



Illuminating Ideas:
**Material Solutions
for LED Lighting**

Sustainable and Ecological Lighting: **Saving Energy and Money with LED as a Light Source**

The market for light-emitting diodes (LEDs) in lighting is booming. That is hardly surprising since LEDs consume less energy than incandescent bulbs and discharge lamps, help protect the environment, and have a much longer service life. Deploying suitable auxiliary optical systems and fiber optics allow light to be focused and directed more precisely, improving light quality and reducing light pollution. Excessive light spillover in urban areas is a concern among many scientists and environmentalists because it can alter the behavior of some birds and animals as well as change quality of life for humans. Properly designed LEDs can bring back the "dark skies".

Advantages of LED lighting:

- **Lower energy costs:** Much more energy-efficient than traditional light sources; maintenance-free
- **Much longer service life:** Up to 50,000 hours; high operational capability
- **Environmentally sound:** No lead, mercury or other heavy metals; lower CO₂ emissions
- **Excellent performance:** Tough, cold-resistant, instant start, controllable, directional light, color reproducibility, stable CCT (Correlated Color Temperature)





The low energy consumption and long service life of LEDs offer wide-ranging potential for a host of applications, e.g. bright street lights, building lighting, automotive lighting, traffic control systems, advertising boards, media displays with moving illuminated text to special color effects, and of course domestic lighting.

Broad portfolio for indoor and outdoor applications

If you are designing or manufacturing an LED lighting component for commercial, industrial or residential use, Covestro has the solution you need – from its broad portfolio of polycarbonate grades that are eminently suitable for the LED market. In addition to high light transmission,

all our grades display good heat resistance, excellent stability when exposed to LED luminous flux, outstanding flame-retardant properties, and a number of special features that are ideal for a wide range of LED applications.

One of the key applications for Makrolon® polycarbonate, the main brand name for our LED products, is in the production of lenses and reflectors that concentrate and direct the light generated by LEDs. Makrolon® improves the performance of the products through its high purity and excellent light transmission qualities. It is also cost-effective to process and, depending on the particular product, can deliver additional benefits such as flame retardancy.

The LED application fields for the use of our polycarbonate grades include:

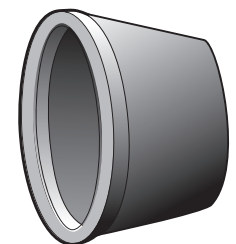
- Lenses, optics, light guides and diffusers
- Reflectors
- Heat sinks
- Housings and closures

Covestro has a wide range of products for indoor and outdoor replacement lamp and luminaire components

Makrolon® LED clear or Makrolon® in diffusion colors for **lenses/optics**



Makrolon® TC alternative to die casted aluminum for **heat sinks**

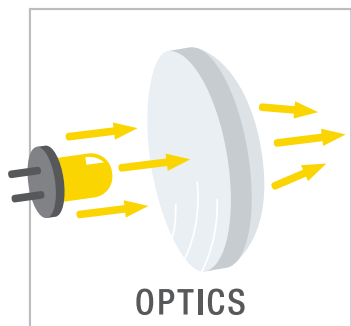


Makrolon® RW for **reflectors**

Makrolon® for **housings**



Credits: Georg Thiel/Fotolia.



Spot On for Secondary Optics

If you design or manufacture lenses (secondary optics) required to turn an LED into a lighting fixture, Covestro can supply Makrolon® polycarbonate grades to meet your specific requirements. For applications such as automotive headlamps, as well as outdoor or indoor lighting, our products display the following qualities:

- High light transmission over a broad range of wavelengths
- Excellent long-term heat and high flux stability
- Much longer product life than other polymers for designs with high heat requirements
- High mechanical stability
- Inherently good flame resistance
- Higher flame retardance of specific grades (UL94 V-0 and/or 5VA)

Covestro has a wide range of product solutions for optical applications:

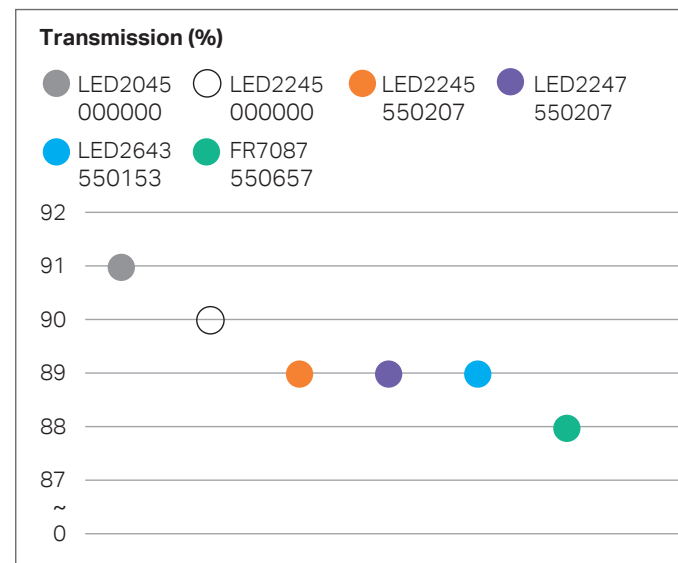
- Makrolon® injection molding grades
- Makrolon® extrusion grades
- Makrolon® based sheets and Makrofol® films as semi-finished products



