High optical quality polycarbonates

For automotive interior, exterior and lighting.

Makrolon® Apec®

covestro

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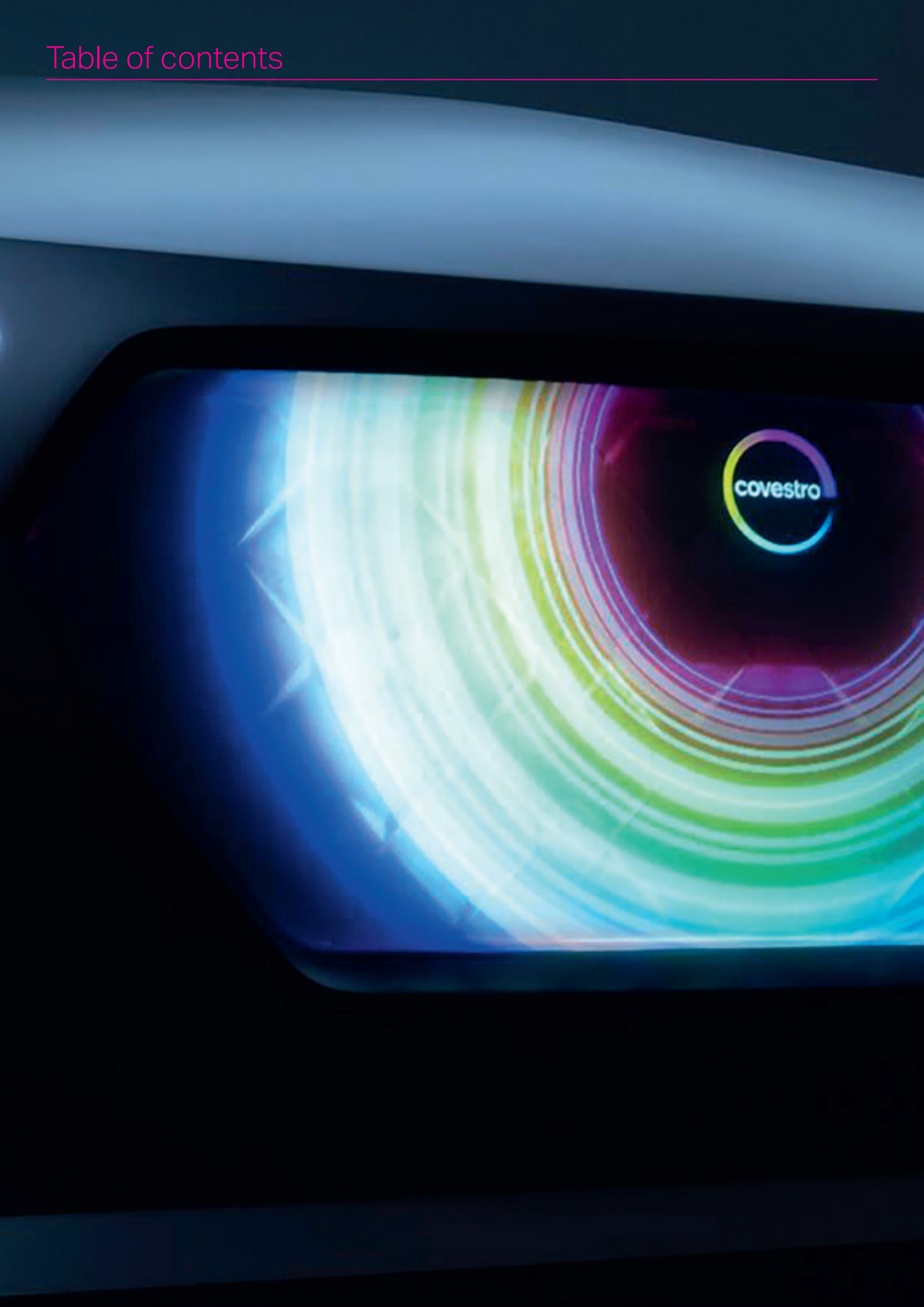

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Optical material portfolio:

Automotive interior, exterior and lighting.

Introduction

More optical application opportunities in sight.

Both the car and how we perceive it are undergoing a rapid transformation. More than just a means of transportation, vehicles have become multifunctional living and working spaces that turn interiors into connected information hubs and entertainment areas.

This technological mix of connectivity, communication, and enhanced driving performance means passengers must also adapt while on the road. Moreover, it requires new developments in ensuring and enhancing comfort, convenience, and safety.

The more cars offer their drivers and passengers, the greater the role lighting plays, both inside and out. From LED technology to headlamps, lighting has developed beyond its merely functional role to become an integral part of automotive design, ambient comfort, and brand differentiation.

New mobility has reshaped the interior lighting landscape to welcome, inform and entertain. From seamless interactive surfaces to large displays and integrated sensors, OEMs now have a wide array of possibilities to offer more ride-enhancing features, while further accentuating their car models.

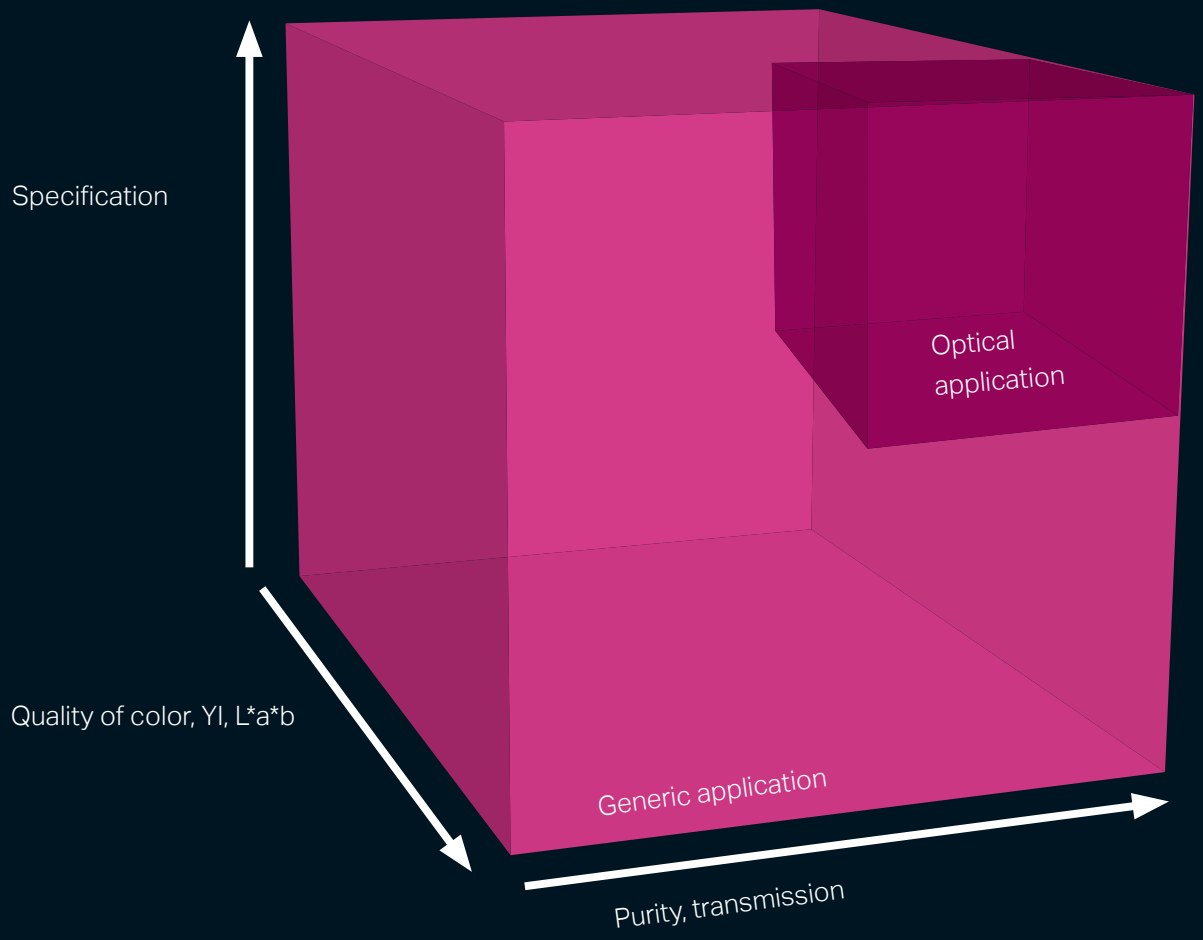
Similarly, exteriors have seen changes that will further advance the customer experience. Lighting with exterior "welcome modes" is just one example of how cars now greet and care for their owners. Headlamps too have made impressive technological strides.

Aside from their safety factor, headlamps have become a major design element whose signature form and function are as defining as the car's silhouette or grille. Like interior lighting, headlamps will also continue to seamlessly merge into the whole of their surroundings, forming integrated, flowing lines that further define a car's individual profile and stance. Together, let`s shape the future of mobility.

Optical quality with an eye on future applications.

Every application consists of multiple properties, all of which must meet the standards set for its field. Moreover, a component must adhere to requirements regarding visual appearance, mechanics, aging behavior, service life, and other performance aspects. When it comes to visible factors such as decorative bezzles and panels, an emphasis is placed on color properties, stable and weatherproof colors, and optimal surface quality.

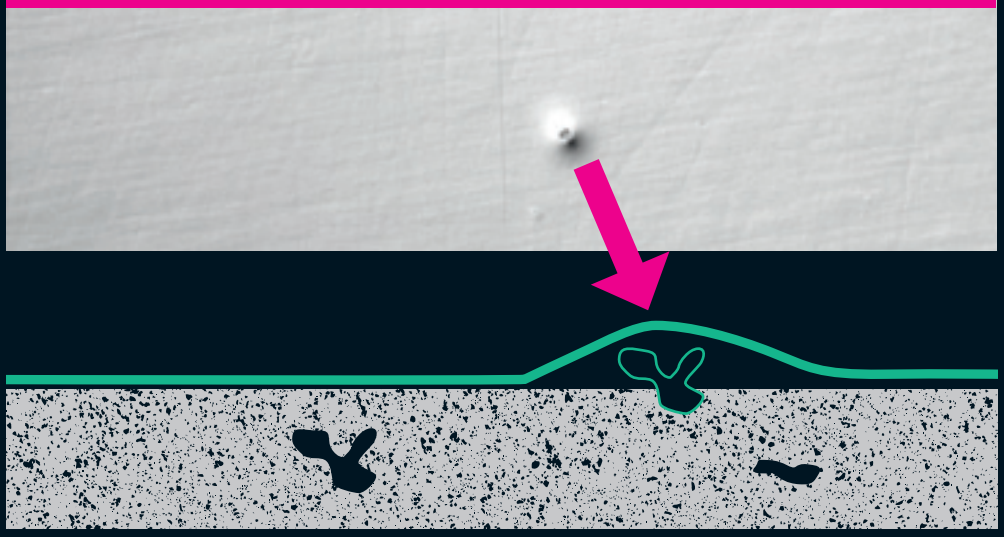
Illuminated decorative components must offer a high light transmission (Ty) with a very low yellowness index (YI). These components often play a "behind the scenes" role but still require unhindered conductivity and light diffusion. Regardless of function, all components are subject to a full spectrum of quality tests. These range from resistance to LED light, aging, sunlight, and heat, to meeting regulatory standards and safety requirements.



Many individual steps in producing optical parts can lead to surface defects or impurities within the part. We take great efforts to ensure a very high degree of purity in all of its optical **Makrolon®** grades. In addition, our technical labs are constantly developing expertise and exploring ways to avoid surface defects and black specks in the molding and coating of optical parts. We are happy to share this knowledge with customers of our optical **Makrolon®** grades.

As illustrated in the comparison below, there is always a possibility of impurity or pigments accumulating. In combination with a coating, this can lead to a lens effect, with a resulting higher scrap rate. (Defects in the picture below are magnified by a factor of 10.) In common applications, these accumulations are usually not a problem.

Possible defects in standard polycarbonate

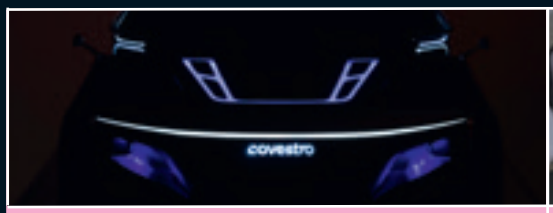


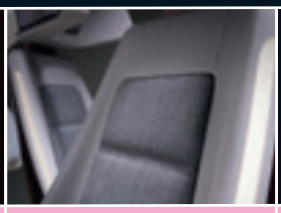
However, optical applications such as sensors, homogenous light distribution, and surface lighting with high transmittance and purity, all require the highest level of material quality. High-purity materials for optical parts with homogenous coloring can enable you to lower your scrap rate (see picture below).

Makrolon® with high optical purity

Application areas

Our optical mobility portfolio couples the highest available optical quality parameters with the added reassurance of tested and proven colorants and optimization for application-related specifications.





	Exterior		Interior	Headlamp	
	Makrolon® AX	**Makrolon®** AG	**Makrolon®** Ai	**Makrolon®** AL	**Makrolon®** LED
Description	High surface quality for decorative and functional **opaque exterior parts**	High-purity resin suitable for wet coating systems for decorative and functional **transparent/ translucent exterior parts**	High optical purity resin with excellent surface quality for decorative and functional **interior parts**	Industry standard for **headlamp outer lens covers**	Highest transmission quality for **inner light guiding parts of headlamps**, exterior and interior parts
Specifications	Exterior specification with specific coating systems	Exterior specification with specific coating systems (AMECA/ECE listing, if required)	Interior specifications	AMECA/ECE listing with specific coating systems	AMECA/ECE listing without coating, for protected/covered applications only
Color and transparency	Available in opaque colors, with functions like sensor transparency on request	Transparent or translucent light stable colors, with special functions on request	Available in aesthetic opaque, transparent, translucent and functional colors	Available in select transparent colors for high volumes	Available in natural, transparent, translucent and functional colors
Individualization	Limited color development	Color development on request	Customized color development	No color development	Limited color development

Nomenclature:

The following system of nomenclature is used for most **Makrolon®** and **Apec®** grades: The designation of **Makrolon®** and **Apec®** sales products are based on a 4-digit, self-explanatory nomenclature.

Makrolon® LED	22	4	5
The first two digits denote the viscosity: 22 low viscosity 24 low viscosity 26 medium viscosity 28 medium viscosity 31 high viscosity			
Digit 3 differentiates between standard grades and special grades: 0 standard grade 1 or 4 special grade, often specified by a prefix, such as OD, LED, AL or LQ			
The fourth digit denotes the additive package: 5 easy release 7 easy release, UV-stabilized			

Apec®	20	9	7
The first two digits denote the heat resistance: 16 Vicat approx. 160° C 17 Vicat approx. 170° C 18 Vicat approx. 185° C 20 Vicat approx. 203° C			
Digits 3 and 4 describe the grade: 95 easy flowing, easy release 97 easy flowing, UV-stabilized, easy release 03 grade with elevated viscosity, UV-stabilized			
The fourth digit denotes the additive package 5 easy release 7 easy release, UV-stabilized			

Color designation

The material designation is used for most **Makrolon®** and **Apec®** grades followed by a 6-digit color code. The first two digits indicate the main color, the other four digits distinguish between different shades. The designation 000000 refers to a natural shade with no added color.

	Opaque colors	Transparent colors	Translucent colors	Transparent IR controlled
Natural	-	000000	-	-
Crystal clear	-	55...	-	-
White	01...	-	02...	-
Yellow	10...	15...	12...	17...
Orange	20...	25...	22...	27...
Red	30...	35...	32...	37...
Violet	40...	45...	42...	47...
Blue	50...	55...	52...	57...
Green	60...	65...	62...	67...
Gray	70...	75...	72...	77...
Brown	80...	85...	82...	87...
Black	90... / 999900	95...	92...	97...

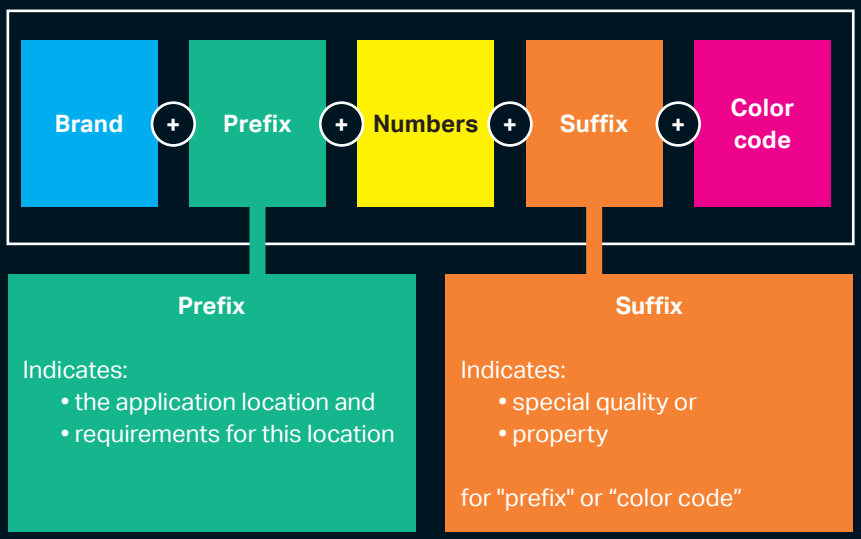
Color designations of **Makrolon®** and **Apec®** grades.

