoplastics are potentially difficult to produce using alternative material solutions like glass or thermoset resins
For example lens arrays.

Optical interconnect lens designed and produced by Nalux Co., LTD.

Integration & Simplification

Thermoplastics are well-suited for the integration of mechanical and optical features to simplify design and assembly for potential cost improvement.
For example alignment fixtures.

Mass Production with High Precision

Injection molding of thermoplastics can enable high precision manufacturing of complex parts at large build numbers.
For example, spherical lenses.

Assembly of mixed materials

Integration of multiple components can be accomplished with two-shot injection molding:

- Optical and light blocking
- Optical and rigid alignment/mounting

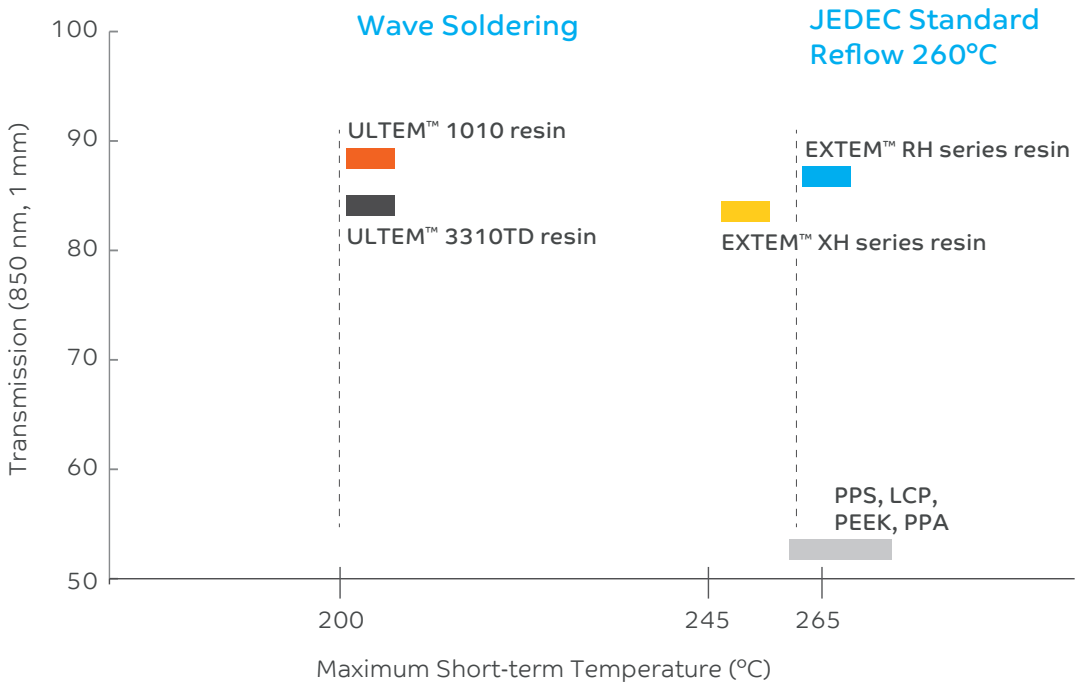
For example, over-molding with other thermoplastics.

Source: Soprod SA

OPTICAL DESIGNS THAT CAN BE PRODUCED AT SCALE

OUR PORTFOLIO MEETS VARIOUS REQUIREMENTS OF THE OPTICAL INDUSTRY

SABIC offers a broad portfolio of ULTEM™ and EXTEM™ resins to address material requirements for the photonics industry, including the ability to withstand the high heat of typical opto-electronic solder processes.



ULTEM Polyetherimide Resin

ULTEM resins are near infrared transparent, amorphous thermoplastic resins with a low thermal expansion coefficient (CTE). They have been used for (multi mode) optical lens assemblies in photonics for decades based on a perfect properties fit for this application area.