Makrolon® injection molding grades for transparent optical applications

Makrolon® grade	Color number	MVR (cm³/10min)(2)	Transmission (%@2mm)	UV stabilized	UL94	RTI (°C)(1)
LED2045	000000	61	91	No	V-2 @ 0.71mm	125/115/125
LED2245	000000	36	90	No	V-2 @ 0.75mm	125/115/125
LED2245	550207	36	89	No	V-2 @ 0.75mm	125/115/125
LED2247	550207	36	89	Yes	V-2 @ 0.75mm	125/115/125
LED2643	550153	13	89	Yes	V-2 @ 0.75mm	125/115/125
FR7087	550657	12	88	Yes	V-0 @ 2.2mm 5VA @ 3.0mm	125/80/80

For more details on the regional availability of the products please contact your local Covestro representative.

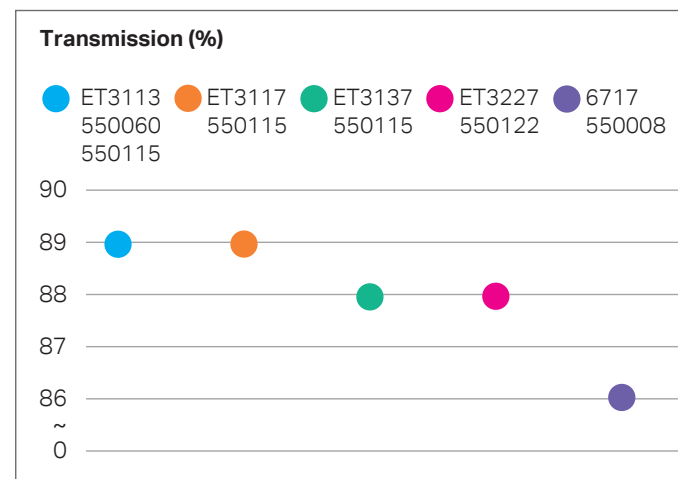


Makrolon® extrusion grades for transparent optical applications

Makrolon® grade	Color number	MVR (cm³/10min)(2)	Transmission (%@2mm)	UV stabilized	UL94	RTI (°C)(1)
ET3113	550060 550115	6	89	Yes	V-2 @ 0.75mm HB @ 1.5mm	125/115/125
ET3117	550115	6	89	Yes	V-2 @ 0.75mm HB @ 1.5mm	125/115/125
ET3137	550115	6	88	Yes	HB @ 0.75mm	80/80/80
ET3227	550122	3	88	Yes	HB @ 1.5mm	125/115/125
6717	550008	3	86	Yes	V-0 @ 2.0mm	125/115/125

(1) The RTI values are given in the following order: electrical/mechanical impact/mechanical strength.

(2) Measured at 300°C/1.2 kg





Makrolon® sheets and Makrofol® films for transparent optical applications

Optical features such as light guiding can be incorporated into semi-finished goods, i.e. sheets and films. These products offer special technical advantages:

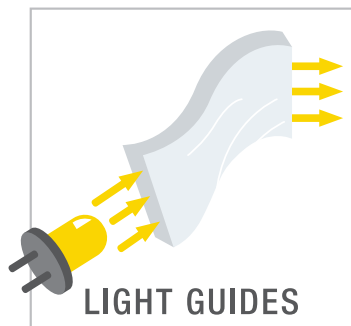
■ Makrolon® SX:
Microprismatic sheets with high-precision microlenses evenly embossed over the entire surface.

■ Makrofol® LM297:
Films with embossed lenticular lenses unite the individual light spots of LEDs. The deployment of two layers in perpendicular orientation to each other delivers full diffusion and de-glaring.