Nomenclature optical mobility portfolio for **Makrolon®**:

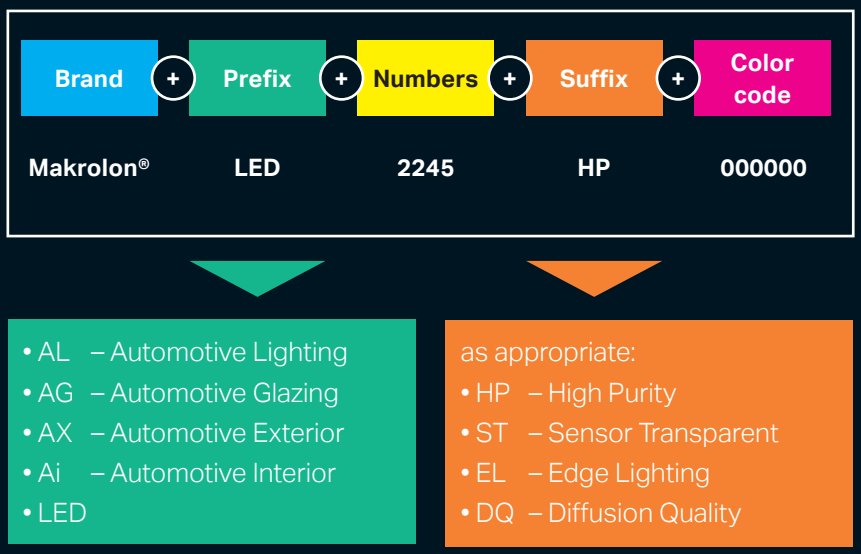
This nomenclature is based on the familiar **Makrolon®** one and subdivides the **Makrolon®** optical portfolio into three different application areas on the basis of application-related features.

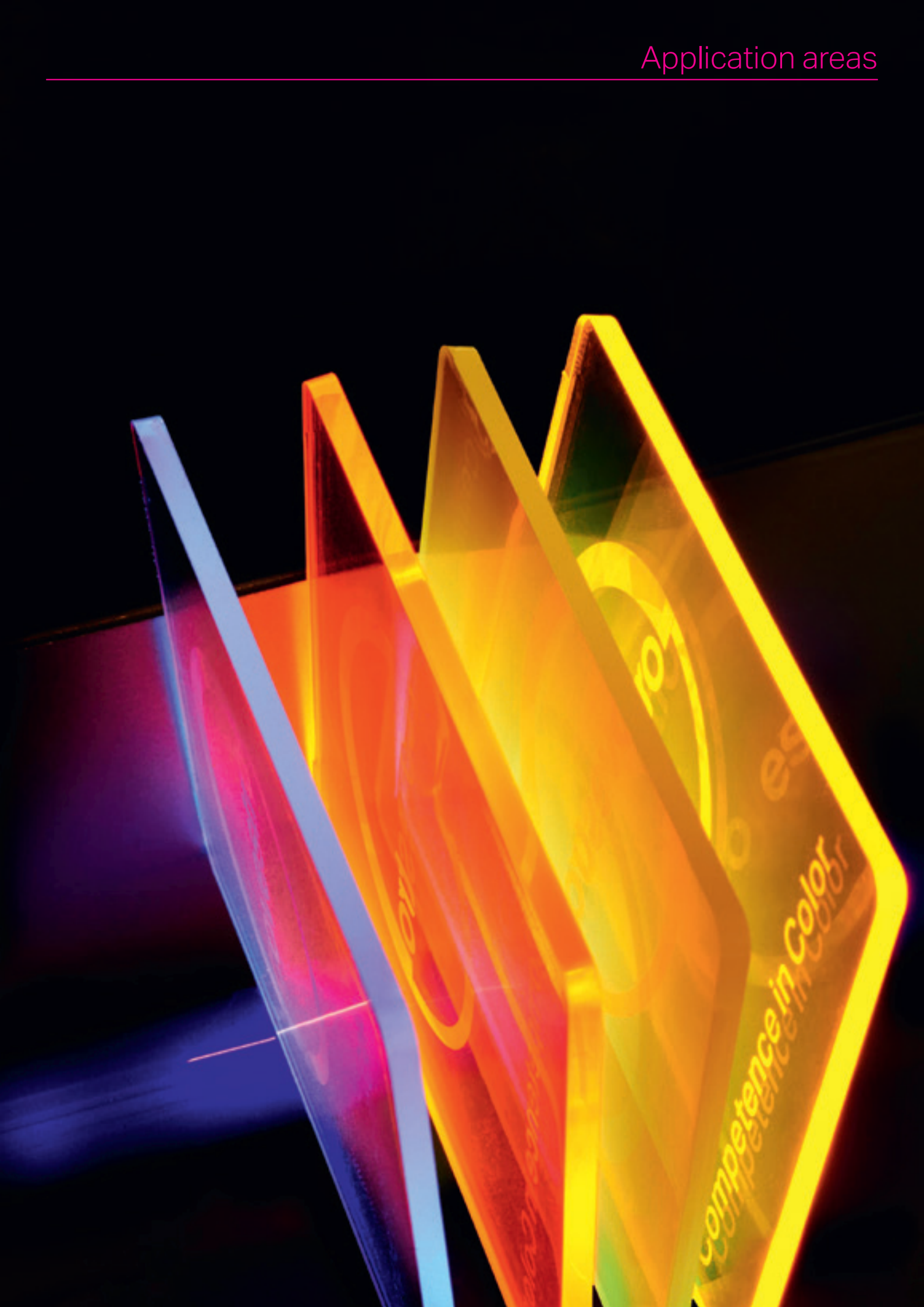
For example, different requirements may consist of:

- **Material properties (exceptional color stability),**
- **Regulatory issues,**
- **Specific testing or treatments**

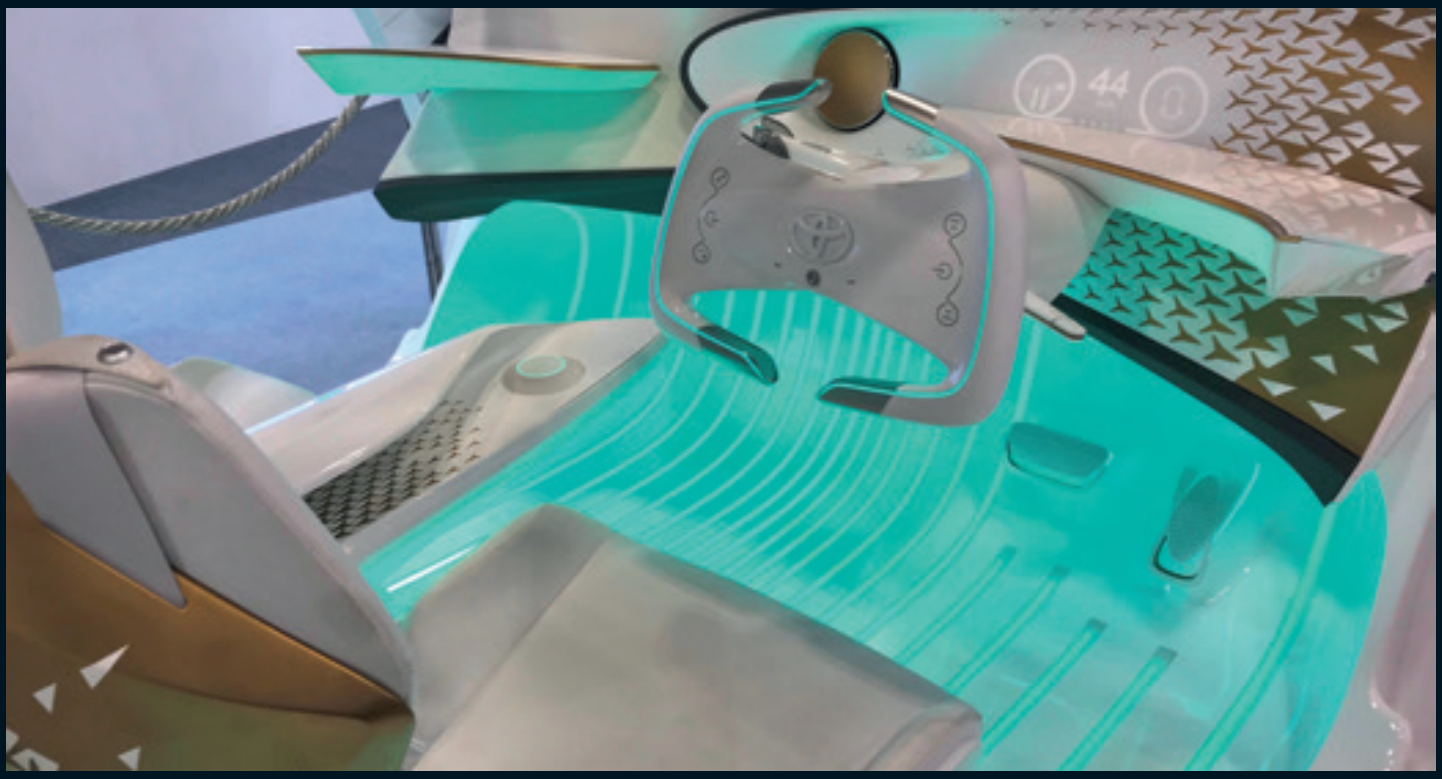


The assignment of a material to the respective area of application is made via the prefix, while the suffix represents a specific feature such as quality or color. This diagram outlines the various prefixes and suffixes with their respective explanations.




competence in color

Interior

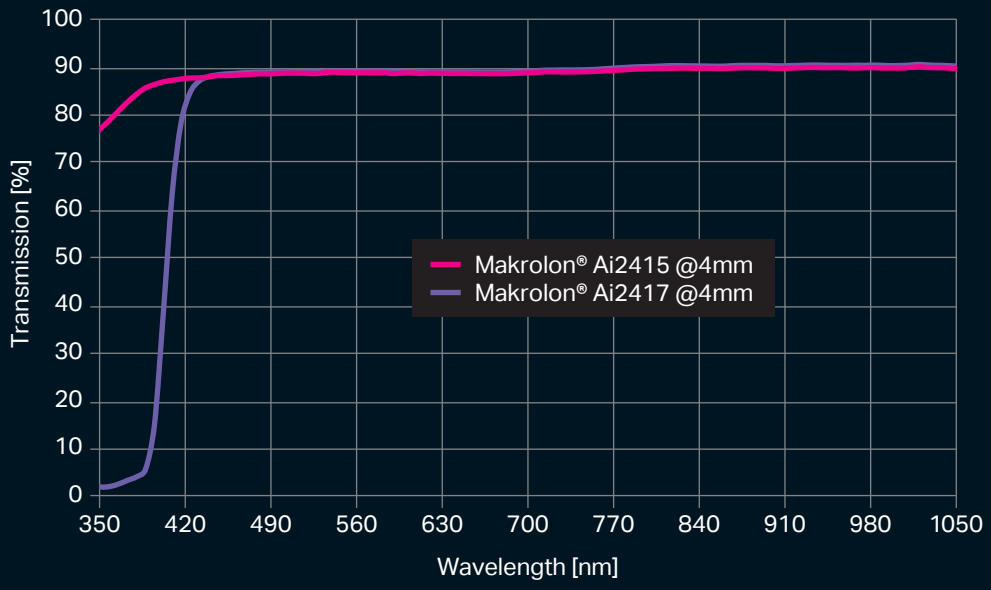


Makrolon® Ai stands for **Makrolon®** automotive interior.

We have created this product portfolio to ensure that the automotive industry can achieve excellent optical performance in future applications using our optical grades.
The transparent and translucent materials in the "Ai" portfolio are produced under extremely pure and clean conditions, using selected additives and melt filtration equipment. They are available in a wide variety of colors and light performance specifications.
We make every effort to deliver high-quality materials that can help reduce your scrap rate. High purity for transparent material, low agglomerates for opaque high gloss material, and low impurity for translucent colors are what we aim to deliver with the new **Makrolon®** Ai portfolio.

High optical transparency interior applications:

Our crystal clear grades have extraordinarily high transmission. Here you can compare the spectra of **Makrolon®** Ai2417 with Ai2415 (without UV absorber).



The **Makrolon®** Ai crystal clear appears neutral and absolutely clear.

Makrolon® Ai2417 **versus Ai2415 550207**
The **Makrolon®** Ai2415 can be used when optical adhesives become UV-cured through the front cover.

Large display covers in 3 dimensions manufactured in a visually brilliant quality with **Makrolon®** Ai2417.

A perfect application would be a 3-dimensionally shaped display cover, directly molded onto an OLED screen (2.5D). The haptically-formed 3D surface allows direct contact with infotainment slider controls.

We are colorful.

Why not apply more color in your transparent applications?

Differing colors for signals are normal, but for interior applications, colors can bring an entirely new dimension to the in-car experience.

Using transparent and/or diffuse colors allows signage for more safety, the display of useful information, or finely-tuned ambient lighting for a perfect sense of well-being.

Black panel lighting – hidden until it's lit.

In daylight you won't see anything. But when backlit, all of the concealed content comes to life!

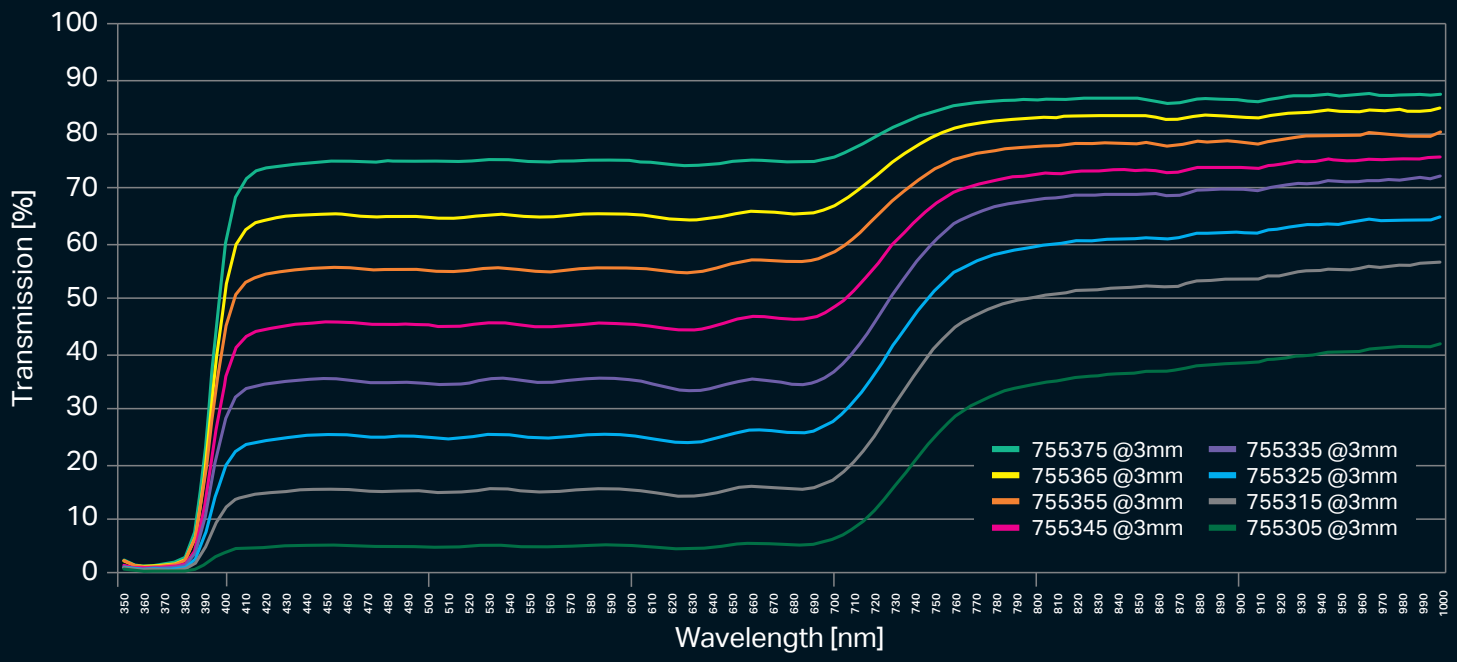
Final color	Transmission (Ty) according to ISO13468-2 [%]			
	1 mm	2 mm	3 mm	4 mm
755305	32	12	5	2
755315	48	27	15	8
755325	57	38	25	16
755335	65	47	35	25
755345	71	56	45	36
755355	76	64	55	47
755365	80	72	65	58
755375	84	79	75	70

Selected colors black transparent, based on **Makrolon®** Ai2417 (Ai2217).

Tailor-made black panel colors are available on request. Please contact our sales representatives.