The new ULTEM 3310TD resin offers ~ 30% reduction in CTE while retaining optical transmission and is well-suited where extra tight alignment tolerances are required, like lenses for single mode optics in data centers.

EXTEM Polyimide Resin

EXTEM resins offer superior heat resistance with near infrared transparency.

They can maintain stiffness and dimensional stability for mounting of parts and modules in a PCB assembly with SAC/SMT reflow soldering (245 - 260°C) process according JEDEC J-STD-020A.

EXTEM™ RESIN WELL-SUITED FOR ONBOARD OPTICAL INTERCONNECTS

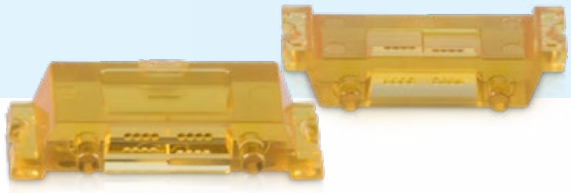
Trends in improved user experience, functionality and connectivity are driving both higher bandwidth and speed. Is the industry we know moving from pluggable to co-packaged solutions? Whichever path you follow, we might have the right material for you.

TODAY

ULTEM™ resin lenses in pluggable optical transceivers

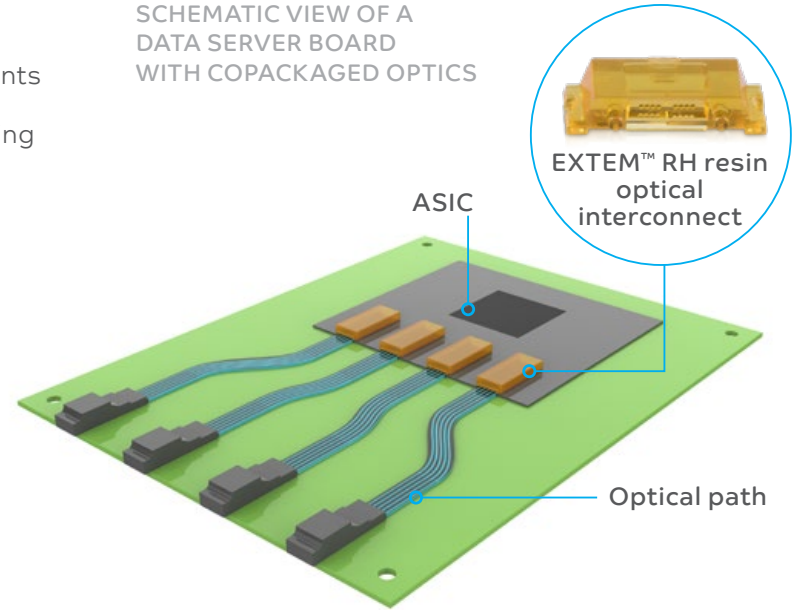
TOMORROW

EXTEM™ RH resin optical interconnect assembled close to ASIC



In order to demonstrate the strong value proposition of our EXTEM RH series resin for possible use in co-packaged optical components requiring reflow soldering at 260°C during assembly, SABIC, together with industry leading partners designed and produced an onboard interconnect with several lens arrays.

SCHEMATIC VIEW OF A DATA SERVER BOARD WITH COPACKAGED OPTICS

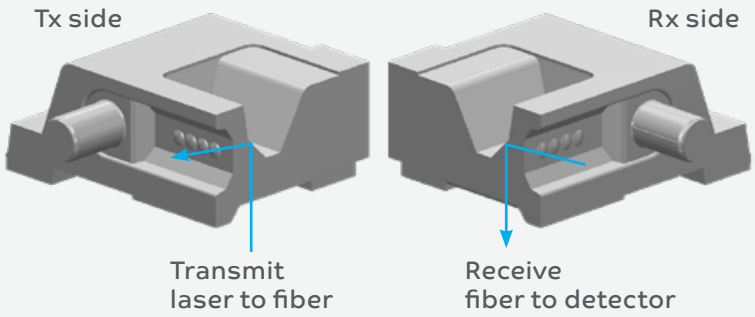


CASE STUDY EXTEM™ RESIN

IMPACT OF REFLOW SOLDERING & HYDRO AGING

Key characteristics of the EXTEM™ RH1016UCL resin based optical interconnect that SABIC tested for real life assembly and exposure to moisture:

- 4 Rx and 4 Tx lens array on bottom and front with 250 µm spacing
- Total internal reflection to front and bottom lenses
- Front MPO fiber connection
- Dimensions: 4.3 x 8.9 x 2.1 mm (W x L x H)

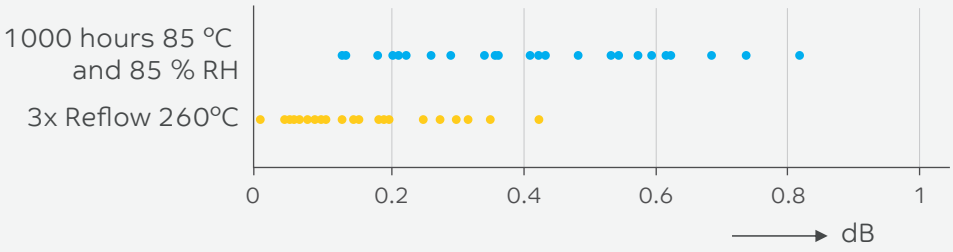


The connector was micro-molded and then exposed to several treatments:

1) Reflow Soldering according JEDEC 260°C (3 x)

2) Hydro aging according Telcordia

The connector was assembled to a PCB and aligned with laser and detector to measure signal loss of all 8 channels in dB before and after these exposures.



Key test results using 5 parts are shown in the graph above.

- After 3 times reflow, the optical interconnects show no blistering while maximum signal loss was only 0.4dB.
- Hydro aging for 1000 hours did not result in haziness or any other visual defect, and signal loss did not exceed 1 dB.

These results are well within OEM specifications that SABIC used as a reference.

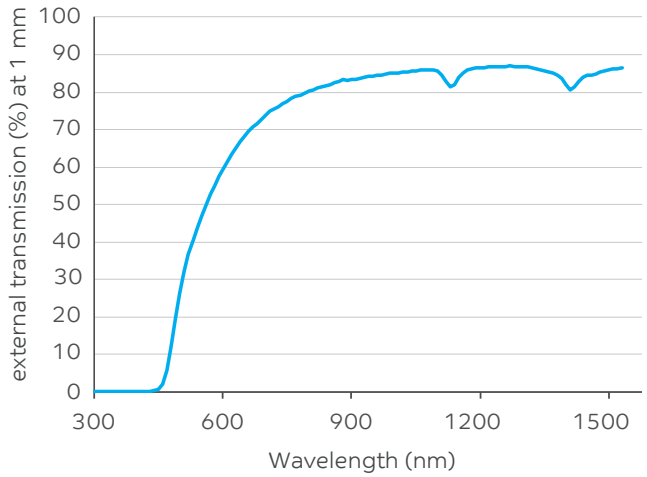
EXTEM™ RH RESIN SERIES WELL-SUITED FOR OPTICAL SENSING

Today, sensors are widely used in a growing number of applications. Some of these are proximity sensors, 3D sensing cameras and biometric monitoring devices. These application spaces keep growing at a high rate and upgraded functionalities require higher lens complexity.

EXTEM's RH series high near IR light transmission may be used in optical sensor applications in various wavelengths. Time of flight lenses for collimating both emitting and receiving light can be produced with EXTEM RH series resin. The use of anti-reflective coatings enables an even higher transmission if required for a specific application.

EXTEM RH resin offers key advantages versus glass such as design freedom, part integration and is easy scalable, with cost-efficient production by multi cavity micro molding. Often JEDEC reflow soldering at 260°C is required during the sensor assembly process and EXTEM RH series do offer this unique capability.