Product grade	Thickness	Transmission (%)	UV stabilized
Makrolon® SX	1.35 mm	90	Yes (1)
Makrofol® LM297	130 µ	85	No
	180 µ	90	
	280 µ	91	
	450 µ	88	

(1) only on one side of the sheet





Leading the Way for Light Guides

If you design or manufacture tertiary optical accessories such as light guides, Covestro can supply polycarbonate grades to meet your specific requirements in optimizing the use of LEDs. Whether your applications are in the automotive or non-automotive field, our light guide grades display the following product qualities:

- High light transmission over a broad range of wavelengths
- Excellent long-term heat and high flux stability
- Much longer product life than other polymers for luminaire designs with high heat requirements
- High mechanical stability
- Inherent flame retardance
- Exceptional purity to optimize light transmission

Makrofol® film for light guides

Light guide film (LGF) applications open up further areas of applications, such as keypads for handheld electronic devices. To make this technology possible, Makrofol® LM907 was developed with very special technical properties:

- Excellent light transmission and color consistency
- Excellent optical properties to enhance homogeneity and deliver high brightness
- Good embossing ability, formability, and dimensional stability

Covestro's range of product solutions for light guides

- Very high-purity Makrolon® LED grades
- Makrofol® films with light-guiding properties

Makrolon® LED grades for injection molding

The high purity of these Makrolon® LED grades makes them extremely suitable for light guides.

Makrolon® grade	Color number	MVR (cm³/10min)(2)	Transmission (% @ 2mm)	UV stabilized	UL94	RTI (°C)(1)
LED2045	000000	61	91	No	V-2 @ 0.71mm	125/115/115
LED2245	000000	36	90	No	V-2 @ 0.75mm	125/115/115
LED2245	550207	36	89	No	V-2 @ 0.75mm	125/115/115

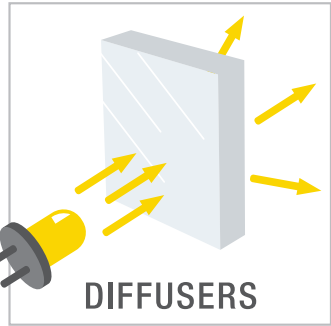
(1) The RTI values are given in the following order: electrical/mechanical impact/mechanical strength.

(2) Measured at 300°C/1.2 kg



Covestro offers a wide range of product solutions with different levels of diffusion properties and viscosity:

- Makrolon® injection molding grades
- Makrolon® extrusion grades
- Makrolon® sheets and Makrofol® films as semi-finished products



Shaping the Performance of Diffusers

If you design or manufacture light shaping diffusers to make LEDs more visually appealing, Covestro can supply you with materials for injection-molded or extruded diffuser parts that will create smooth and uniform light emissions, and avoid unwanted glare. Whatever applications your LED products are used for, our diffusion products display the following qualities:

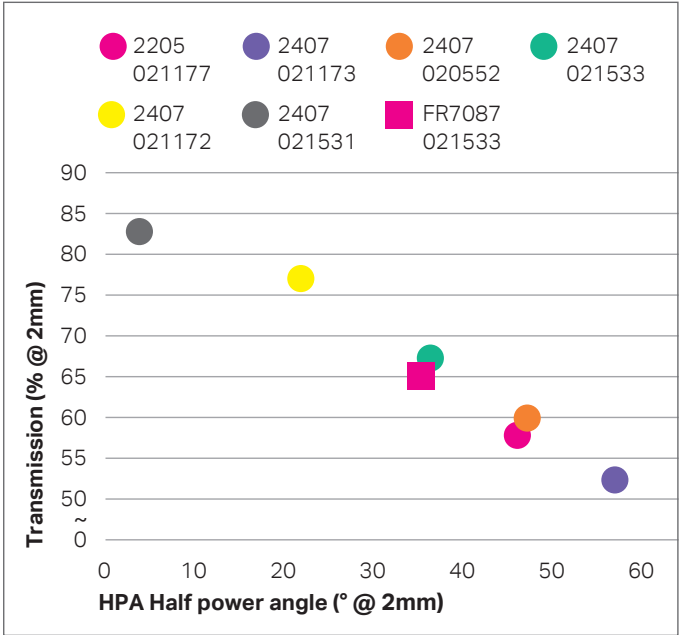
- High light transmission
- High half-power angle
- Strong hiding power of LED light source
- Diffusion products and colors adjusted to your requirements

Makrolon® injection molding products for diffusers

Makrolon® grade	Color number	MVR (cm³/10min)(2)	Transmission (% @ 2mm)	Half power angle (° @ 2mm)	UV stabilized	UL94	RTI (°C)(1)
2205	021177	36	58	47	No	V-2 @ 1.5mm	125/115/125
2407	021173	19	52	57	Yes	V-2 @ 0.75mm	125/115/125
2407	020552	19	60	48	Yes	V-2 @ 0.75mm	125/115/125
2407	021533	19	67	36	Yes	V-2 @ 0.75mm	125/115/125
2407	021172	19	77	22	Yes	V-2 @ 0.75mm	125/115/125
2407	021531	19	83	5	Yes	V-2 @ 0.75mm	125/115/125
FR7087	021533	12	66	37	Yes	V-0 @ 2.2mm 5VA @ 3mm	125/80/85

(1) The RTI values are given in the following order: electrical/mechanical impact/mechanical strength.
 (2) Measured at 300°C/1.2 kg

Additional products with different levels of diffusion properties and viscosity are available to meet customers' specific needs. For more details on the regional availability of the products please contact your local Covestro representative.