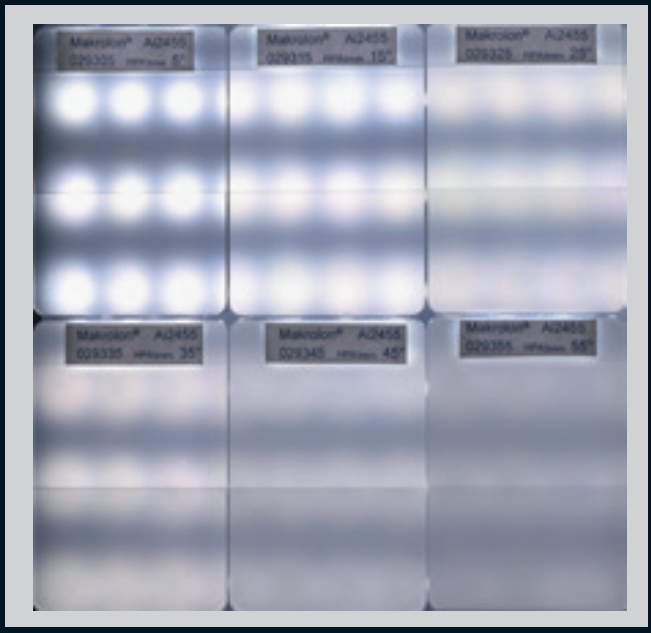
Black panel and high-gloss piano black:

This deep black effect appears when light is absorbed by tinted **Makrolon®** Ai2417. The difference between this and the black panel effect may be only minimal. It can be tailored at customer request, and also tuned for wall thickness.



Translucent colors for functional and ambient lighting.

Translucent colors are widely used for ambient lighting to support and enhance the well-being of passengers. An increasing number of translucent color settings offer varying degrees of transmission and light diffusion.
A special application is backlit switches, which carry white lighting for applications like infotainment boards, and require red for functions such as alarm buttons. These can be coated, and the symbols in red created by laser-etching.
Covestro's portofolio of colors is enriched and completed with a new range of 6 translucent colors. They offer light scattering with a linear increment while maintaining maximum light transmittance at the relative HPA grade.These colors are now available in both Makrolon Ai 2455 and Ai 2457 (with UV protection).



Makrolon® Ai will supply diffusion to your specification.

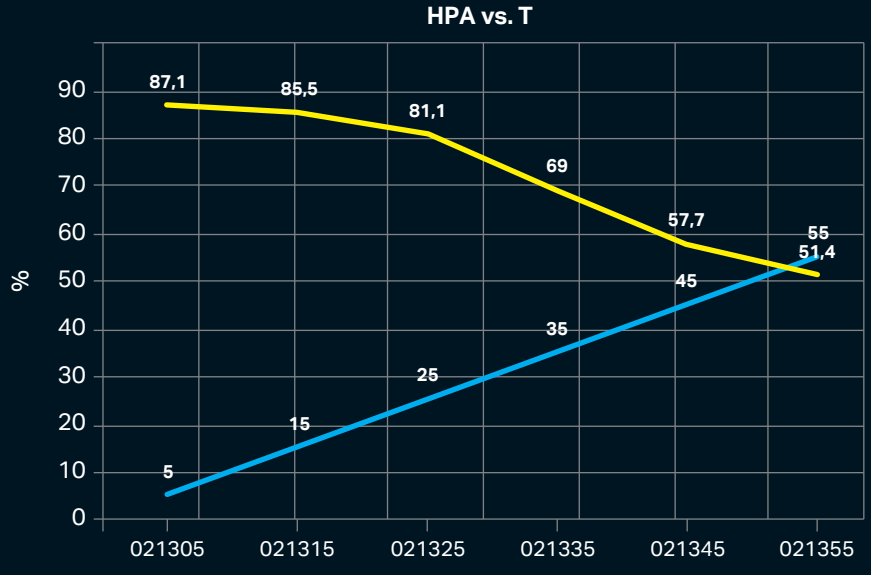
Translucent grades:

For light design (ambient, dynamic, and signal lighting):
Makrolon® Ai2257,
Makrolon® Ai2457,
Makrolon® Ai2657
translucent colors, applied on **Makrolon®** Ai2457

The color 921061 appears dark black, but in reality it is translucent. There is no color-shift when backlit.

Color code available in Makrolon® Ai	Thickness mm	Half power angle HPA (average)	Transm. Ty (%)
029305		5° (3 mm)	87.1
029315		15° (3 mm)	85.5
029325		25° (3 mm)	81.1
029335		35° (3 mm)	69
029345		45° (3 mm)	57.7
029355		55° (3 mm)	51.4

Overview of translucent colors for **Makrolon®** Ai



Thermoplastics for displays of the future.

We collaborated with Continental Automotive, a company that develops pioneering technologies for the automotive industry.

Task: Develop large curved display concept

Our goal was to create an innovative display with Continental Automotive that meets the needs of future autonomous and electric vehicles. We wanted to demonstrate how we bring new applications to market by solving previously unmet material needs and supporting our partners with our technical expertise in polycarbonate resin and films.

"We were excited to develop the first large curved display cover with Continental. With a strong partner like Continental, coupled with our technical support and material development technology, we were able to explore the possibilities of new technology and develop tailor-made materials for the future interconnected auto. The result: the first large display made entirely of polycarbonate."

Ciro Piermatteo / Global Technical Marketing Mobility Interior, Covestro

Solution: Rely on proven materials and processing knowledge

Working together with Continental Automotive, we developed the OLED display with **Makrolon®** Ai 2417 polycarbonate, which offers high optical purity, and **Makrofol®** HF polycarbonate film. Film insert molding technology was used to create the display's decorative effect.

"The combination of different processing technologies like FIM and compression molding for large optical parts is a leap into the next generation of decorated plastic parts. We were thrilled to take an active role in this huge project and to contribute innovative solutions for diverse processing challenges."

Roland Künzel / Head of Technical Center Films (TCF), Covestro

Challenge: Find the right material with high optical quality

The selected materials and supporting technologies such as film insert molding needed to meet a variety of development requirements. This included a material with high optical purity and excellent mechanical capabilities along with a tailor-made color shade with extreme tight color specifications designed for the OLED display.

The surface utilizes in-mold decoration technology for scratch and chemical resistance, combined with injection compression molding to achieve the ideal optical properties.

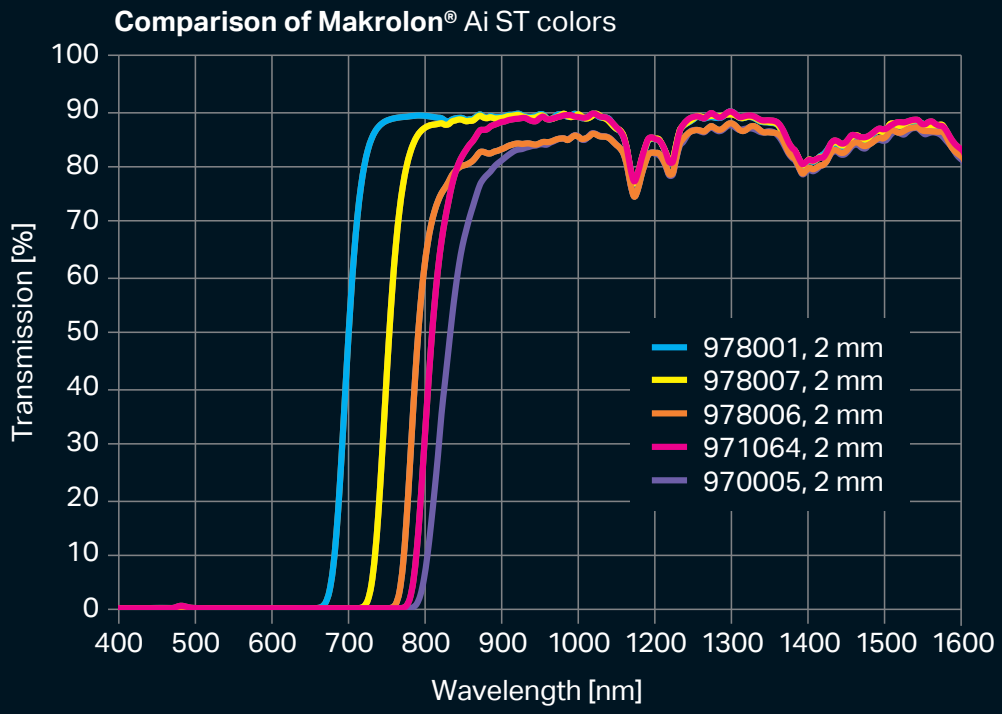
"Our display solution shows the next evolutionary step for large-sized automotive user interfaces. Smaller curvature radii in combination with topographic surface elements significantly improve the user experience of multi-display systems in the vehicle and offer a new level of design flexibility."

Martin Lenz / Technical Project Manager Curved Plastic Lens, Continental

Interior sensor transparent applications:

Makrolon® Ai – ST for interior sensors.

Infrared sensors are also required in car interiors. Cameras and sensors can be used to monitor and prevent the driver from falling asleep. IR-open **Makrolon®** can be used for camera covers and for 'simple' lenses that focus the light on the driver.
The driver should not even notice that he or she is being monitored with red LEDs. In addition to a very high surface quality, **Makrolon®** IR-open color formulations also show an amazing depth effect. For this reason, some NIR transparent colors are recommended for aesthetic reasons, or for signal transmission, in applications such as light barriers, remote controls, and laser absorption welding. More NIR colors are available on request.



Product Recommendations

Driver Monitor System cover:
Makrolon® Ai2675 ST, 978007
Makrolon® Ai2497 ST, 978006
Makrolon® Ai2497 ST, 971064
Makrolon® Ai2497 ST, 970005

Comparison of Makrolon® Ai ST colors
ST stands for sensor technology
Depending on the application's need, we can choose from different color matches – although all simply appear black.
These can open transmission at different wavelengths, for example to avoid 'red glimming'. All colors in this range are transmission-controlled.*

Makrolon® Ai... has a nomenclature determined by its appearance.

Appearance ↓	**← Viscosity →**		
Clear	**Makrolon® Ai 2215** **Makrolon® Ai 2217** **Makrolon® Ai 2215 EL** **Makrolon® Ai 2215 ST**	**Makrolon® Ai 2415** **Makrolon® Ai 2417** **Makrolon® Ai2417 ST**	**Makrolon® Ai 2617**
Translucent	**Makrolon® Ai 2257**	**Makrolon® Ai 2455** **Makrolon® Ai 2457**	**Makrolon® Ai 2657**
Opaque	**Makrolon® Ai 2295** **Makrolon® Ai 2297**	**Makrolon® Ai 2495** **Makrolon® Ai 2497** **Makrolon® Ai 2497 ST**	**Makrolon® Ai 2695 ST** **Makrolon® Ai 2697 ST**

*5 without / 7 with UV absorber, EL = edge lighting, ST = sensor technology

Makrofol® and **Makrolon®** Ai enable smart surfaces in cars.

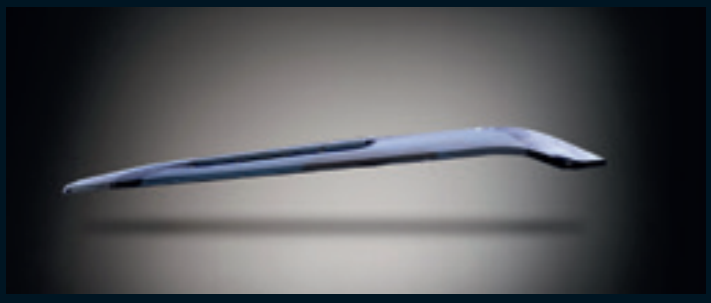
Injection molded structural electronics (**IMSE™**) technology brings electronics into thin, durable 3D plastic surfaces. Using **Makrofol®** film and **Makrolon®** Ai resin, we helped our partner **TactoTek®** to create a fully functioning demonstrator overhead control panel that is strong, lightweight and sleek.

Task: Create a slim, light and smart overhead control panel

The way passengers interact with their vehicles is changing rapidly. Almost any visible surface in an automobile, from door trim to cover panels, can now integrate buttons, controls, switches and lighting. Our partner **TactoTek®** is a Finland-based specialist in Injection Molded Structural Electronics (**IMSE™**). For CES® 2019, they wanted to create a lightweight, durable overhead panel that integrated printed circuitry and controls, to prove how this technology increases design freedom.

Challenge: Combine different functionalities with low height and a cutting-edge design.

Our challenge was to demonstrate how double-sided Film Insert Molding (FIM) technology can be used to create an elegant, low-profile and lightweight structure that integrates touch controls and lighting at a minimum depth of the molded part. Printed electronics and components had to be combined with a slim, elegant 3D shaped surface that is both durable and appealing, while saving both weight and space.



IMSE™ and FIM Technology with polycarbonate material create ultra-slim parts

"The combination of different processing technologies like FIM and compression molding for large optical parts is a leap into the next generation of decorated plastic parts. We were thrilled to take an active role in this huge project and to contribute innovative solutions for diverse processing challenges."

Marko Suo-Anttila / SVP Engineering, TactoTek Oy

Solution: A robust, smart surface produced with Makrofol® film and Makrolon® Ai resin

For the **TactoTek®** demonstrator, we supplied a two-in-one FIM solution, with products qualified for use in **IMSE™** applications. For the touch surface on the front, we used a hard-coated UV curable **Makrofol®** HF312 film, ensuring scratch and chemical resistance. On the back side, an uncoated **Makrofol®** DE1-1 was printed with conductive inks. The electronic components were integrated on the printed **Makrofol®** DE1-1 film. The two films were formed and trimmed before **Makrolon®** Ai 2217 polycarbonate was injected between the two film inserts. **Makrolon®**Ai resins offer a high optical purity and enable tailor-made coloration.

Electronics enabled in 3D shaped plastic surfaces

- **Design freedom: Makrolon®** Ai resin allows complex 3D shaped smart surfaces with high mechanical stability.
- **Functional: Makrofol® film and Makrolon®** Ai resin allow the integration of electronics into plastic parts.
- **Ultra-slim:** Formable hard-coated films and resins minimize weight and enable space-saving designs.
- **Lightweight:** Film and resin materials are combined in a single lightweight structural part.
- **Robust: Makrofol®** film ensures a surface that is scratch and chemical resistant.
- **Printable: Makrofol®** HF312 hard coated film can be printed on, thus allowing for customized designs.

Automotive exterior

Automotive exterior:

For automotive exteriors, we offer customized polycarbonate grades for transparent, translucent and opaque coated applications:

Makrolon® AG and AX have a high degree of purity and are optimized for best compatibility with coatings thanks to special raw materials and additives. They are manufactured on selected production lines equipped with special melt filtration systems. Light fast colorants in combination with established coating systems ensure the necessary long-term color stability (see graphic page 25). For customers using **Makrolon®** AG and AX, we offer intensive support in terms of part design, CAE and mold design as optimization of the injection molding and coating process.

Makrolon® AG: Visually transparent optical polycarbonate in light or dark colors for automotive exteriors.

Makrolon® AG (Automotive Glass like):

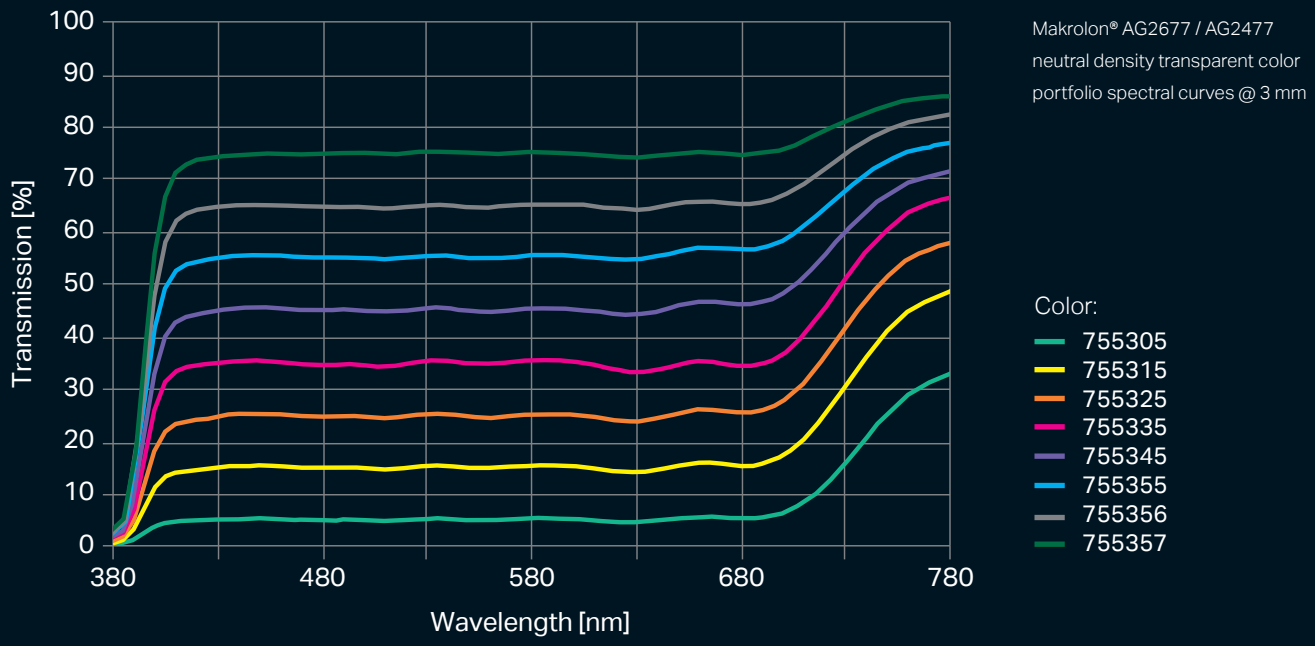
Makrolon® AG is ideally suited for existing and new transparent coated applications in automotive exteriors. It has been used successfully for years in windows and transparent roofs and now enters glass-like components such as vehicle front panels. These new applications enable exciting fresh and seamless designs in large body panels: Thanks to its optical properties, achievable surface qualities and dimensional stability, **Makrolon®** AG allows the integration of attractive color- and light accents on the exterior. As for such applications color neutrality is important, Covestro has developed a neutral density color portfolio for **Makrolon®** AG. Many exterior components must also meet high requirements in terms of pedestrian protection and crash safety – among highly transparent materials, only polycarbonate offers the necessary impact strength. Polycarbonate is also ideally suited for the invisible integration of sensors in self driving vehicles: As **Makrolon®** AG ST (**S**ensor **T**ransparency), it offers excellent transmittance for LiDAR, RADAR or cameras.