EXTERNAL TRANSMISSION OF EXTEM RH1016UCL RESIN



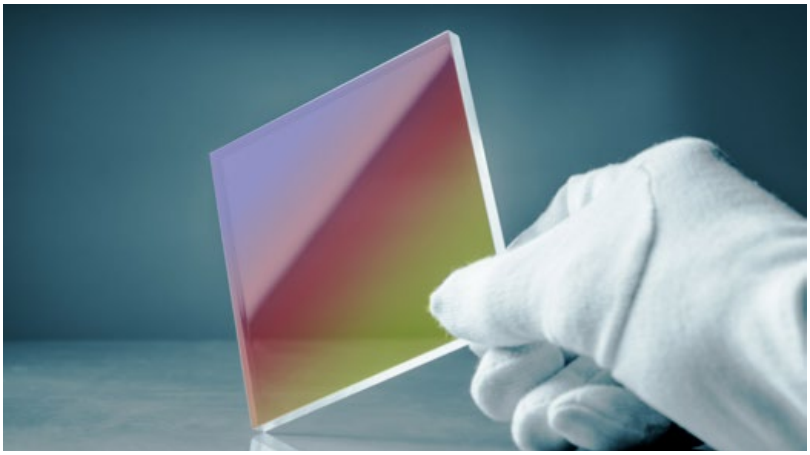
ANTI-REFLECTIVE COATINGS TO IMPROVE EXTEM™ RESIN OPTICAL TRANSMISSION

Anti-reflection coatings (ARC) reduce first surface reflection losses, improve contrast and boost the transmission through the optical surface. By applying these coatings on EXTEM™ resin, more light is transmitted through the lenses, enabling a higher sensitivity for optical sensors or lower signal losses for fiber optical connectors.

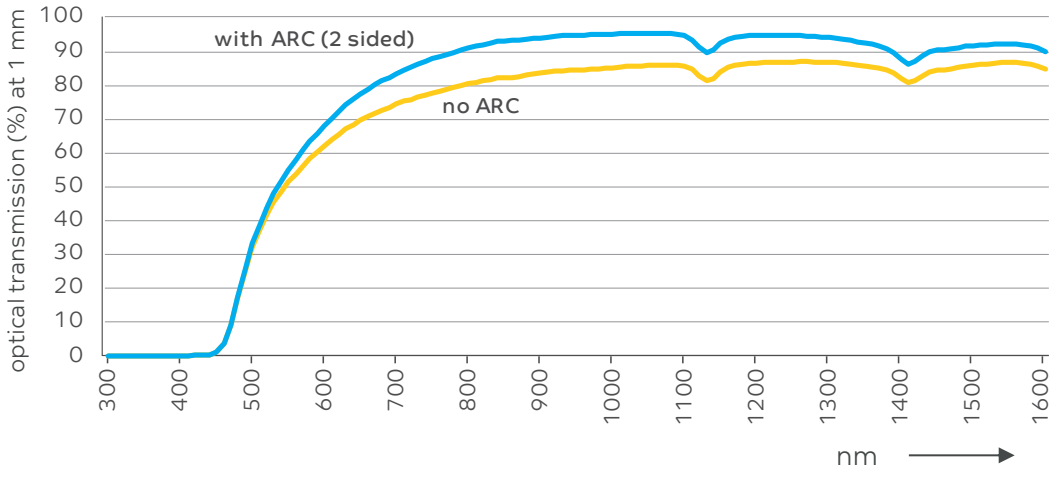
SABIC has worked with multiple manufacturers to test anti-reflective coatings for EXTEM resin. Plaques of 1 mm thickness successfully passed solder reflow conditions* and 2000 hours of hydro-aging**. The anti reflective layer did not show any cracking.