The scattering effect can be controlled by the film thickness as well.

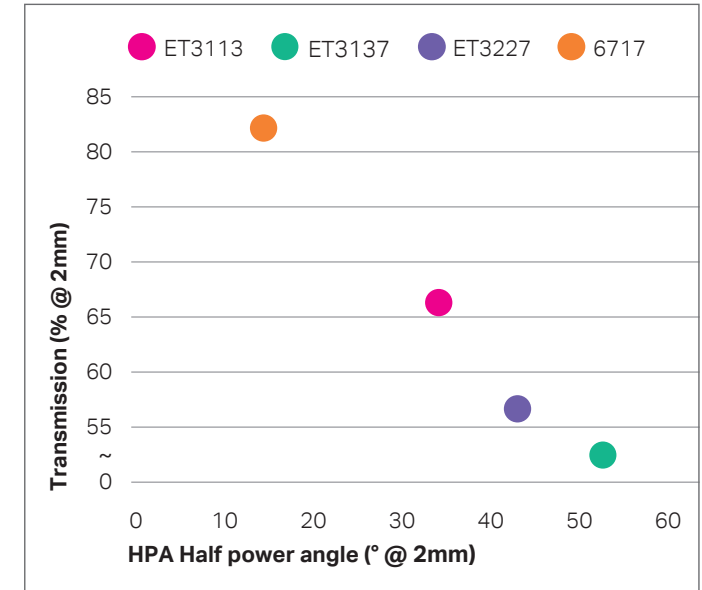
Makrolon® extrusion products for diffusers

Makrolon® grade	Color number	MVR (cm³/10min)(2)	Transmission (% @ 2mm)	Half power angle (° @ 2mm)	UV stabilized	UL94	RTI (°C)(1)
ET3113	021549	6	66	32	Yes	V-2 @ 0.75mm HB @ 1.5mm	125/115/125
ET3137	021458	6	50	52	Yes	HB @ 0.75mm	80/80/80
ET3227	021298	3	56	41	Yes	HB @ 1.5mm	125/115/125
6717	021449	3	82	14	Yes	V-0 @ 2mm	125/115/125

(1) The RTI values are given in the following order: electrical, mechanical impact, and mechanical strength.

(2) Measured at 300°C/1.2 kg

Additional products with different levels of diffusion properties and viscosity are available to meet customers' specific needs.



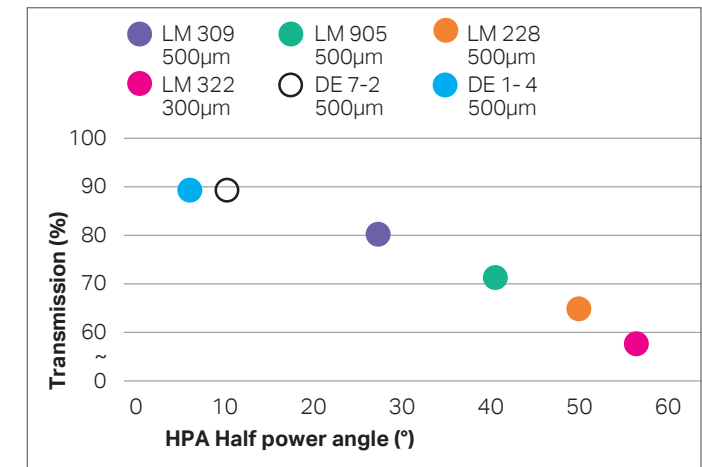
Makrofol® films for diffusion applications

Makrofol® films offer a broad variety of diffusion properties:

- The diffusion can vary from translucent and strongly light-scattering films to highly transparent and weakly scattering ones.
- The light scattering effect can be influenced by the amount of additive and/or a textured surface.

Makrofol® grade(1)	Transmission (%)	Half power angle (°)
LM 309 500µm	81	28
LM 905 500µm	73	41
LM 228 500µm	65	51
LM 322 300µm	57	58
DE 7-2 500µm	89	10
DE 1-4 500µm	89	7

(1) Also available in other thicknesses



The scattering effect can be controlled by the film thickness as well.