Grade	MVR (300 °C, 1.2 kg) cm³/10 min	Key properties
Makrolon® AG2677 **Makrolon®** AG2477 Neutral density grey colors 7553x5 Transparent colors x5xxxx	12 18	• Well-known Makrolon® AG quality • Optimized for transparent automotive exterior applications • Neutral density grey color portfolio • Wide range of other transparent colors
Makrolon® AG2677 **Makrolon®** AG2477 IR-absorbing colors x7xxxx	12 18	• IR-absorbing properties that reduce heat energy transfer from the sun into the car • Optimized for transparent automotive exterior applications

Makrolon® AG neutral density color portfolio

The neutral density color portfolio within **Makrolon®** AG covers transmission levels from 5% to 75%. These colors have a flat spectral curve and therefore virtually do not change the color of light which is passing through them. This is important for LED backlit or backside decorated transparent parts. Also displays require covers which do not alter the color of the emitted light.
The color numbers of the neutral density portfolio are self-explanatory: The first two digits "75" indicate a transparent grey color. The fourth digit "3" refers to the wall thickness of three mm at which the transmission yields the level indicated by digits five and six (05% to 75%).

Color no.:	Transmission (Ty) according to ISO11664-3 [%]		
	2 mm	3 mm	4 mm
755305	12	**5**	2
755315	27	**15**	8
755325	38	**25**	16
755335	47	**35**	25
755345	56	**45**	36
755355	64	**55**	47
755365	72	**65**	58
755375	79	**75**	70



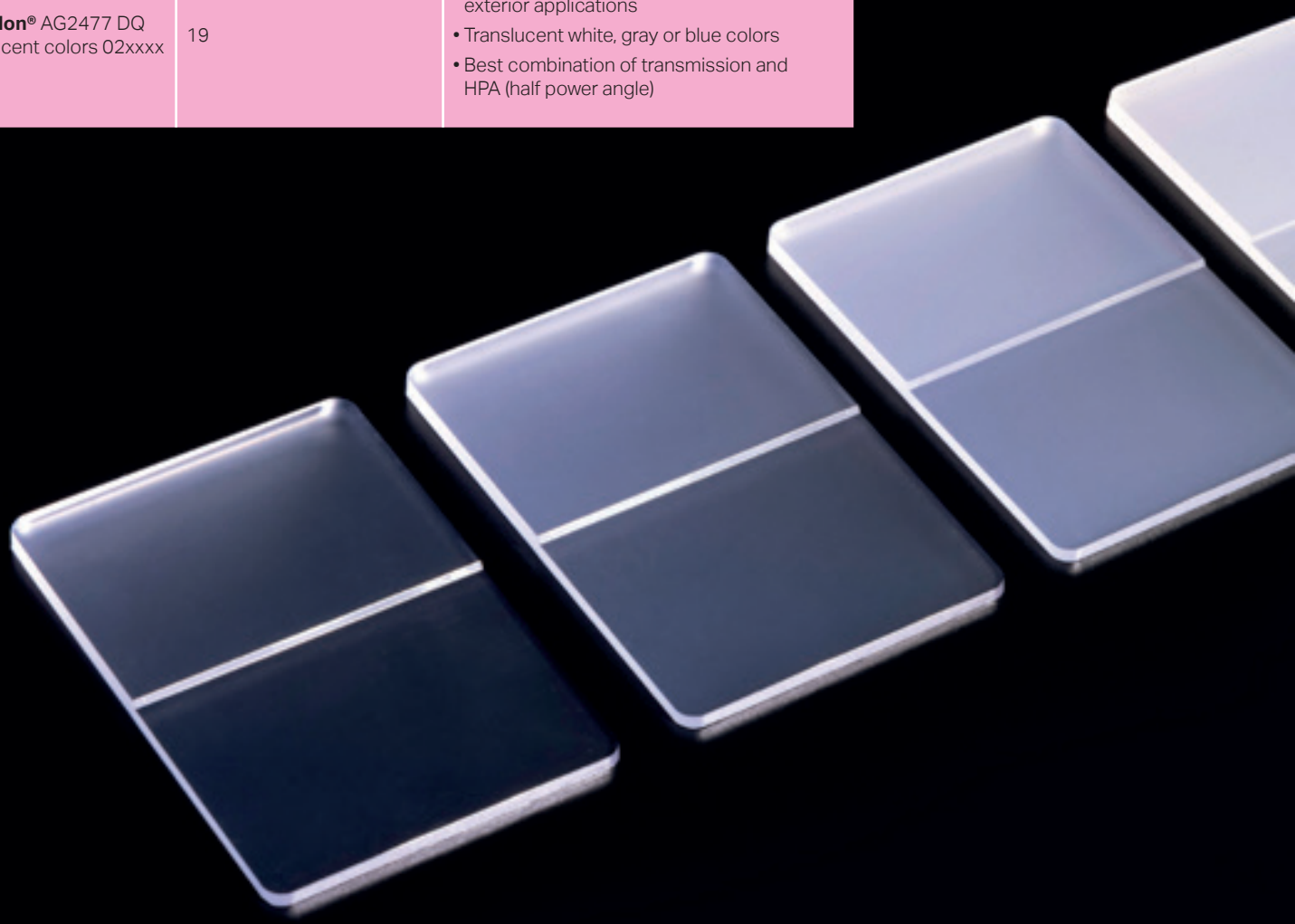
Makrolon® AG2677 / AG2477 neutral density transparent color portfolio spectral curves @ 3 mm

Makrolon® AG DQ (Diffusive Quality):

Another application for design-driven or safety-relevant light integration is opened up by **Makrolon®** AG DQ (Diffusive Quality). This translucent Makrolon® enables a wide range of combinations in light diffusion, color and transmission. **Makrolon®** AG DQ is the ideal polycarbonate for diffuse or translucent coated exterior parts. These can be e.g., illuminated light blades, emblems or covers for day time running lights. With its high transmission and adjustable half-power-angle (HPA), **Makrolon®** AG DQ efficiently resolves individual light sources and produces very homogeneous luminance distributions. In addition to a portfolio of white colors with a broad range of half-power-angles, we offer individual translucent colors such as white, grey and blue. As in all grades of the **Makrolon®** AG and AX family, only light stable dyes and scattering pigments are used in **Makrolon®** AG DQ.

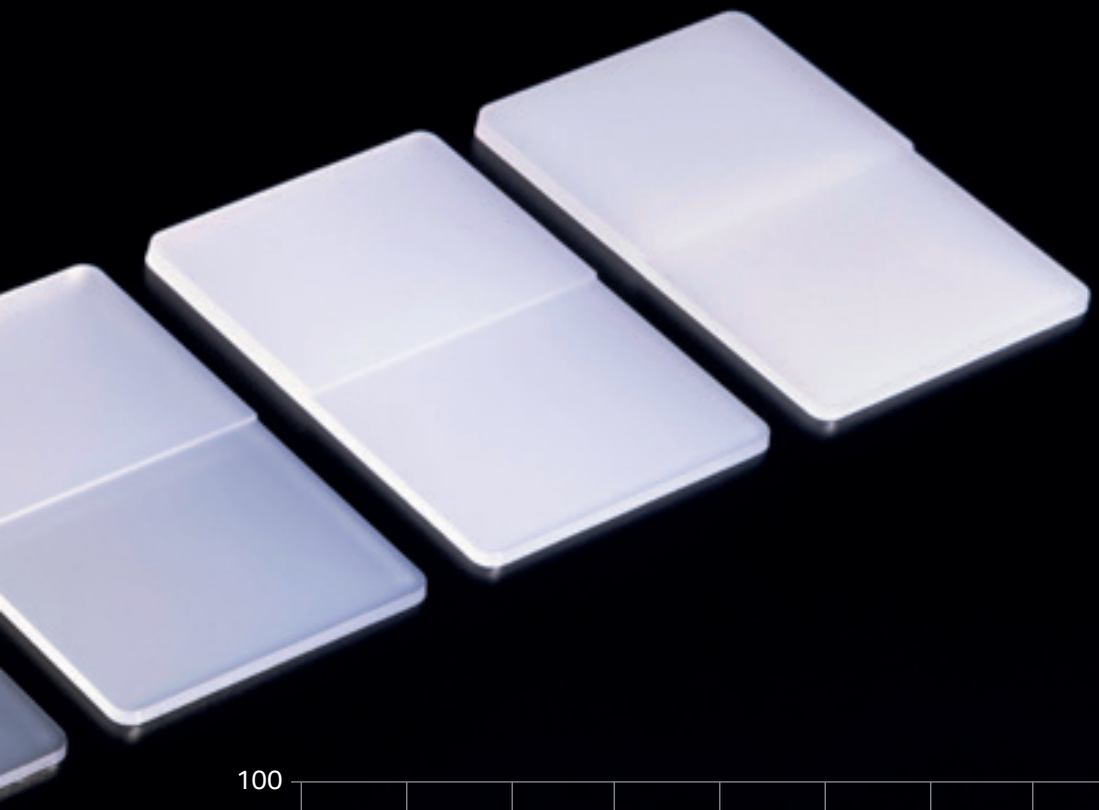
The color numbers of the translucent white color portfolio are self-explanatory: The first two digits “02” indicate a translucent white color. The fourth digit “3” refers to the wall thickness of three mm at which the half power angle yields the level indicated by digits five and six (05° to 55°).

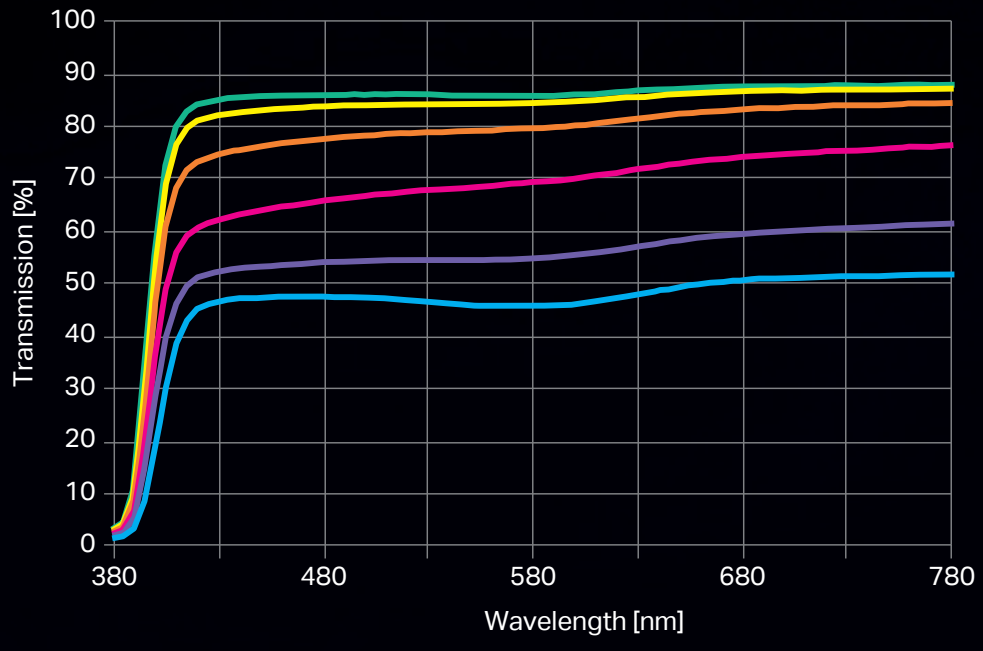
Grade	MVR (300 °C, 1.2 kg) cm³/10 min	Key properties
Makrolon® AG2477 DQ Translucent colors 02xxxx	19	• Optimized for translucent automotive exterior applications • Translucent white, gray or blue colors • Best combination of transmission and HPA (half power angle)



Color no.:	Transmission (Ty) according to ISO11664-3 [%]	
	2 mm	3 mm
028305	86	86
028315	86	85
028325	85	81
028335	77	68
028345	65	54
028355	54	46

Color no.:	Half power angle (HPA) according to Covestro Test [°]	
	2 mm	3 mm
028305	2	**5**
028315	10	**15**
028325	18	**25**
028335	28	**35**
028345	37	**45**
028355	54	**55**



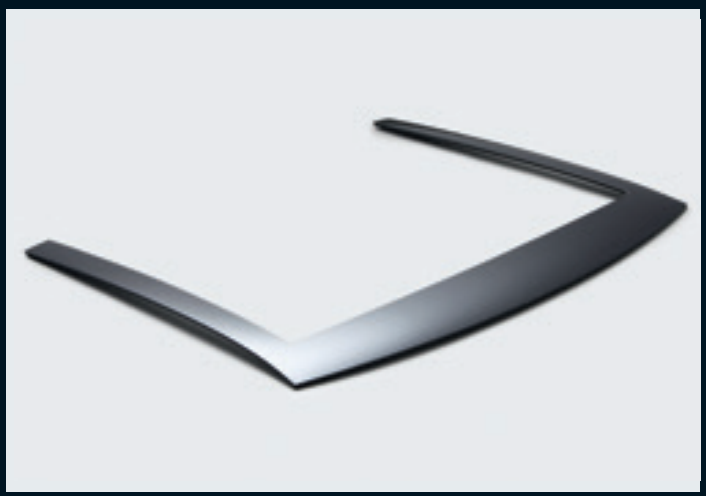


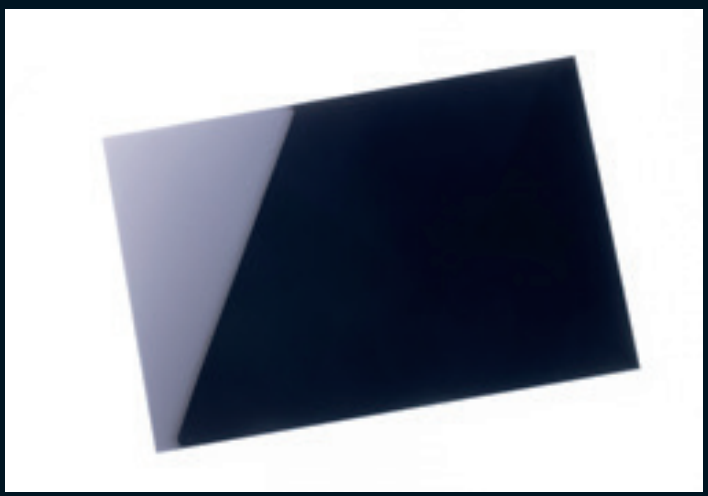
Makrolon® AG2477 DQ neutral white translucent color portfolio spectral curves @ 3 mm

Makrolon® AX:

Black and visually opaque optical polycarbonate for automotive exteriors.