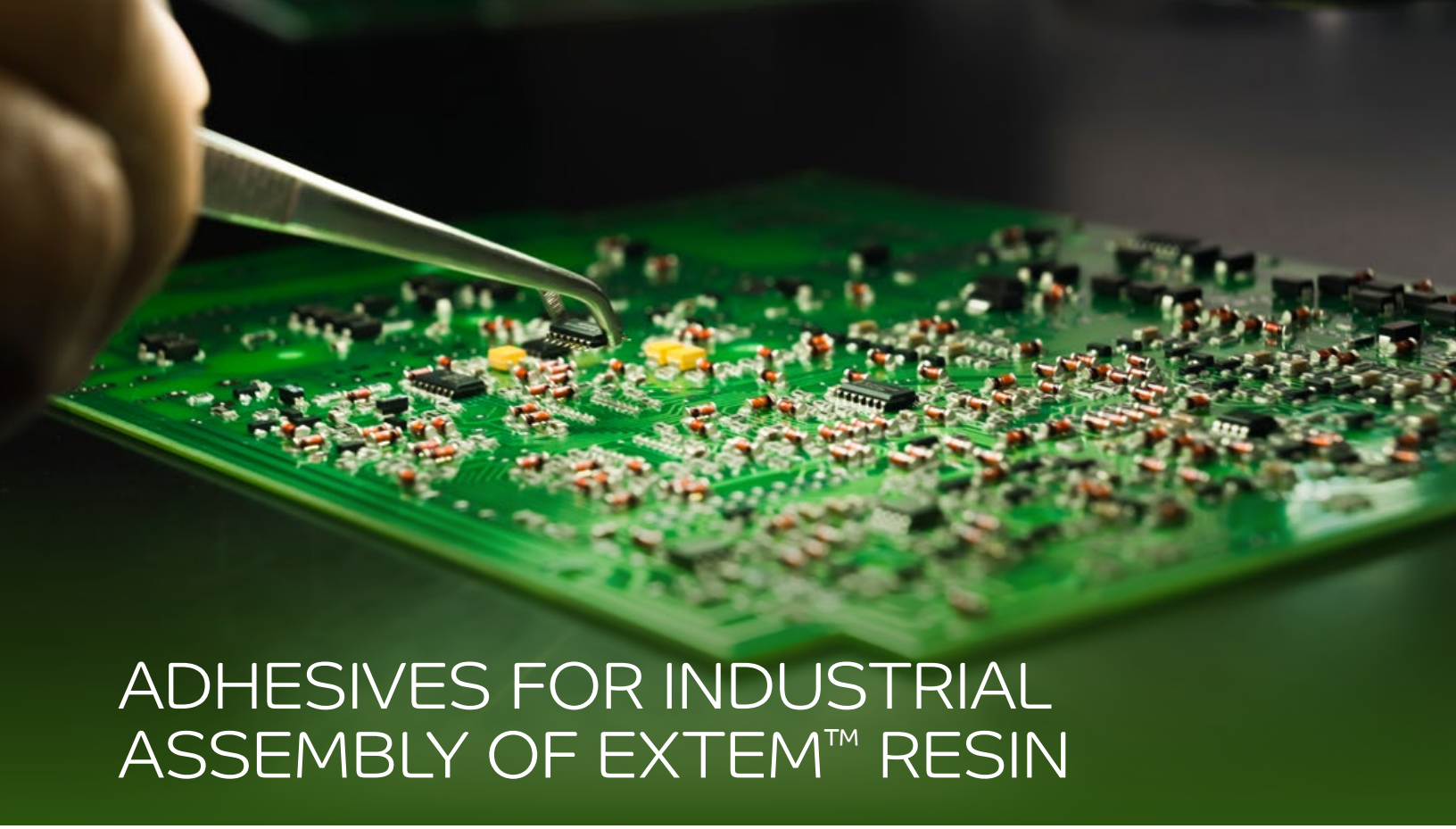
* according industry standard JEDEC J-STD-020A (3 x 260 °C)