Makrolon® sheets for diffusion applications

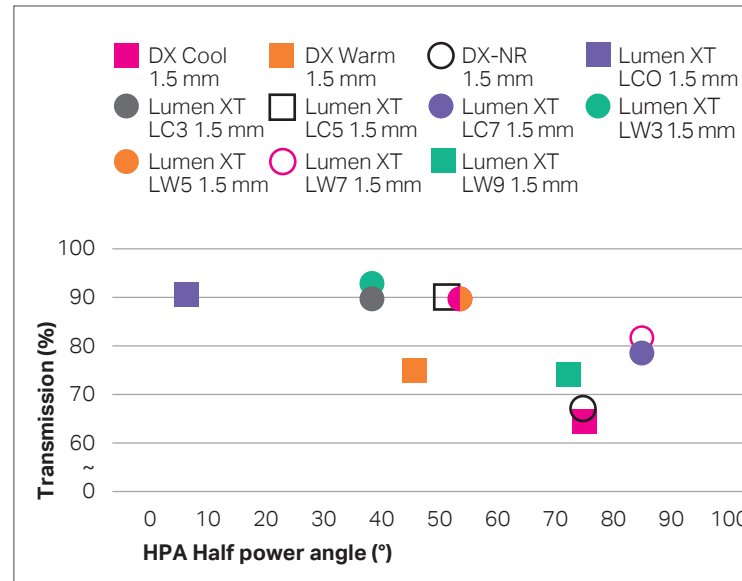
If you are designing new LED luminaires or retrofitting conversions to LED, sheets may be the solution you need:

- Makrolon® DX and Makrolon® Lumen XT diffuser sheets deliver a unique combination of high light diffusion and transmission.
- Makrolon® DX offers excellent hot spot obscuration.
- Makrolon® Lumen XT comes in a wide range of standard diffusion levels.
- Makrolon® DX sheets can be formed into a variety of shapes without losing the optical properties.
- Makrolon® Lumen XT is covered with a special surface structure.
- Makrolon® DX has a special matte surface which can be thermoformed.

Makrolon® grade	Thickness (mm)(2)	Transmission (%)	Half power angle (°)
DX Cool	1.5	65	76
DX Warm	1.5	76	47
DX-NR	1.5	69	75
Lumen XT LCO	1.5	91	7
Lumen XT LC3	1.5	90 ⁽¹⁾	38
Lumen XT LC5	1.5	90	53
Lumen XT LC7	1.5	79	86
Lumen XT LW3	1.5	93	38
Lumen XT LW5	1.5	90	53
Lumen XT LW7	1.5	82	86
Lumen XT LW9	1.5	73	73

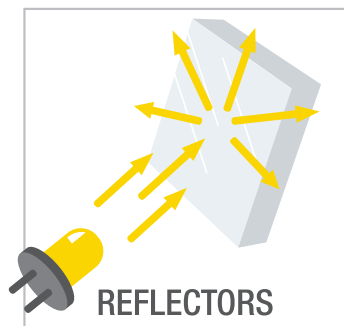
(1) ASTM D 1003

(2) Also available in other thicknesses





Credits: Christian Hillebrand/Fotolia



Enhancing Diffusive Reflectors

If you design or manufacture LED components, Covestro can supply you with top-quality polycarbonate grades, sheets and films for diffusive reflectors. As diffuse reflection involves incident light being reflected from a surface at many angles rather than one, an ideal reflecting surface will display equal luminance from all directions lying in the half-space adjacent to the surface.

This is where our polycarbonate grades excel with convincing product qualities:

- High reflectivity
- High temperature stability
- Mechanical strength

Covestro offers a wide variety of product solutions to meet specific needs:

- White reflective surfaces without any secondary operation needed
- Makrolon® RW grades for injection molding and extrusion
- Makrolon® sheets and Makrofol® films as semi-finished products



Makrolon® injection molding grades for diffusive reflectors

Makrolon® (1) grade	Color number	MVR (cm³/10min)(2)	Total reflectance (%)	UV stabilized	UL94	RTI (°C)(3)
RW2407	012363	19	96.5	Yes	V-2 @ 1.5mm	125/115/115
RW2407	010226	19	94.5	Yes	V-2 @ 1.5mm	125/115/125
RW6267X	012363	19	96	Yes	V-0 @ 1.5mm	125/115/125
RW6265X	010226	19	94	No	V-0 @ 1.5mm	125/115/125
RW6267X	012268	19	95	Yes	V-0 @ 1.5mm	125/115/125

Makrolon® extrusion grade for diffusive reflectors

Makrolon® (2) grade	Color number	MVR (cm³/10min)(3)	Total reflectance (%)	UV stabilized	UL94	RTI (°C)(1)
ET RW210	012346	10	96	No	HB @ 0.75mm	80/80/80

(1) The RTI values are given in the following order: electrical/mechanical impact/ mechanical strength.
(2) Also available in non-UV stabilized grades
(3) Measured at 300°C /1.2 kg



Makrolon® sheets and Makrofol® films for diffusive reflector applications

Makrolon® sheets and Makrofol® films for diffusive reflector applications offer a broad spectrum of technical benefits and improve the light output:

- Combination of dimensional stability and rigidity in case of sheets
- High reflectance (~97%)
- Increase in LOR (Light Output Ratio) values of luminaires
- For visible parts Makrolon® sheets are available with a matte surface
- Housings or other visible parts can be thermoformed from Makrolon® sheets to optimize the total reflectance of the luminaire
- Malleable films

Makrolon® sheets for diffusive reflectors

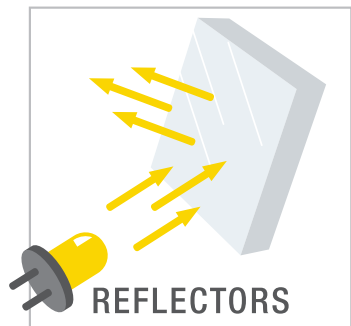
Makrolon® grade	Light reflectance (%)	UL
RX	> 96	V-2 @ 1.5mm V-2 @ 3.0mm
RX Matte	94	V-2 @ 1.0mm
RX-UV	95	
RX-FR	> 94	V-0 @ 1.5mm V-0 @ 3.0mm

Makrofol® films for diffusive reflectors

Makrofol® grade	Thickness (µm)	Light reflectance (%)
LM 903	300/400/500	> 96
LM 327	250/330	> 97



Credits: Olaser/Stockphoto



Improving the Surface Qualities of Specular Reflectors

If you design or manufacture LED components, Covestro can supply you with top-quality base materials for specular reflectors – either made by injection molding or extrusion. Our polycarbonate grades ensure your specular reflectors perform better through displaying the following qualities:

- High gloss surface allowing excellent reflectivity of metal layers
- Good adhesion of metallic surface to base polymer
- Best surface quality due to specially developed production cycle
- Low thermal expansion coefficient

The Covestro product solutions include the following:

- Base materials for metallic reflectors with secondary operation needed
- Metallic surfaces applied either by sputtering or physical vapor deposition (PVD)

Product grade	MVR (cm ³ /10min) ⁽²⁾	Vicat (°C)	CLTE parallel (10 ⁻⁴ /K)	CLTE trans- verse (10 ⁻⁴ /K)	UL94
Makrolon® 2405	19 ⁽¹⁾	143	0.65	0.65	V-2 @ 1.5mm
Makrolon® 9415	6 ⁽¹⁾	145	0.4	0.65	V-0 @ 1.5mm
Bayblend® T80 XG	27 ⁽²⁾	130	0.55 – 0.75	0.55 – 0.75	HB @ 0.85mm
Apec® 1695	45 ⁽³⁾	158	0.7	0.7	HB @ 1.5mm
Apec® 2095	8 ⁽³⁾	203	0.7	0.7	HB @ 1.5mm

Further grades are available on request.

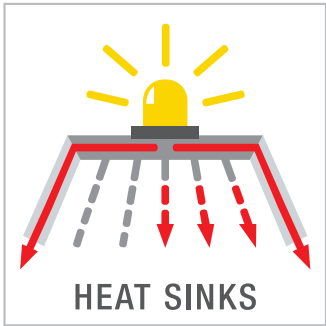
⁽¹⁾ 300°C / 1.2 kg

⁽²⁾ 260°C / 5 kg

⁽³⁾ 330°C / 2.16 kg



Credits: Zhudi Feng / Shutterstock



Optimizing LED Heat Management

As a designer or manufacturer of LED lamps or luminaires, you know how crucial thermal management is to the long-term performance. To meet the need for efficient cooling, Covestro supplies a high-performance Makrolon® polycarbonate for injection-molded heat sinks.

This Makrolon® based grade offers a thermal conductivity up to 22W/m·K (depending on the measuring technique employed).

The benefits include:

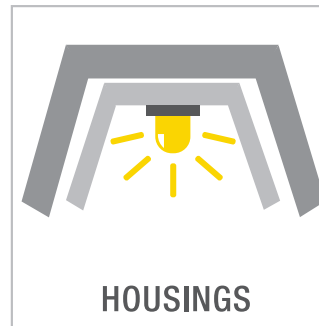
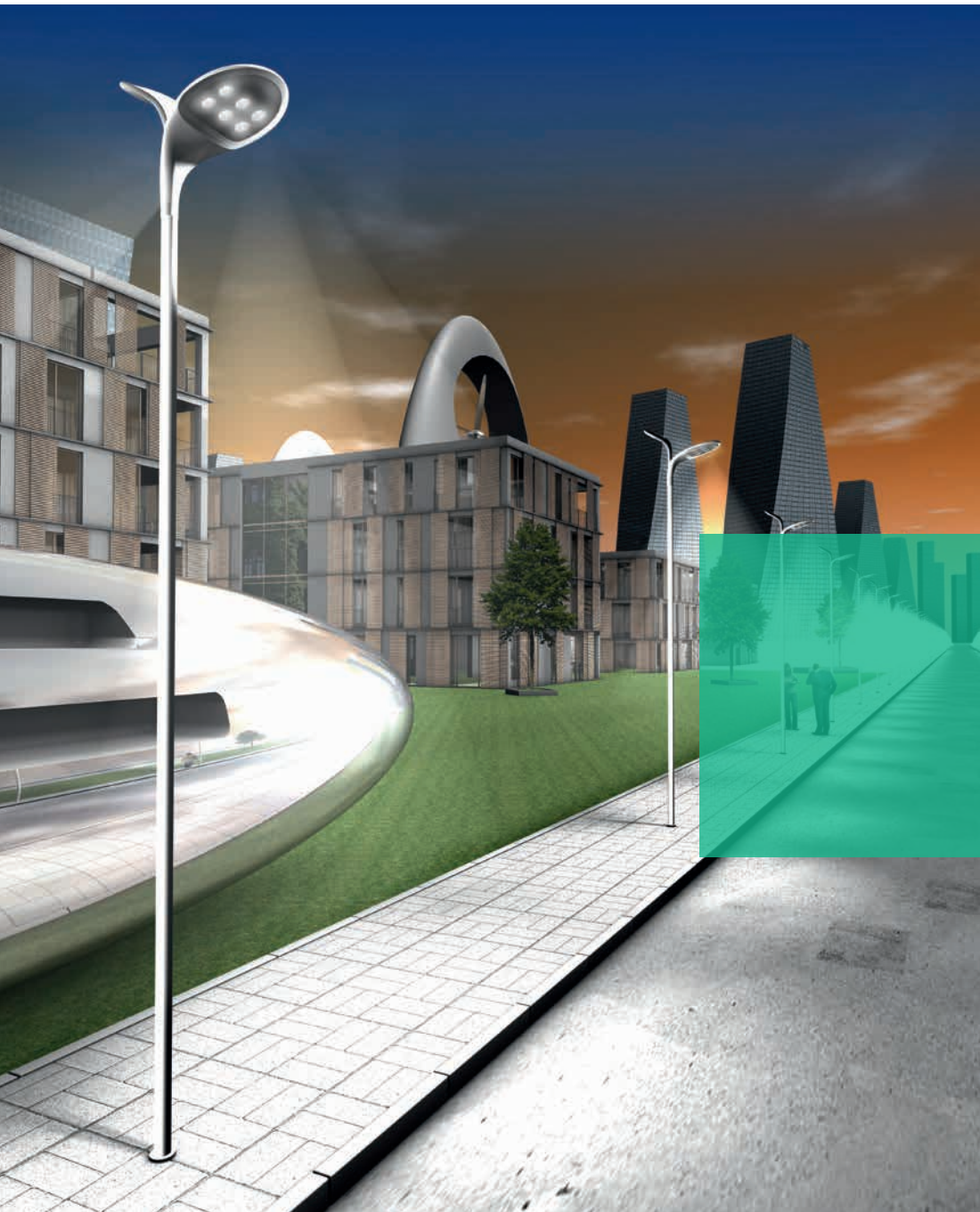
- Reduced weight of LED light engine
- Strong heat-transferring capability
- High level of design freedom
- Cost-effective production
- Easy processing though high viscosity

Makrolon® grade	Color number	Thermal conductivity (W/m·K)	UL94	RTI (°C) ⁽¹⁾
TC8010	999900	10 ⁽²⁾	V-0 @ 3mm	-/80/80
TC8030	999900	20 ⁽²⁾ 14 ⁽³⁾	V-0 @ 2mm	80/130/130

⁽¹⁾ The RTI values are given in the following order: electrical/mechanical impact/mechanical strength

⁽²⁾ ISO 22007-2

⁽³⁾ ASTM E 1461-01



Building Better Housings

As an LED lighting designer or manufacturer, you know what a key role the housing plays. Covestro can supply you with Makrolon® polycarbonate and Bayblend® and Makroblend® polycarbonate blends for LED housing applications.

The product qualities include:

- Makrolon®: high mechanical strength, heat and flame resistance
- Bayblend®: high impact strength and good indoor light stability
- Makroblend®: good low-temperature impact strength and coatability; improved chemical resistance

Product grade	MVR (cm ³ /10min)	UV stabilized	UL94	RTI (°C) ⁽¹⁾
Makrolon® 6487	10.5 ⁽²⁾	Yes	V0 @ 1.5mm 5VA @ 3mm	125/115/125
Bayblend® T85 XF	19 ⁽³⁾	No	HB @ 0.85mm	
Makroblend® UT 3907	44 ⁽³⁾	Yes	HB @ 1.6mm	

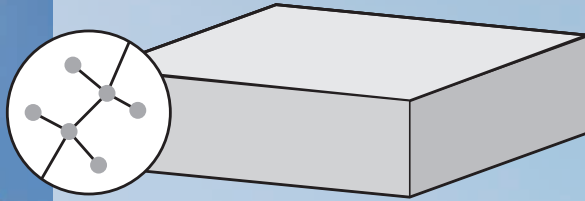
⁽¹⁾ The RTI values are given in the following order: electrical, mechanical impact, and mechanical strength.