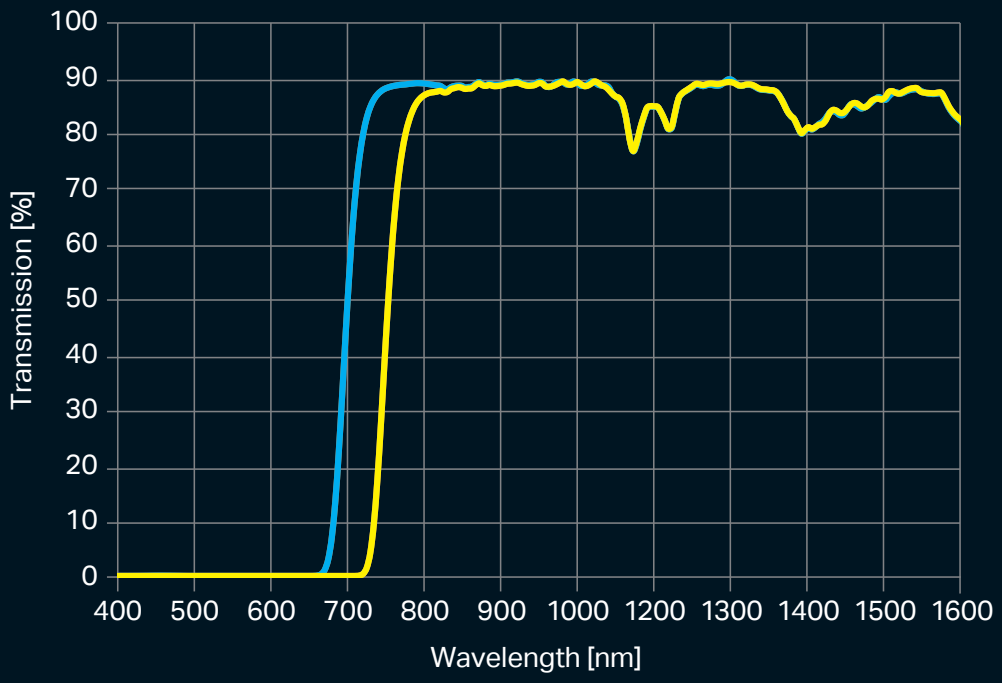
Makrolon® AX (Automotive Exterior) is used for high-quality black roof panels and exterior door pillar covers. It is optimized for brilliant surface qualities, color stability in exterior applications, and high consistency of its properties from batch to batch. A protective coating on the surface of the components provides weather resistance and scratch resistance as well as a glass-like surface appearance. Special grades for specified LiDAR-signal transmission are available as well (**Makrolon®** AX ST).





Grade	MVR (300 °C, 1.2 kg) cm³/10 min	Key properties
Makrolon® AX2675 Black color 901510	12	• Well-known **Makrolon®** AX quality • Optimized for opaque automotive exterior applications which do not require increased weathering performance • Not IR-transparent
Makrolon® AX2675 Cool black color 900346	12	• Significantly increased weathering performance compared to standard black • Near-IR transmission not specified • Not suitable for safety-relevant applications where sensors rely on IR transmission (e.g. LiDAR)

Makrolon® AX ST:



Transmission examples for LiDAR colors in **Makrolon®** AX ST @ 2 mm

Color:
978001
978007

Makrolon® AX ST (**S**ensor **T**ransparent) is black to the human eye, but has very good signal transmission capabilities in the near infrared range (NIR) up to approx. 1600 nm. This combination makes it the ideal material for the covers of LiDAR sensors. To cater to the needs of several LiDAR technologies, a range of black IR-transparent colors is available which is offering different transparency onsets at wavelengths.

We ensure that every delivered batch of **Makrolon®** AX ST has a minimum transmission of 89% at 905 nm and 2 mm wall thickness. In addition, this polycarbonate grade also produces very good surfaces in combination with transparent protective coatings. For more information on our products for sensor applications please see our brochure *„Tailored Materials for Automotive LiDAR, RADAR, Near-IR & Antenna Applications".*

Grade	MVR (300 °C, 1.2 kg) cm³/10 min	Key properties
Makrolon® AX2675 ST Sensor transparent black colors	12	• For black LiDAR covers • Excellent near-IR transparency for LiDAR signal transmission • IR transmission specification: > 89% @ 2 mm @ 905 nm

Coated **Makrolon®**: Excellent solution for design-driven exterior parts.

Unprotected polycarbonate will suffer from direct exposure to UV light. The main effects would be yellowing, bleaching of colors and deterioration of mechanical properties.

Therefore, UV stabilization is essential when parts made of **Makrolon®** are expected to withstand intensive UV exposure. In the last few decades, our coating labs have built wide know-how and experience in the field of surface protection. Based on this expertise, we have developed solutions for automotive lighting and exterior applications.

- UV absorber embedded in **Makrolon®** resin combined with organic and inorganic coatings containing concentrated UV absorbers

- In addition, all **Makrolon®** AG and **Makrolon®** AX
  - use lightfast colorants exclusively
  - are optimized for coatability

Weathering performance of hardcoats depending on substrate color

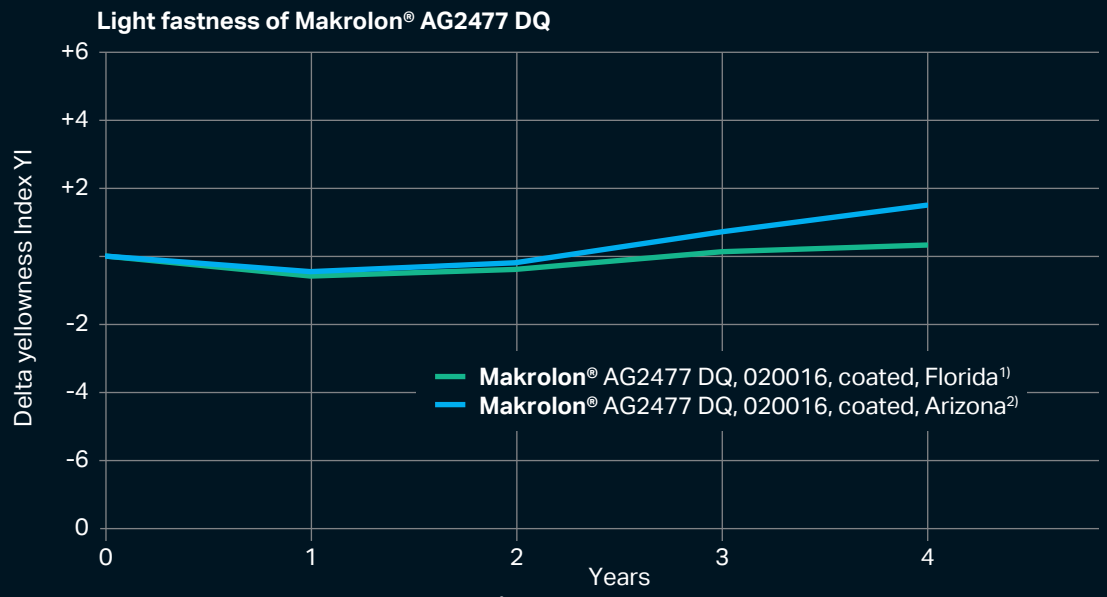
Substrate and color	1100 h	2200 h	3300 h	4400 h	5500 h	6600 h	7700 h	8800 h	9900 h	11000 h
Clear transparent **Makrolon®** AG2677 color 550396										
Dark tinted transparent **Makrolon®** AG2677										
Cool black IR-transparent **Makrolon®** AX2675 color 900346										

Further data available on request.

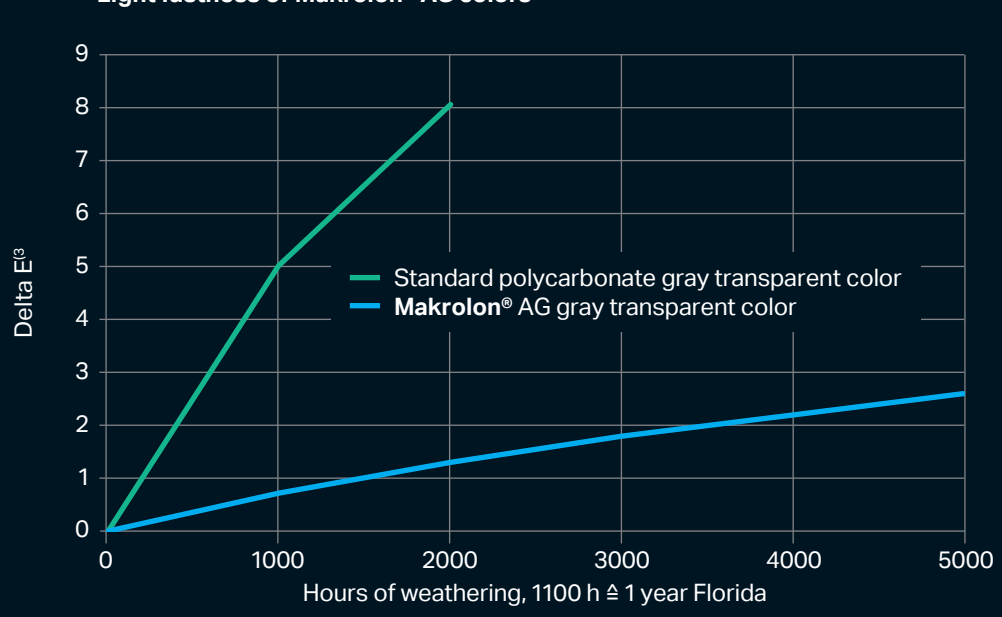
no damage **starting micro cracks** **strong micro cracks/delamination**

Two-layer polysiloxane coating,
weathering acc. to ASTM G155 mod.; 0.75 W/m²nm @ 340 nm; 1,100 hours ≙ 1 year Florida.Flat lab samples. Results may differ from real parts.

Weathering performance of translucent and transparent **Makrolon®**:



1) Weathering according to ASTM G155 mod.; 0.75 W/m²nm @ 340 nm; 1.100h ≙ 1 Year Florida
2) Weathering according to PV3929; 0.6 W/m²nm @ 340 nm; 1.500h ≙ 1 Year Arizona



3) Delta E is the difference between two colors according to EN ISO 11664-4

In weathering acc. to ASTM G155 mod.; 0.75 W/m²nm @ 340 nm. Flat lab samples coated with two-layer polysiloxane coating.

Automotive lighting

Safety, Communication, Styling:

Lighting is the signature of the car.

Every car has its own identity, expressed in a unique headlamp and rear lamp design. Safety, communication and styling are three basic requirements for automotive lighting applications, and the right choice of materials for optical parts can help achieve all three. Furthermore, materials with special colors and effects are also needed to help underscore the unique nature of the headlamp.
Light integration and the use of LEDs will increase tremendously in the future, so materials will need to couple high optical performance with the ability to withstand long-term exposure to LEDs. We offer **Makrolon®** (polycarbonate) optical grades which can bring out some of the most/highly efficient LED lighting and enable great freedom of design with a wide range of color effects. **Makrolon®** offers superior optical, mechanical, thermal properties and long-term stability with LEDs, already anticipating the future needs of headlamp/rear lamp manufacturers and automotive OEMs.

Transparent/translucent applications:

One of the most common applications for **Makrolon®** in the automotive sector is in headlamps and rear lamps, thanks to its high optical transmission properties.

Makrolon® AL in combination with a coating system is a state-of-the-art material for headlamp cover lenses, and fulfills all requirements of the ECE and AMECA.

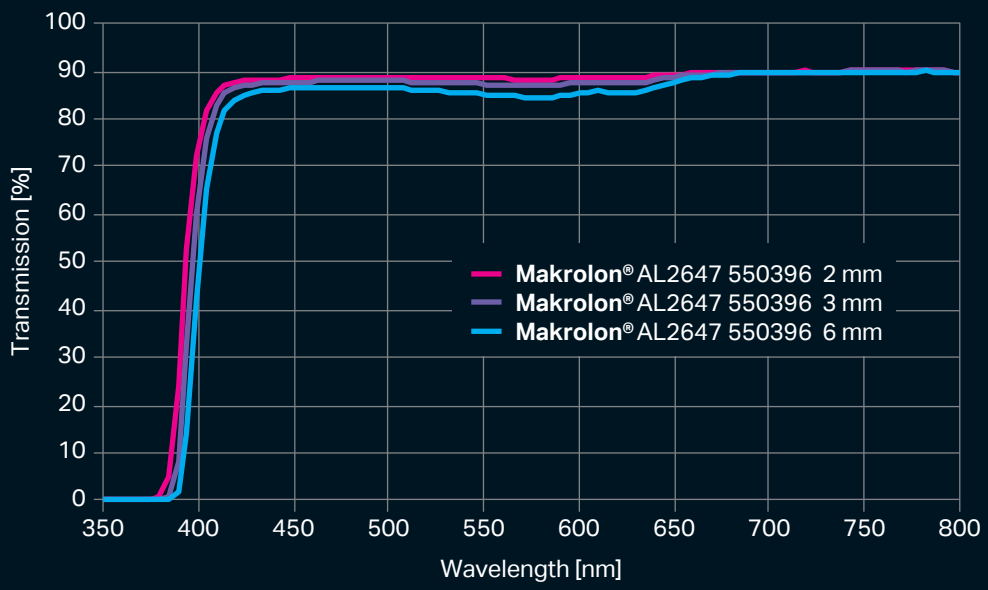
Makrolon® LED offers the highest optical transmission and optical quality, and is suitable to be used for optics and light guides with regulatory approvals (e.g. AMECA).

Protective function and design freedom in headlamp shapes.

Makrolon® AL industry standard grade for headlamp covers.

Makrolon® AL is an industry standard polycarbonate grade for headlamp covers. It offers an optimal trade-off between melt-flow and the mechanical properties that enable design freedom in terms of geometry. The properties are tailored to the high demands of this mass application in terms of optical quality, impact resistance and heat resistance.
In order to achieve good weathering performance and scratch resistance, a special coating needs to be applied.
Makrolon® AL in combination with coating is approved by AMECA and UNECE.

Materials	MVR (300 °C, 1.2 kg) cm³/10 min	Key properties
Makrolon® AL2447	19	High melt-flow for thin-wall parts
Makrolon® AL2647	12	Medium melt-flow for superior impact resistance



Transmission spectra of **Makrolon®** AL2647 550396 at different thicknesses.

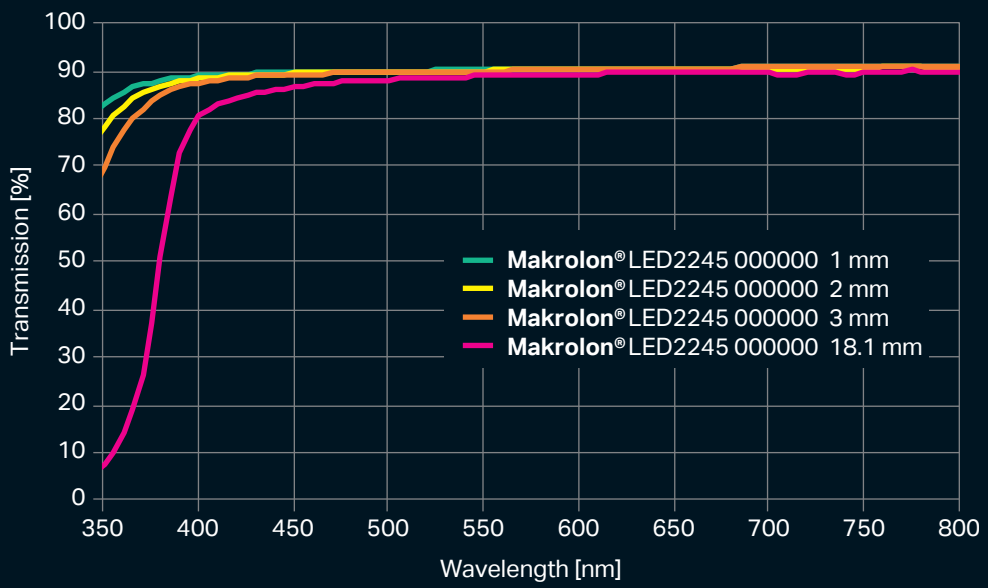
Control the light, the way you like it.

Makrolon® LED offers our highest transmission for light guidance applications such as DRLs.

Makrolon® LED offers the high transparency (90% at 4 mm thickness) and excellent optical quality which are necessary for accomplished light distribution in daytime running lights, signal functions and other ambient lighting applications. It combines long-term color stability under LED light with good melt-flow and heat resistance. For protected applications (e.g. behind coated **Makrolon®** AL2447/AL2647 cover) it is approved by AMECA and UN ECE in a range of different colors.

Materials	Colors	MVR (300 °C, 1.2 kg) cm³/10 min	Key properties
Makrolon® LED2245 HP	Natural	34	Excellent transmission and high optical purity for thick-walled lenses with some of the best/great color consistency
Makrolon® LED2245	Natural, Ice Colors (550207, 550128*, 551592*, 551467**)	34	Excellent transmission, available in different transparent colors like "Ice color"
Makrolon® LED2045[4)]	Natural	61	Excellent transmission with very high melt-flow

* Available only in APAC countries ** Available only in NAFTA countries 4) Available only in APAC and NAFTA countries

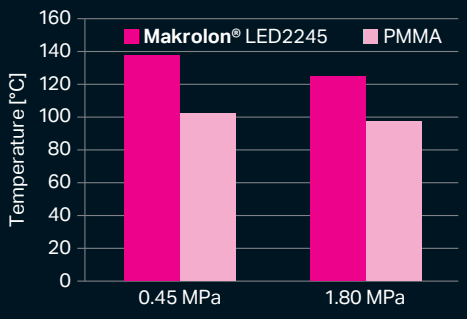


Transmission spectra of **Makrolon®** LED2245 in neutral (000000) and ice colors (550207, 551592, 550128).

Makrolon® LED provides an optimal balance of optical and mechanical properties for light guides and thick lenses.