** 85 °C and 85 % RH



EXTEM™ RH1016UCL RESIN OPTICAL TRANSMISSION IMPROVEMENT USING ANTI REFLECTIVE COATING (ARC)





ADHESIVES FOR INDUSTRIAL ASSEMBLY OF EXTEM™ RESIN

In the assembly of opto-electronic packages adhesives play a key role to bond lenses and substrates. Using mainstream assembly techniques for mass production of optical modules, SABIC tested a wide range of adhesives in collaboration with DELO. This includes transparent, low-outgassing and tension-equalizing adhesives to compensate for thermal expansion differences between EXTEM resin and substrates.

All the tested adhesives are light fixable and suitable for heat curing (130°C) and perform well with die shear higher than 20N.

The test specimen are EXTEM resin lenses (4*2*0.6mm) with an adhesive area of 8mm^2. Average bond line thickness is maintained at 10 to 100 µm and after curing the assemblies are exposed to solder reflow conditions* and 1000 hours of hydro-aging**.

ADHESIVES SUITABLE FOR EXTEM RH SERIES BASED OPTICAL COMPONENTS

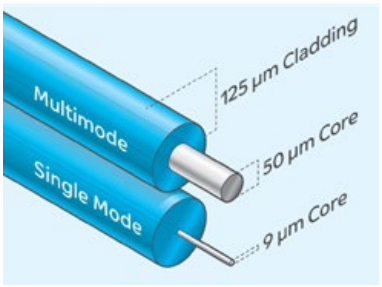
DELO INDUSTRIAL Adhesives	Substrate	Optics	Curing method
DELO DUALBOND® OB786	FR4	Translucent	Light/Heat
DELO DUALBOND® OB749	FR4	Translucent	Light/Heat
DELO DUALBOND® SJ2718	FR4	Opaque	Heat (Light fixable)
DELO DUALBOND® LT2208	Ceramics	Opaque	Heat (Light fixable)
DELO DUALBOND® AD761	Ceramics	Transparent	Light/Heat

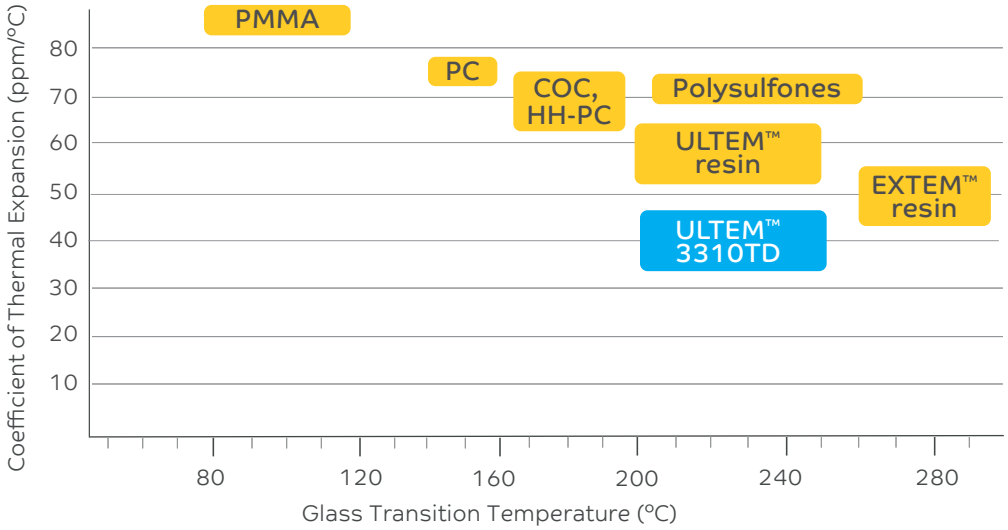
* according industry standard JEDEC J-STD-020A (3 x 260 °C)
** 85 °C and 85 % RH

ULTEM™ 3310TD RESIN FOR POTENTIAL USE IN SINGLE MODE OPTICS

To enable the transmission of large amounts of data, the industry is embracing single mode (SM) fibers as a solution. These optics have a smaller fiber core and dimensional tolerances for the lens are much tighter. The new ULTEM 3310TD resin addresses this through a reduced Coefficient of Thermal Expansion (CTE).