⁽²⁾ 300°C / 1.2 kg

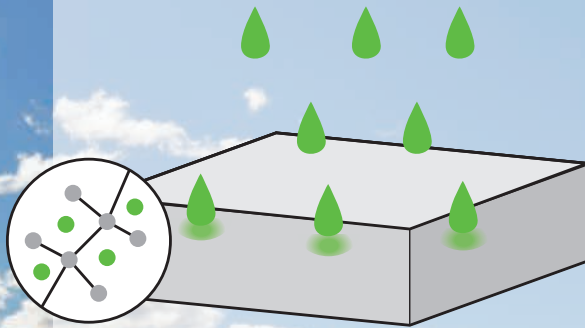
⁽³⁾ 260°C / 5 kg

The AURA™ UV protection process

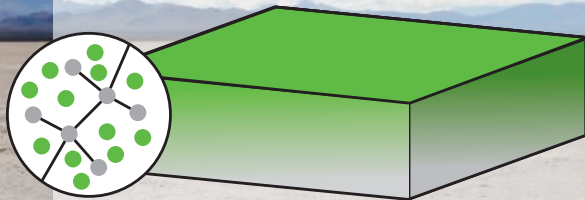
Clear amorphous
Makrolon®
polycarbonate matrix



UV additives are in-
fusing into Makrolon®
polycarbonate matrix



UV additives infused
in Makrolon® poly-
carbonate matrix
40 micron deep



Credits: Wesvandinter/Stockphoto

AURA™ UV Protection

AURA™ UV protection is an additional technology to improve the lifetime performance of luminaires. UV protection is of course particularly important if you are designing or manufacturing outdoor LED fixtures. Thanks to the AURA™ infusion process transparent parts display:

- Long-term UV stability
- Minimal change in light transmission and haze development
- No additional surface required, e.g. a coating

The benefits you enjoy from this straightforward UV protection technology are significant:

- Greater UV stability of finished parts
- No chemical or physical impact on the part
- Easy application
- Solvent-free

For further information:

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The manner in which you use and the purpose to which you put and utilize our products, technical assistance and information (whether verbal, written or by way of production evaluations), including any suggested formulations and recommendations, are beyond our control. Therefore, it is imperative that you test our products, technical assistance, information and recommendations to determine to your own satisfaction whether our products, technical assistance and information are suitable for your intended uses and applications. This application-specific analysis must at least include testing to determine suitability from a technical as well as health, safety, and environmental standpoint. Such testing has not necessarily been done by Covestro.

Unless we otherwise agree in writing, all products are sold strictly pursuant to the terms of our standard conditions of sale which are available upon request. All information and technical assistance is given without warranty or guarantee and is subject to change without notice. It is expressly understood and agreed that you assume and hereby expressly release us from all liability, in tort, contract or otherwise, incurred in connection with the use of our products, technical assistance, and information. Any statement or recommendation not contained herein is unauthorized and shall not bind us. Nothing herein shall be construed as a recommendation to use any product in conflict with any claim of any patent relative to any material or its use. No license is implied or in fact granted under the claims of any patent.

With respect to health, safety and environment precautions, the relevant Material Safety Data Sheets (MSDS) and product labels must be observed prior to working with our products.

Typical value

These values are typical values only. Unless explicitly agreed in written form, they do not constitute a binding material specification or warranted values. Values may be affected by the design of the mold/die, the processing conditions and coloring/pigmentation of the product. Unless specified to the contrary, the property values given have been established on standardized test specimens at room temperature.

These products are not designated for the manufacture of a medical device or of intermediate products for medical devices¹. [These products are also not designated for food contact², including drinking water, or cosmetic applications. If the intended use of the products are for the manufacture of a medical device or of intermediate products for medical devices, for food contact products or cosmetic applications Covestro must be contacted in advance to provide its agreement to sell such products for such purpose]. Nonetheless, any determination as to whether a product is appropriate for use in a medical device or intermediate products for medical devices, for food contact products or cosmetic applications must be made solely by the purchaser of the product without relying upon any representations by Covestro.

¹ Please see the "Guidance on Use of Covestro Products in a Medical Application" document.

² As defined in Commission Regulation (EU) 1935/2004.