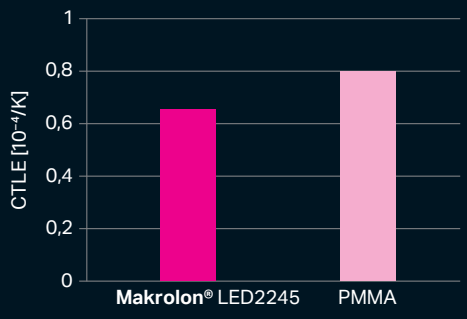
Complex optical components such as the thick lenses in daytime running lights (DRLs) require precise optical properties united with high mechanical requirements. For example, when it comes to the necessary fastening elements or the component stability in application and production, a correct balance of optical and mechanical properties is necessary. **Makrolon®** LED offers the opportunity to produce long, thick optical lenses for DRLs in high optical quality combined with mechanical strength.
Ask about optical data for our materials to help design your automotive parts.

Heat deflection temperature



Heat deflection temperature
Heat deflection temperature of **Makrolon®** LED2245 and PMMA.

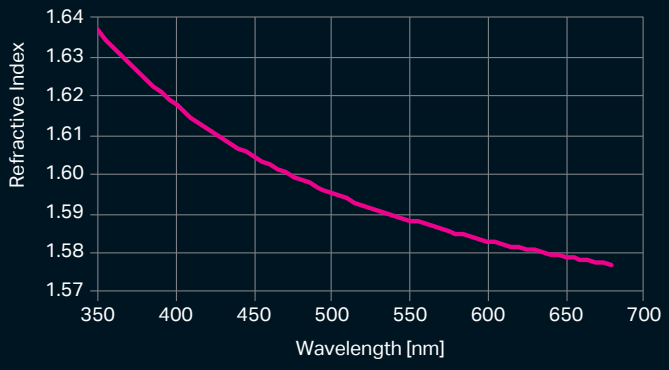
Coefficient of linear thermal expansion (CLTE)



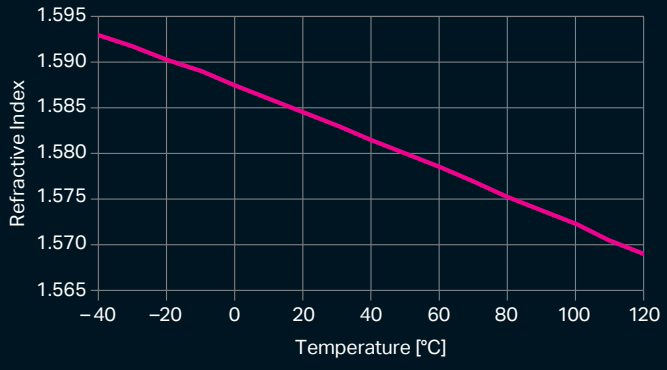
Coefficient of linear thermal expansion (CLTE)
Coefficient of linear thermal expansion at 23-55 °C of **Makrolon®** LED2245 and PMMA.

Makrolon® LED offers the opportunity to produce long, thick optical lenses for DRLs in high optical quality combined with mechanical strength.

An additional benefit of using **Makrolon®** LED2245 instead of PMMA as light guide and optic material is the dimensional stability at higher temperatures. The above left-hand graphic shows that **Makrolon®** has thermal resistance performance superior to PMMA, as Makrolon starts to deform at a temperatures of 125 °C (at 1.80 MPa) and 138 °C (at 0.45 MPa) while PMMA already deforms at 100 °C. Furthermore, **Makrolon®** LED2245 offers less thermal expansion, as shown in the graph above.



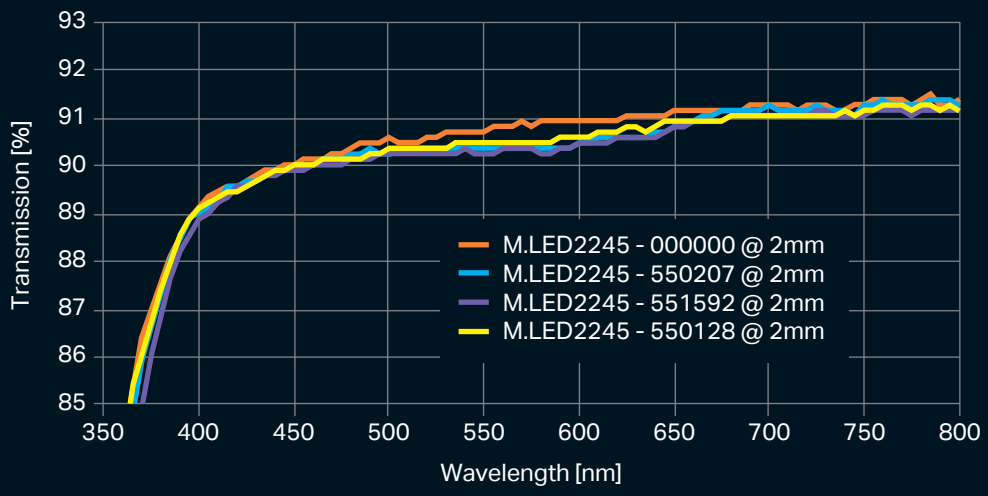
Refractive index as a function of wavelength of **Makrolon®** LED2245 000000.



Refractive index of **Makrolon®** LED2245 000000 at different temperatures.

Makrolon® LED is available in a variety of transparent color temperatures.

The visual impression of a light such as a daytime running light is determined by its color temperature, and by how the component looks when switched off. So **Makrolon®** LED2245 materials are available in high transparency settings for light color temperatures ranging from warm white to cool white.

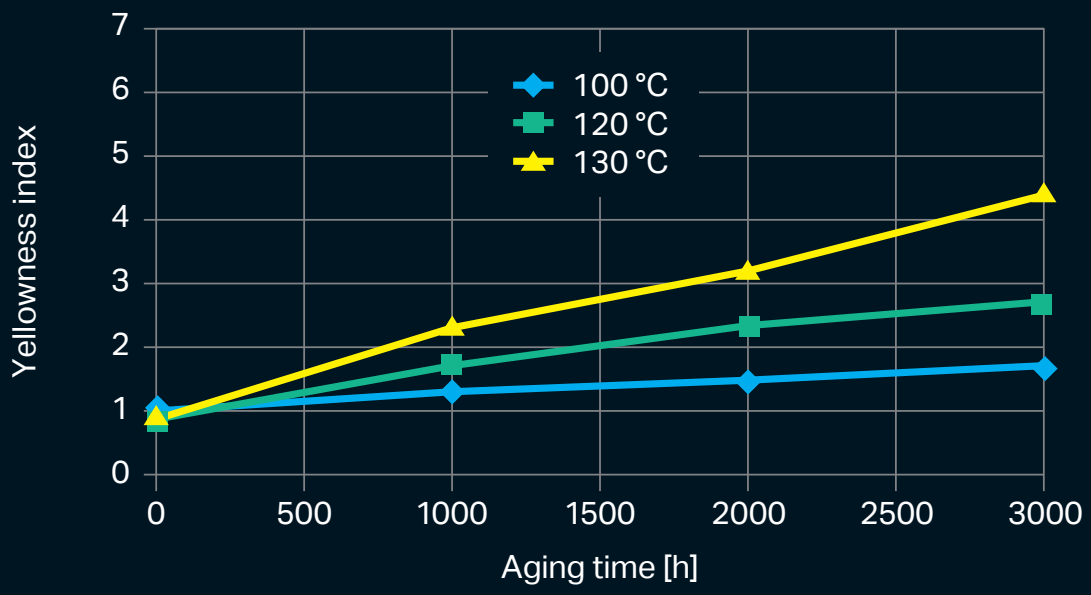


"Transmission spectra of Makrolon LED2245 in neutral (000000) and ice colors (550207, 551592, 550128)."

Crystal clear/ice color impression parts are possible with **Makrolon®** LED2245 (color code 550207). However, as illustrated above, the transmission of ice color material is slightly lower than with natural color (color code 000000).

Makrolon® LED offers lowest tendency towards yellowing

Components made of **Makrolon®** typically display high temperature resistance. A distinction is made between short- and long-term temperature resistance. Different methods exist for measuring short-term temperature resistance, such as the glass transition temperature, the Vicat softening point, and heat distortion temperature (HDT) test. Short-term temperature resistance is comparably high within the group of clear, transparent **Makrolon®** grades. Extended exposure to extreme temperatures can lead to yellowing over time. The kinetics of the yellowing also depend on the individual **Makrolon®** grade. **Makrolon®** LED2245 000000 and **Makrolon®** LED2245 HP 000000 display the lowest tendency towards yellowing. This behavior is illustrated for **Makrolon®** LED2245 000000 below.



Thermal aging of **Makrolon®** LED2245 000000 (4 mm) at different temperatures

This graph shows that **Makrolon®** LED2245 000000 displays a very low tendency towards yellowing at temperatures up to 120 °C. In contrast, discoloration occurs much more rapidly at higher temperatures. Apart from yellowing, other changes in properties can also occur after extended exposure to high temperatures. However, yellowing starts with transmission or the gradual appearance of a cloudy haze, and becomes more apparent only after even longer exposure to heat. Nonetheless, the mechanical properties such as good impact strength remain at a high level even after an extended period.

Makrolon® polycarbonate drives innovation in a thick light bar.

General Motors Company (GMC) wanted to achieve a unique, crystal-like effect for the light bar component of its 2019 Sierra 1500 LD truck headlamp. GMC teamed up with Valeo Lighting Systems and Covestro to bring this design to life, using one of our tailor-made color and highly transparent polycarbonate.

Task: Create a light bar with a sculptured crystalline appearance
We collaborated with GMC and Valeo to create an advanced light bar design for the headlamp, which features a larger and brighter daytime running lamp for improved visibility in clear or inclement weather. In addition to improved safety, the thick light bar also allowed GMC to create a unique brand differentiation for the vehicle. Non-standard, multi-shot thick molding, tooling and processing were instrumental in achieving the light bar's unique styling and functionality.

Challenge: Achieve unique crystalline aesthetics with minimal shrink and warpage
The team aimed to design a light bar that looks like crystal, with low yellowness after a long life cycle. With the part's large, complex shape, the tooling needed a modified surface and special ejection design to properly eject the thick light bar. Since there was a risk of high stress in the part, dimensional accuracy and warpage were also areas of concern.

Why Makrolon® LED2245 polycarbonate was the right solution for the light bar

- **Good optical quality: Makrolon® LED2245** offers high optical clarity in extremely thick cross-sections.
- **Unique aesthetics: Custom color development** enables crystal-like appearance and effects.
- **Dimensional accuracy: Makrolon® LED2245** maintains the desired size with minimal shrink and warpage.
- **Replicated micro-optics:** Enable exact replication of optic surfaces.

"Automotive lighting plays a dual role, contributing to a vehicle's safety and its distinctive styling. This light bar illustrates how using Covestro materials can create new opportunities to enhance both of these important aspects."
Michael George / Polycarbonates Market Manager, Lighting Covestro

Solution: Makrolon® LED2245 illuminates the road ahead
To meet color and optical clarity requirements, our **Makrolon®** LED2245 polycarbonate was manufactured using a different process than standard polycarbonate. As a result, this grade offers high optical clarity in extremely thick cross-sections and provides crystal color development to reduce the yellowness that often occurs in traditional unlit thick polycarbonate parts. Additionally, Valeo used a proprietary molding process for a low-stress part with high clarity and minimal shrinking and warpage.

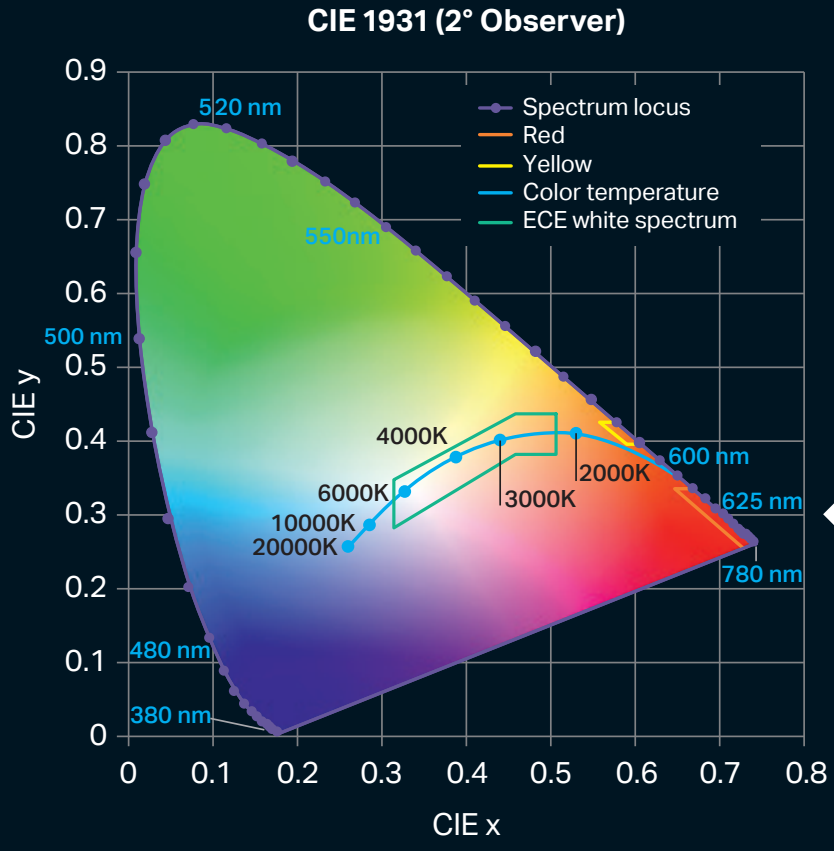
Color the light the way you like it:

Makrolon® is available in signal colors and a variety of additional transparent colors.

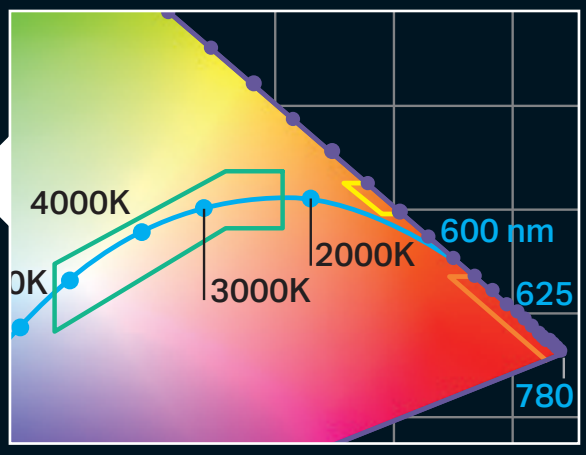
Transparent signal colors have been used for many years in various applications such as automotive lighting, signal transmitters and signal lights. Furthermore, thanks to its excellent mechanical properties and very high heat resistance, **Makrolon®** is qualified for automotive applications including turn signals, daytime running lights, rear lights, traffic lights and warning lights on emergency vehicles.

As a safety and communication tool, these colors are subject to strict requirements in terms of accuracy and stability. Whether in standard colors such as yellow for turn signals, red for taillights, or in new requirements such as turquoise for autonomous driving, our competence in colors ensures that all requirements can be met. All current colors are AMECA and ECE compliant, and future colors will be developed to meet current legal standards.

Beyond signal colors, **Makrolon®** offers a rich spectrum for design and branding themes. Ask our experts and color competence team about a customized color with high purity **Makrolon®** to suit your optical application.



CIE 1931 (2° observer)
shows the current range of signal colors in accordance with the standard specifications in the CIE chromaticity diagram. Some of the typical signal colors – white, yellow and red – are shown in the diagram to illustrate the large number of signal colors available.

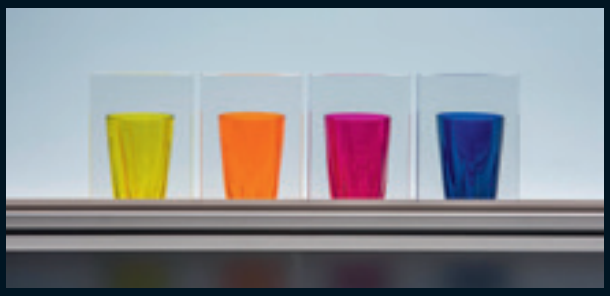


Shape the light the way you like it:

Makrolon® LED2245 EL offers functional colors for illuminated surface applications.

In addition to the many possibilities in the color design of a component, there is also the need to shape the light in a component so that there is, for example, a uniform illumination area without a recognizable origin of the light source. Our edge lighting colors are among these special functional colors.