Optical Fibers





Property	Standard	Unit	ULTEM™ 1010UCL resin	ULTEM™ 3310TD resin
CTE(-40-150°C), flow	ASTM E831	10^{-5}/°C	5.5	3.9
CTE(-40-150°C), xflow	ASTM E831	10^{-5}/°C	5.5	4.0
Transmission at 1mm @ 1270nm	ASTM D1003	%	>88.5	>85.0
Light Scattering at 1mm @ 1270nm	ASTM D1003	%	<1	8.5
Refractive index 1270 nm	ISO 489	-	1.627	1.627
Abbe number	ISO 489	-	21	19
MFR (337°C/6.7kg)	ASTM D1238	g/10min	17.8	6.8
dn/dT(+23°C-140°C) @1270nm	ISO 489	10^{-5}/°C	-10.3	-7.6

SABIC CAN HELP SUPPORT FROM PART DESIGN TO PRODUCTION

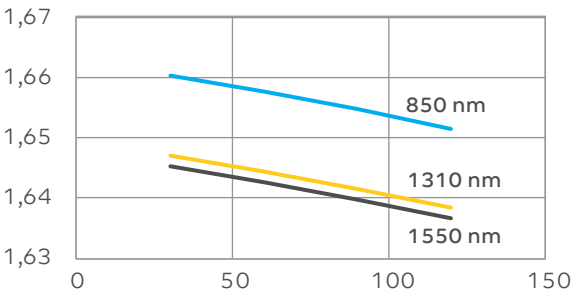
SABIC does not only offer resins but also provides design support and conducts performance testing following industry specific standards.

Optical constants for modeling and pre-design

Our optical resins are listed in the Zemax® Optic Studio database.

- Thermo-optic coefficients
- Internal optical transmission data

REFRACTIVE INDEX BY °C,
EXTEM™ RH1016UCL RESIN

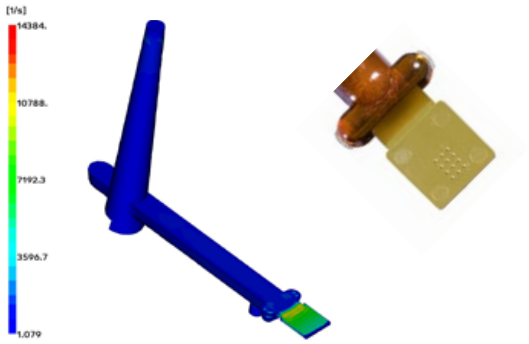


Mold design for manufacturability

Validate optical replication and dimensional positioning

- Part Capability and Fill Design
- Flow and Stress Optimization to reduce Birefringence
- Part Production and Lens Analysis

EXAMPLE OF A SHEAR RATE ANALYSIS
ON A 4X3 LENS TEST ARRAY (0.3 MM THICKNESS)



Micro Molding for Research

Selected to match customer capabilities:

- Arburg 370A
- Sumitomo SE30EV

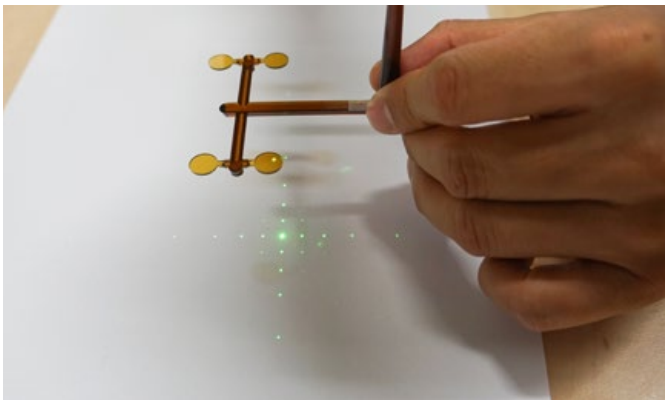
Shot weight capabilities:

- 0.05 g to 9.5 g

Complex light manipulation capabilities

Some examples

- Injection molding replication techniques for diffractive optics
- Metallization to integrate reflective and transmissive optics



MATERIAL PROPERTIES

MATERIAL PROPERTIES OF ULTEM™ AND EXTEM™ RESIN GRADES

Property*	Standard	Unit	ULTEM™ DT1810EVUCL resin	ULTEM™ 1010UCL resin	EXTEM™ XH1015UCL resin	EXTEM™ RH1016UCL resin
Flexural Modulus	ISO 178	MPa	3100	3300	2870	2950
Flexural Strength	ISO 178	MPa	120	160	120	130
HDT, 0.45 MPa	ISO 75	°C	190	207	250	262
Vicat B120	ISO 306	°C	195	212	260	273
Density	ISO 1183	g/cm^3	1.28	1.27	1.31	1.35
CTE (-40 to150°C)	ISO 11359	10^{-5}/°C	6	5.5	5	5
Transmission at 1mm @ 850nm	ASTM D1003	%	89	88	82	82
Transmission at 1mm @ 1310nm	ASTM D1003	%	89	89	87	87
Refractive index 589 nm (nD)	ISO 489	-	1.655	1.662	1.657	1.691
Refractive index 850 nm	ISO 489	-	1.633	1.639	1.634	1.663
Refractive index 1310 nm	ISO 489	-	1.620	1.626	1.622	1.651
Abbe number	ISO 489	-	21	21	18	18
dn/dT (+23°C-140°C) @ 1270nm	ISO 489	10^{-5}/°C	-11	-10	-10	-10

* The data shown are typical properties

ZEMAX OPTICSTUDIO® PARAMETERS FOR EXTEM RH1016UCL RESIN

Sellmeier Dispersion Equation for Refractive Index

$$n^2 - 1 = \frac{B_1\lambda^2}{\lambda^2 - C_1} + \frac{B_2\lambda^2}{\lambda^2 - C_2} + \frac{B_3\lambda^2}{\lambda^2 - C_3}$$

Constants of Sellmeier Dispersion# Formula	
B1	0.56262
B2	0.56145
B3	0.56329
C1	0.03324
C2	0.03264
C3	0.03307

Temperature Dependence of Refractive Index

$$\Delta n_{abs} = \frac{n^2 - 1}{2n}\left[D_0\Delta T + D_1\Delta T^2 + D_2\Delta T^3 + \frac{E_0\Delta T + E_1\Delta T^2}{\lambda^2 - \lambda_{tk}^2}\right]$$

Constants of of Dispersion dn/dT	
Do	-1.78×10^{-4}
D1	5.42×10^{-8}
D2	2.89×10^{-10}
Eo	1.13×10^{-5}
E1	-1.98×10^{-7}
λ_{tk}	0.00

These constants are valid for a temperature range from 30 °C to 120 °C and from 0.5 to 1.7 µm.
Dispersion formula returns a valid refractive index between 0.4 and 1.7 µm.

SABIC IS A MEMBER OF

ADVANCED PHOTONICS COALITION

EPIC European Photonics Industry Consortium

iNEMI

OPTICA Formerly OSA

SABIC ISCC+ CERTIFIED RENEWABLE ULTEM RESIN SOLUTIONS

A new portfolio of bio-based ULTEM™ resins that delivers a lower carbon footprint while offering the same high performance and processability as incumbent ULTEM materials is now available.

ISCC International Sustainability & Carbon Certification

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