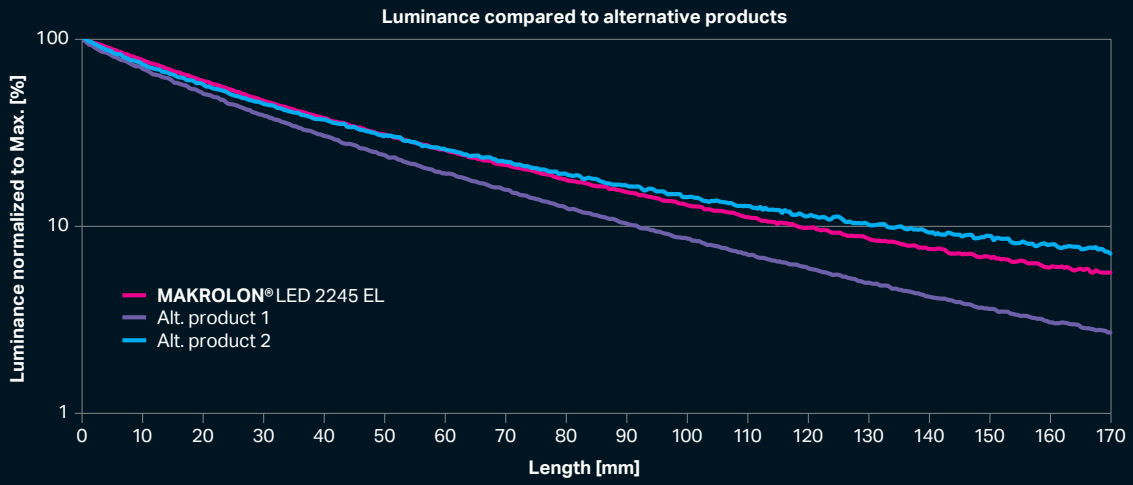
Makrolon® LED2245 EL offers a translucent effect under LED light with optimized transparency, giving more freedom of design.



The material has a high transparency with minimal haze in the non-illuminated state, which can also be used for optical applications. If light is coupled to one edge of the component, the entire surface lights up translucently. LED2245 EL is available in different color shades from warm white to cold white:

Materials	Colors	MVR (300 °C, 1.2 kg) cm³/10 min	Haze	Transmission (%)	Key properties
Makrolon® LED2245 EL	021760	34	3	88	Edge light effect, warm white
	021769	34	3	86	Edge light effect, cool white
	021754	34	6	85	Edge light effect, warm white
	021767	34	6	85	Edge light effect, cool white
	320017	34	12	13	Transparent red color, edge Light effect

Optical properties (4 mm) and color impression of **Makrolon®**LED2245 EL.

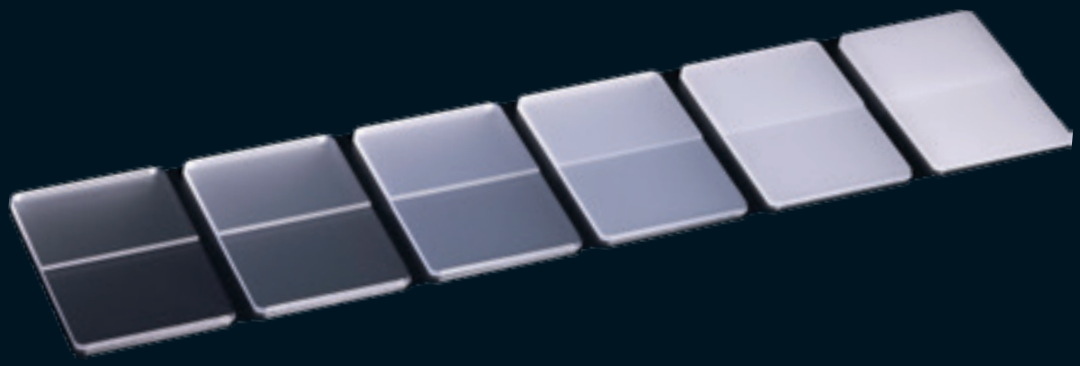


Luminance compared to alternative products Luminance of the luminous surface as a function of the distance to the light source (light coupling at a plate edge).

Shape the light the way you like it:

Makrolon® LED2245 DQ ensures a homogen surface illumination with highest transparency at same time.

Surface light is increasing in Automotive Ligthing applications where at the same time the light efficiency is a must demand. **Makrolon®** LED2245 DQ including a new generation of scattering additives offer highest transparency to ensure an efficient light shaping.

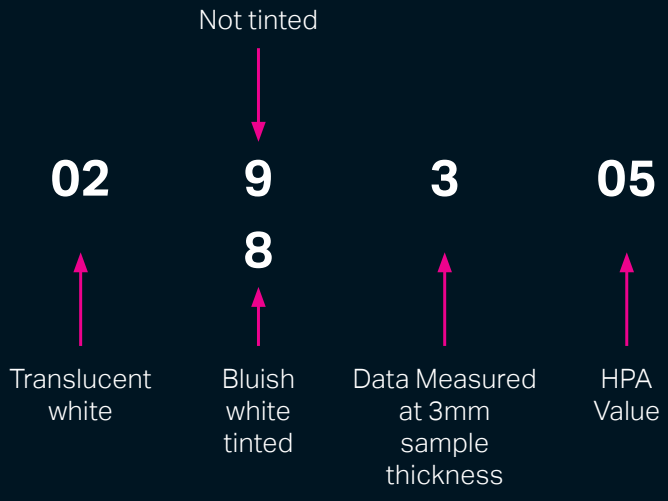


Makrolon® LED2245 DQ is available in a basic portfolio offering the total range on translucency in 6 steps of HPA (Half Power Angle) from 5 to 55 at 3mm thickness.

Grade	Color Code	Thickness [mm]	Ty [%] (D6510°)	HPA [°]
Makrolon® LED2245DQ	029305	3	87	5
	029315	3	86	15
	029325	3	82	25
	029335	3	68	35
	029345	3	58	45
	029355	3	51	55

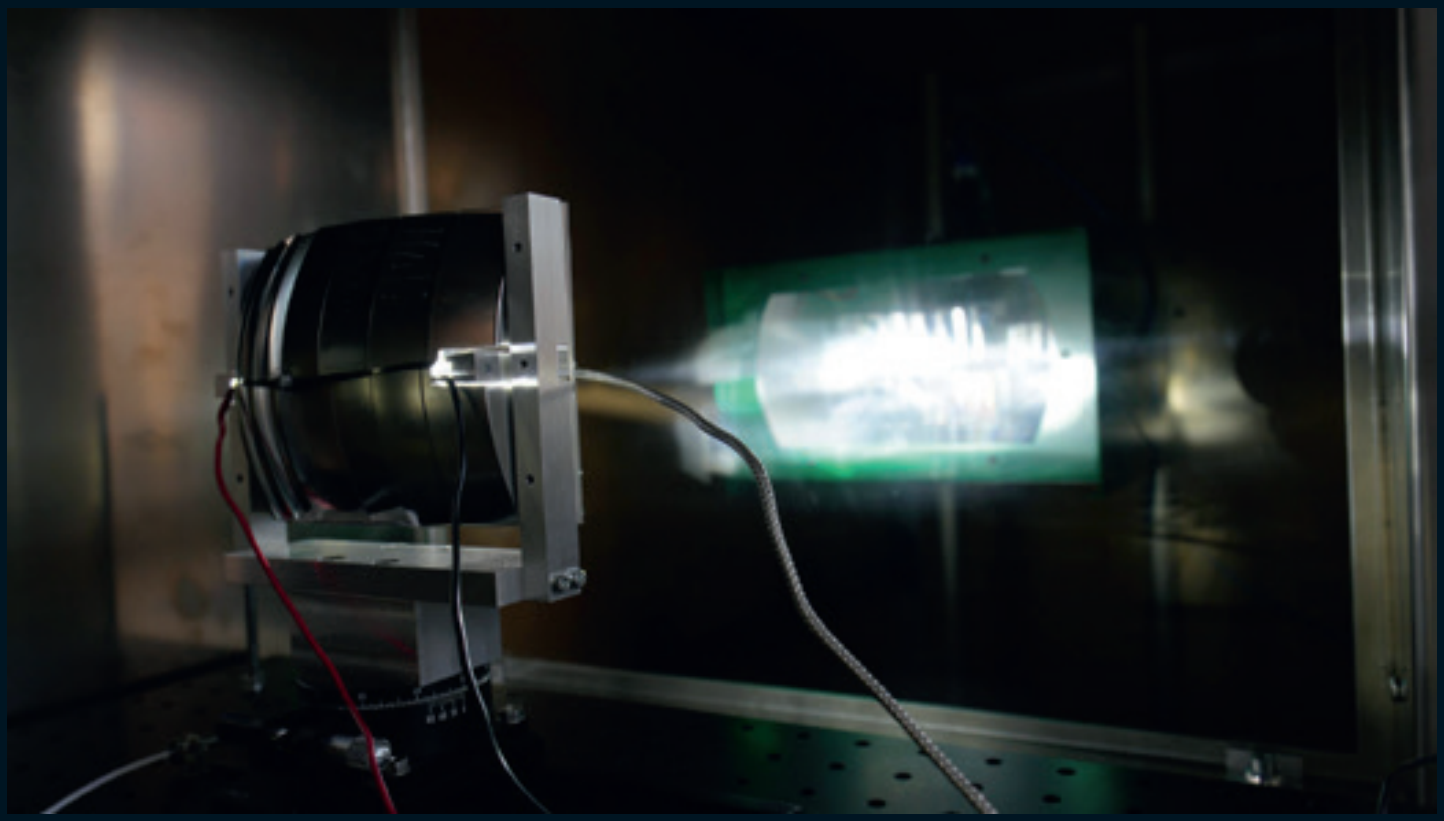
All portfolio colors are also available in a bluish white version to support the trend of cold surface impression.

Nomenclature for translucent portfolio color codes:



For deep tinted applications like automotive rearlamp we offer colored translucent grades like:

Grade	Color Code	Thickness [mm]	Ty [%] (D6510°)	HPA [°]
Makrolon® LED2245DQ	320021	3	12	5



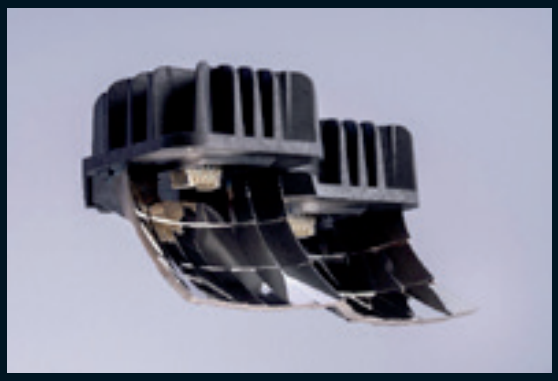
Light shaping applications based on material solutions for reflective parts.

Beneath the characteristic transparency of **Makrolon®** which offers multiple application benefits for lighting, **Makrolon®** also offers a variety of possibilities for directing and shaping light in non-transparent versions. In reflective applications, **Makrolon®** RW offers diffusive potential while **Makrolon®** DS is focused on imaging reflection.

Makrolon® RW enables the shaping of a diffusive reflector where both high reflection and uniform light distribution are needed and allows it without additional processing steps.
Makrolon® DS is a highly filled product. In combination with variothermal injection molding, it offers a high quality surface in combination with high dimensional stability, making it a good solution for items such as imaging reflectors that require a precise light pattern under widely varying temperatures.

Innovation meets integration in reimagined low-beam module

Covestro continues our auto innovation by debuting a concept for a modular LED low-beam optical unit with built-in heat management and precission optical alignement. This 2K, in-mold electronics (IME) prototype reduces weight, space, cost and complexity while offering more creative liberties for cutting-edge OEMs.



Modularity and miniaturization: compact design with complex reflectors in one plug-and-play module

Covestro, in collaboration with an industry lighting leader, has developed a slim, space-saving design that is just what designers have been looking for, enabling them to achieve in-demand, low-profile styles where the headlamps are less noticeable, while mitigating heat management issues. And, by embracing a more efficient manufacturing process – reducing parts and assembly steps – OEMs can slash costs and assembly complexity.

Less is more: Covestro consolidates parts, processes and materials

Currently, producing low-beam headlamps often requires multiple parts (six), materials (six) and process steps (four). What if there were a better approach – one that reduced the parts, materials and processes needed? There is. Covestro, in collaboration with industry leaders, has developed a solution for modular, slim, lightweight headlamp designs utilizing LED technology. Remarkably, the module consists of one part, and only three material sets are required: our poly-carbonates, metallization and the LED-module). Furthermore, the prototype module requires just two process steps – two-component (2K) injection molding with IME (in-mold electronics) followed by metalizing. What's particularly significant is that the metallization process can be completed directly after molding, with no additional surface preparation needed.

Key Benefits

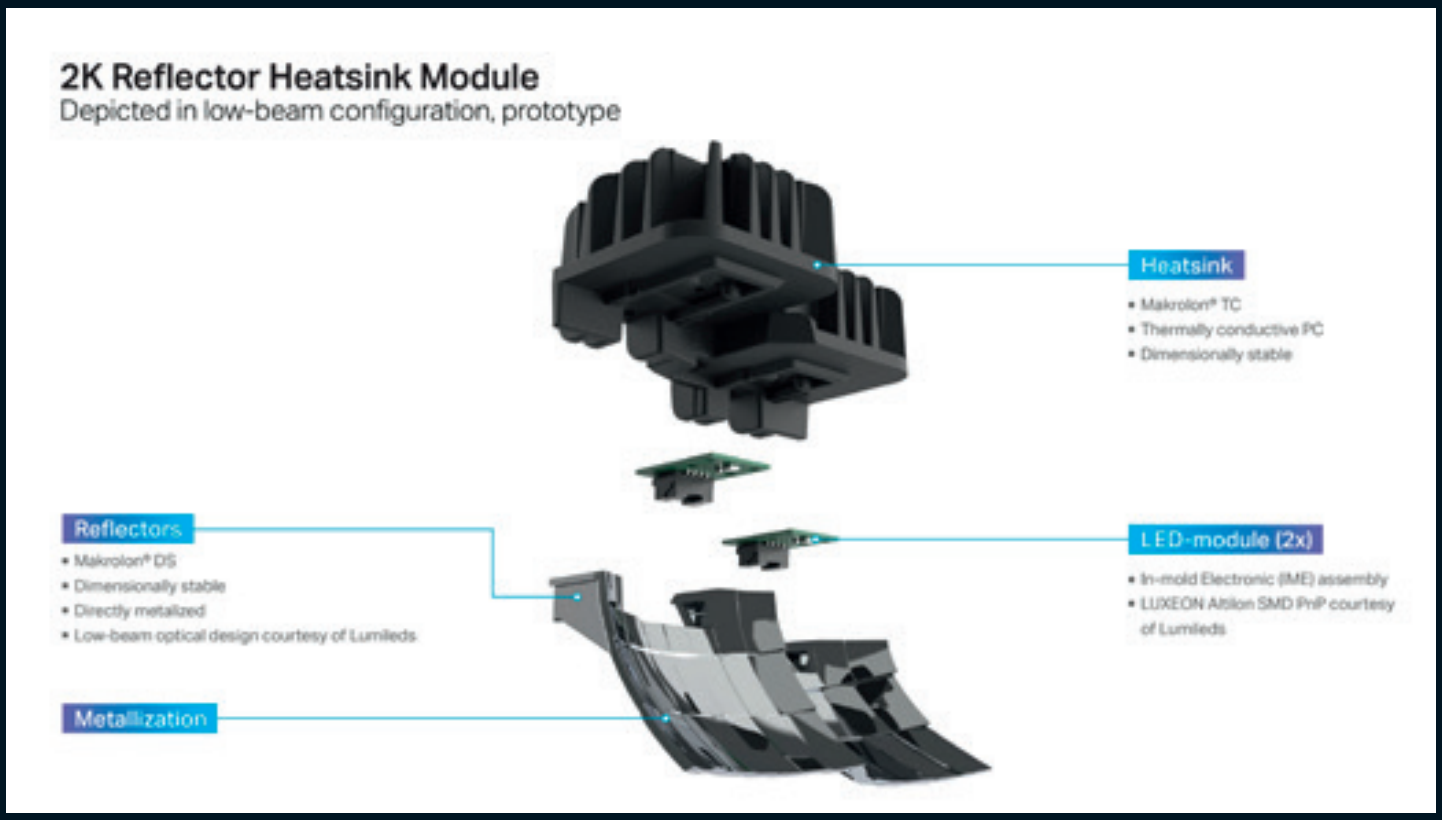
- **Heat dissipation** Maintain LED-case temperature within 2-3 degrees C of cast aluminum heatsinks with Makrolon® TC polycarbonate
- **Innovative molding process** Precision, two-shot injection molding and IME enable the heatsink, reflector and LED module to be formed in a single injection mold including a precission optical aligenemtn
- **Consolidation** Fewer parts, processes and materials are needed to create the low-beam configuration with complex reflector
- **Miniaturization** Compact, plug-and-play design
- **Cost reduction** Over 20% system cost savings compared to PC reflector and cast aluminum heatsink
- **Smaller, lighter by design** A slim, lighter weight headlamp supports sustainability goals

Slim and trim module reduces weight, but not performance

The 2K reflector heatsink module consists of a single part – that's five fewer parts than the typical unit. As such, our low-beam module is over 40% lighter in weight. For the heatsink alone, we achieved up to a 49% weight reduction compared to cast aluminum and for the reflector a 26% weight reduction compared to BMC (bulk molding compound).

Materials make the difference: Dimensional stability for stable photometrics

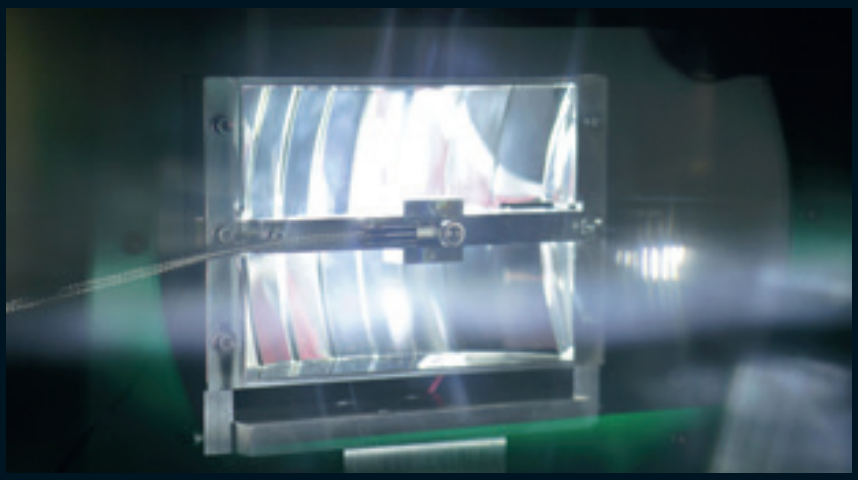
By uniting Makrolon® TC and Makrolon® DS polycarbonate grades from Covestro, designers can achieve dimensional stability for consistent photometrics. More specifically, these Covestro polycarbonates offer low CLTE (Coefficient of Linear Thermal Expansion) values that closely match each other – translating into good dimensional constancy over end-use temperature changes. Further, the materials' low mold shrinkage contributes to less warpage during injection molding.



Imaging reflectors:

Precise and stable light pattern independent of temperature.

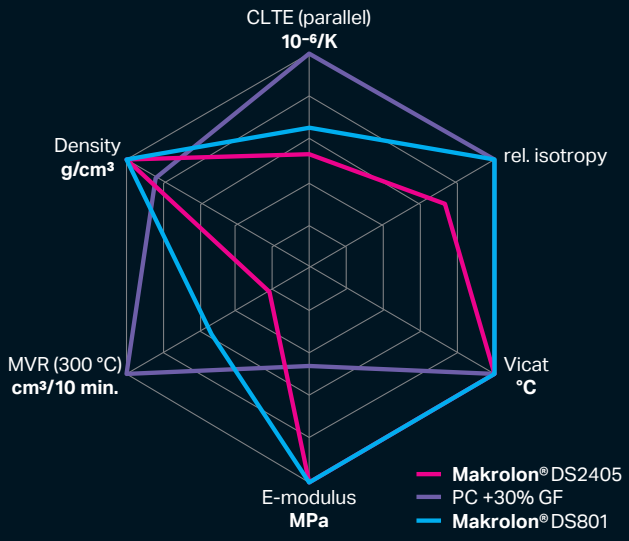
Makrolon® DS offers dimensionally stable (low isotropic CLTE) properties at a wide range of temperatures. Headlamp reflectors are growing more complex and miniaturized, as is the case with multi-cavity reflectors. An intelligent combination of innovative processes and suitable materials can give you the opportunity for flexible and efficient production.



Makrolon® DS801 development demonstrator suitable for full headlamp light pattern, stable under varied temperature conditions.

Makrolon® DS offers high dimensional stability at temperatures up to 120 °C, making it suitable for precise light-pattern reflectors. The material offers excellent surface quality via variothermal heating in addition to low isotropic coefficient linear thermal expansion (CLTE) values. It can be metalized through a sputtering process. Ask us for high-temperature or improved CLTE versions!

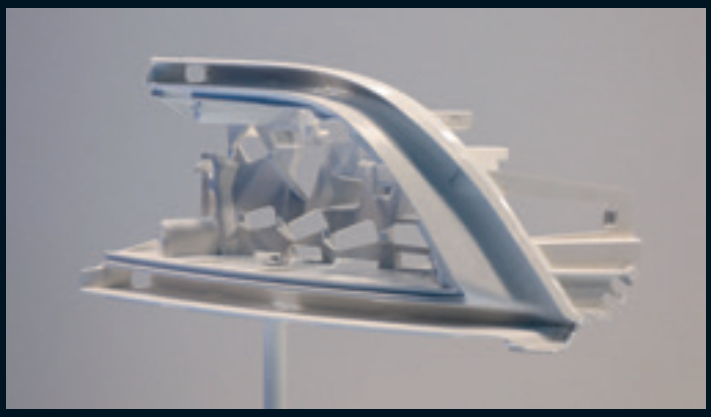
Materials	MVR	Key properties
Makrolon® DS801	10	Mineral-filled polycarbonate with low (isotropic) CLTE



Properties of **Makrolon®** DS801 compared with unfilled and fibre-filled polycarbonate.

High luminous efficiency with uniform light distribution

Makrolon® RW offers reflectivity up to 97% combined with excellent light blocking and impact resistance.

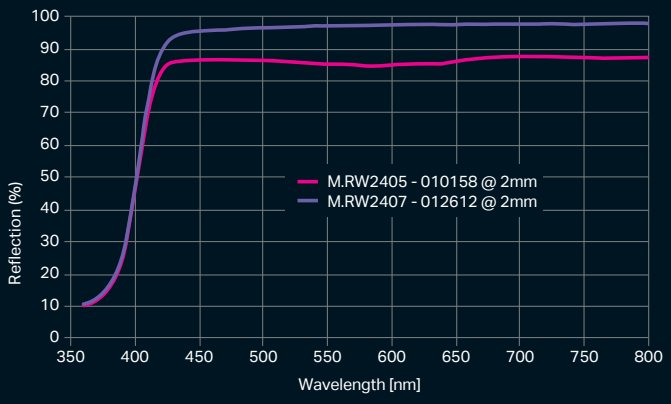


Characterized by their high efficiency in diffuse reflecting visible light, high-reflectance white **Makrolon®** grades are noted for their increasing application as raw materials for LED rear lamp reflectors and similar components.

Makrolon® RW offers highest diffuse reflectivity, up to 97% total reflectance, together with excellent light blocking properties, which make it suitable for non-metalized reflectors and other decorative parts inside headlamps and rear lamps.

We offer several reflective white colors with a range of color impressions and light blocking properties. The graph in the lower left corner shows the reflectance spectra in the visible range of two representative colors.
Also available as **Apec®** grades for high temperature applications.
More information about this material is available upon request.

Materials	MVR (300 °C, 1.2 kg) cm³/10 min	Key properties
Makrolon® RW2405	19	High melt-flow reflective white polycarbonate
Makrolon® RW2407	19	High melt-flow reflective white, UV-stabilized polycarbonate
Makrolon® RW5181	26	Improved melt-flow with increased Impact resistance



Reflection of **Makrolon®** RW colors at different wavelengths.

Color	Thickness [mm]	Rest transmission % (D65 10°)	Reflection % (D65 10°)
010158	0.5 1 2 3	1.15 0.25 0.02 < 0.01	96 96 96
012612	0.5 1 2 3	0.02 < 0.01 < 0.01 < 0.01	87 87 87

Example of reflectance and transmission values of different thicknesses for two selected colors.

Reimagining automotive forward lighting with polycarbonates.

When it comes to materials and technologies for future auto lighting, We are ahead of the curve, developing a functional headlamp concept to illustrate how polycarbonates enable functional and aesthetic benefits. This visionary approach can also reduce weight, space and cost while offering greater sustainability.

Part consolidation: less is more.

Traditional headlamps are complex, usually incorporating dozens of components and screws. We advocate a forward-looking approach to forward lighting, with a headlamp module concept comprised of a reflector/ housing, collimator lens, bezel and outer lens cover that results in significantly fewer parts.

Multi-shot molding of **Makrolon®** TC629 thermally conductive polycarbonate and **Makrolon®** DS801 dimensionally stable polycarbonate, along with a molded-in-place design strategy, enable the low- and high-beam LED modules and their corresponding reflectors to be produced less expensively through the elimination of added heat sinks, attachments and other components. The bezel of **Makrolon®** polycarbonate uses multi-shot molding to consolidate turn signals and daylight running lamps, while also hiding sensors behind a LiDAR-transparent mask. Beyond reducing system complexity and costs, simplifying assembly and saving valuable space, this novel approach also reduces headlamp weight, which improves fuel mileage while lowering emissions or increasing battery range.

Integrating electronics:

Future automotive headlamps will integrate electronics such as LiDAR, radar and cameras in addition to light sources. This will require the use of thermally conductive materials to dissipate the heat generated by the electronics and light sources.

This headlamp demonstrator is the first of its kind to work with **Makrolon®** TC629 polycarbonate.
The low- and high-beam reflectors utilize **Makrolon®** DS801 polycarbonate for highly efficient reflectivity of visible light. The reflectors can be molded directly into the **Makrolon®** TC629 polycarbonate housing with multi-shot molding and vario-thermal mold control techniques. This eliminates the need to attach the reflector with brackets and fasteners, contributing to lighter vehicle weight..
Our **Makrolon®** DS801 polycarbonate material provides a metalizable, smooth surface finish similar to unfilled polycarbonate and can enable greater lumen output compared to other systems. In fact, the single, metalizable component yields a beam pattern performance that remains stable throughout the operating temperature of the LED lamp system due to its low, isotropic thermal expansion.

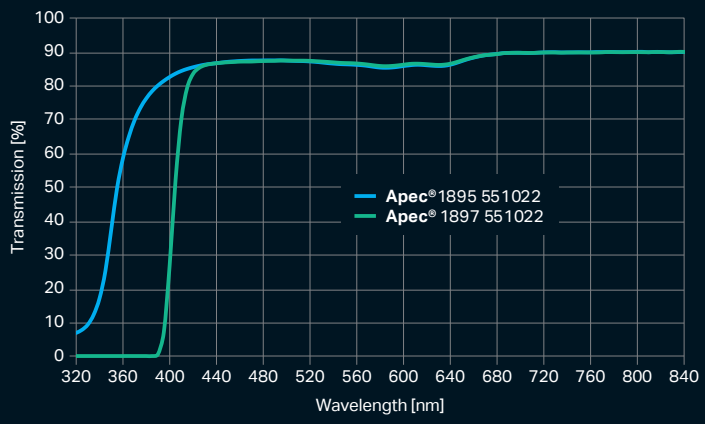
The bezel is a three-shot molded part with **Makrolon®** LED2445 in both amber color for the turn signals and a diffusion color for the daytime running lights or DRLs, coupled with **Makrolon®** ST sensor transparent polycarbonate. The bezel hides advanced driver-assistance systems (ADAS) sensors and consolidates DRLs, turn signals and pedestrian communication lighting into a single part. The bezel blends cutting-edge performance and aesthetics, including a “dead front,” seamless appearance, a high gloss finish enhanced with laser-etched effects and diffused back-lighting for safety and signature lighting.

Beat the heat in lighting applications:

Apec® offers high temperature resistance.

Apec® offers elevated short-term thermal resistance and good optical transmission which is suitable for items like fog lamp outer covers, optics and lenses. It features good outdoor weathering performance, and in combination with a coating system, offers AMECA and ECE approvals.

Apec® is the brand name for co-polycarbonates that constitute a further development of **Makrolon®** polycarbonate. Its unique combination of toughness, transparency, light stability, flowability, and its high heat resistance – which can reach 203°C (VST/B 120) – make **Apec®** ideal for molded parts that are subject to pronounced thermal stressing that general-purpose polycarbonate cannot cope with.



Transmission spectra of **Apec®** 1895 551022 and **Apec®** 1897551022 (4mm).*

The variable composition of the Apec® grades is reflected by their refractive index. As the bisphenol TMC content rises (rising heat resistance), the refractive index drops.

	Very high-flow Apec® grades	High-flow Apec® grades				High-viscosity grades
Properties*	**Apec®** 2095HF	**Apec®** 1695	**Apec®** 1795	**Apec®** 1895/1897	**Apec®** 2095/2097	**Apec®** 1803
Crystal-clear color	551022	551022	551022	551022	551022	551022
Vicat temperature (50N 120 K/h ISO306)	203 °C	158 °C	173 °C	183/182 °C	203/202 °C	184 °C
Transmission Ty (1 mm DIN5036-1)	89%	89%	89%	89%	89%	89%
Refractive index nD (ISO489A)	1.566	1.578	1.576	1.573	1.566	1.573
Abbe number	30	30	30	30	31	30
RTI relative temperature index (static yield stress) (UL 7468)	–	140 °C [5]	140 °C [6]	150 °C	150 °C	150 °C
UV protection	no	no	no	no/yes	yes	yes

5) Expected RTI
6)Typical value, no specification

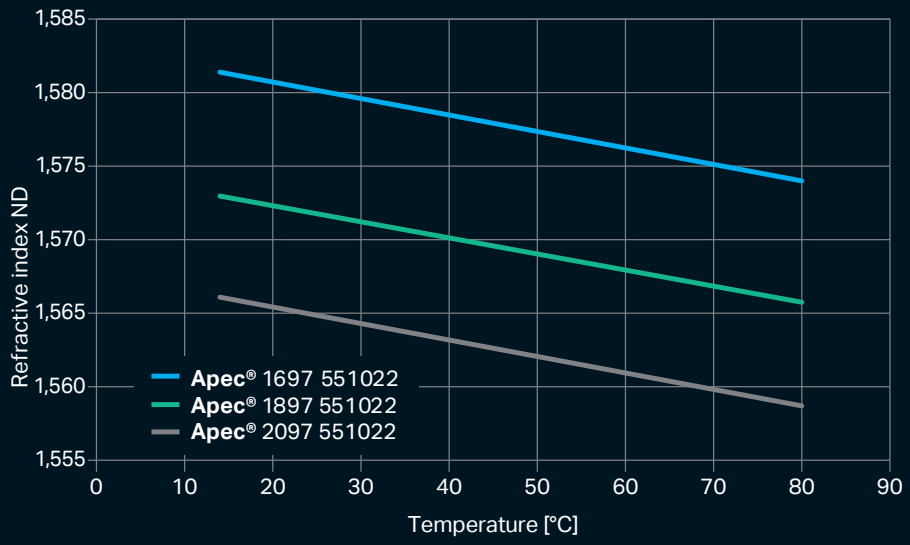
*Typical values and properties of Apec grades.

Apec® grades are frequently used in **Makrolon®** applications where elevated temperatures occur, particularly in automotive lighting. More detailed information is available in our Apec® brochure.

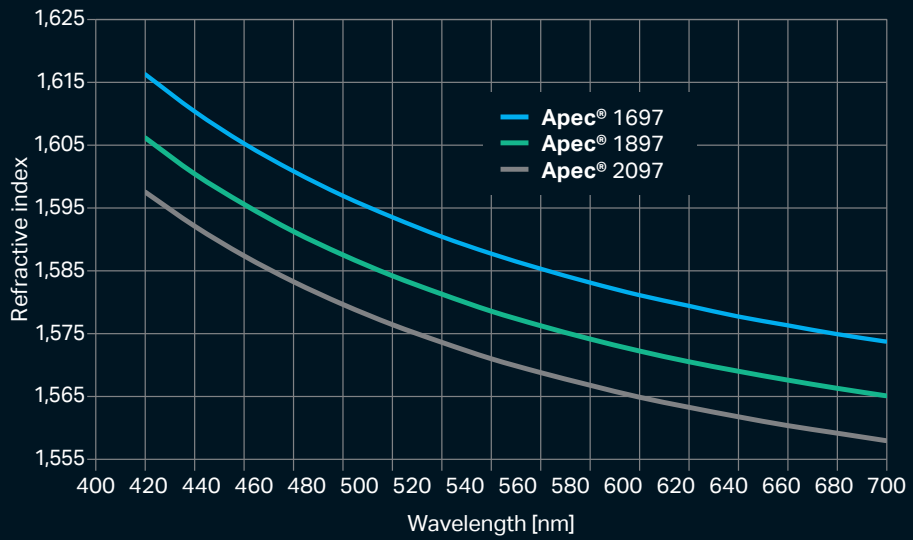
Apec® offers outstanding transparency and brilliance coupled with a high resistance to heat.

The dispersion of the refractive index is similar to that of **Makrolon®**, but shifted as a function of the bisphenol TMC content.

Internal lens which can be made from **Apec®**



Refractive index nD as a function of temperature



Refractive index as a function of wavelength

Leader in polymer materials.

We create materials the world relies on every day. Our high-tech polymers are used in nearly every area of modern life and in a wide range of industries: automotive, construction, healthcare, cosmetics, energy, electronics, sports and leisure.

But we don't just produce materials. Together with our partners and customers, we're taking big steps to tackle a fundamental challenge: shifting towards a Circular Economy. To achieve this bold goal, we're innovating efficient ways to close energy and material cycles, pushing the boundaries of what is possible with polymers.

We are a global partner with local production and customer support capabilities.

As the inventor of polycarbonates, We have been one of the largest producers of these materials on a global scale for over 60 years. We operate around 30 production sites in Europe, Asia and America – eight of which have world-scale plants.

Innovation process:

Collaborative approach with our customers from the very start.

Definition of customer requirements

Distinctive and innovative automotive concepts

Material and concept development

Specialized material solutions providing function integration and safety

New application technologies

Optimized and highly integrated manufacturing process
Advanced processing support

Material and concept development
Scale-up and customer production

Global competitive offerings
Comprehensive and competent product support

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