

LED EVENEMENT 2013

LED applicaties voor designers,
engineers en lichtarchitecten

1931 CONGRESCENTRUM
BRABANTHALLEN DEN BOSCH

WOENSDAG 27 NOVEMBER 2013



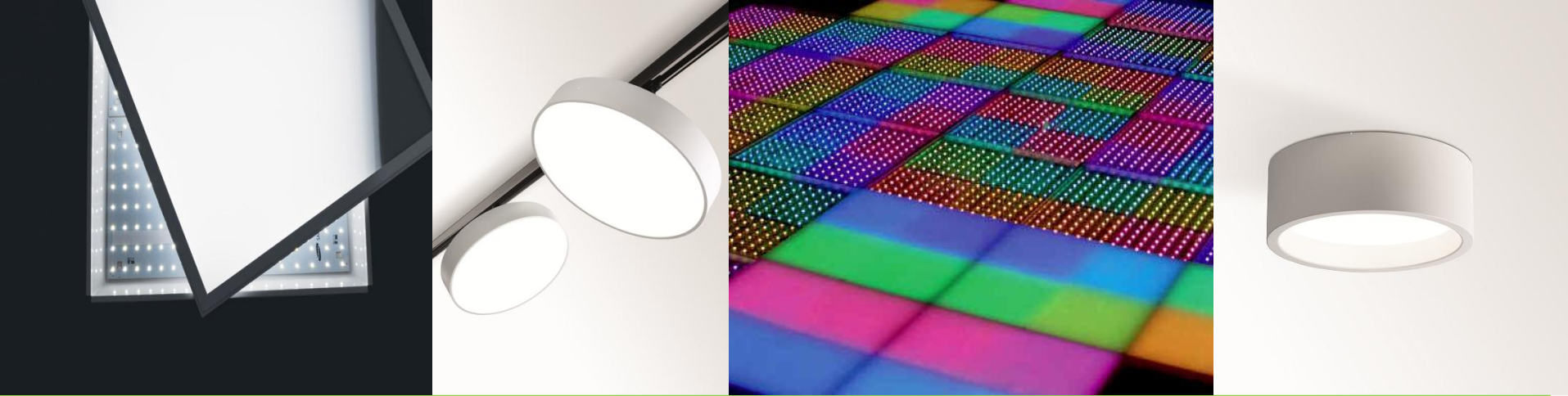
Science For A Better Life

Advanced plastics for LED lighting

Polycarbonate sheets: solution for light diffusion

Wojciech Cieplik

Global Business Development Manager LED



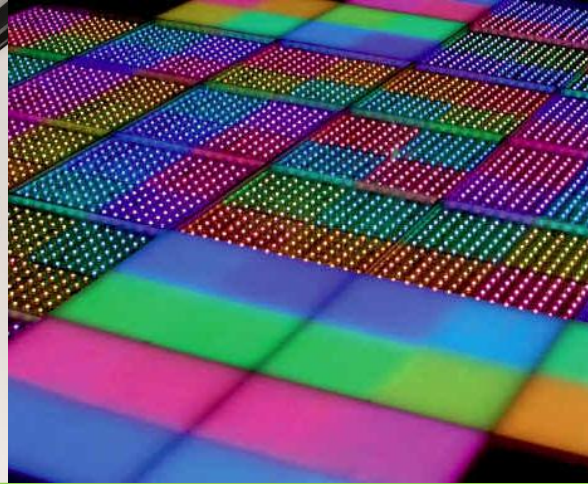
Contents:

Bayer MaterialScience's focus on LED lighting

Sheet business @ BMS

Special polycarbonate sheets for light diffusion

Other sheet, films and resin solutions for LED lighting from BMS



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LED Lighting Market

- LED lighting is growing fast and will be a significant lighting technology in the future
- Market for LEDs used in lighting grew 44% in 2011 (\$1.2 to 1.8 billion)
- Double digit growth for next 5 years
- Drivers for the LED lighting technology growth
 - Long life
 - No UV light
 - No mercury
 - Dimmable
 - Cold temperature operation
 - Rugged / vibration resistant
 - Design flexibility / small profile
- Decreasing costs
- Increasing efficacy (energy efficiency)

Figure 1.2
White LED Technology and Cost
Cost per Kilolumen

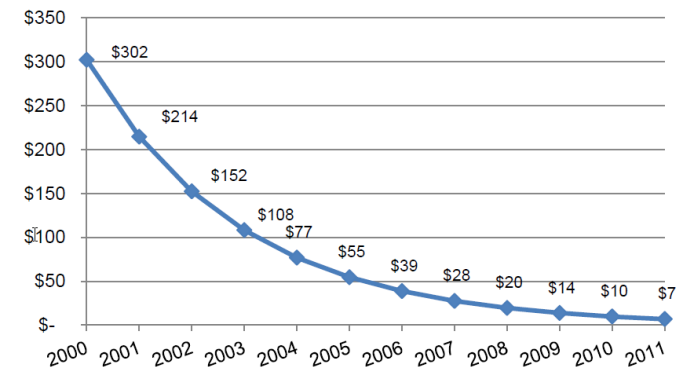
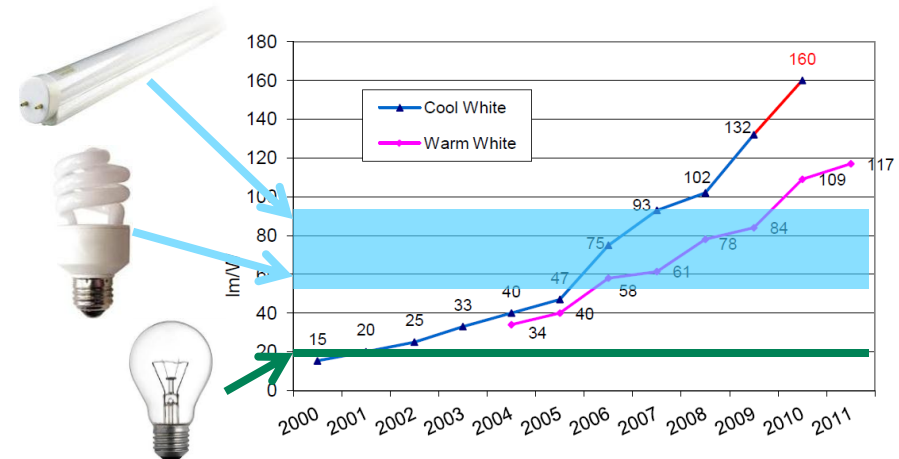


Figure 1.1
Evolution of White LED Luminous Efficacy
Best Available 1W Commercial Products



Source: Strategies Unlimited
2012 The Market for High-Brightness LEDs in Lighting

The view of the Earth at night

20% of the electrical power is consumed by general lighting – the demand will increase by 80% until 2030 (acc. to UNEP, 2009)





BAYER's focus on global challenges:

Longer life expectancy results in increasing demand for innovative medicine and therapies

longer life

Ensure sufficient food supplies while acreage per capita is decreasing

food

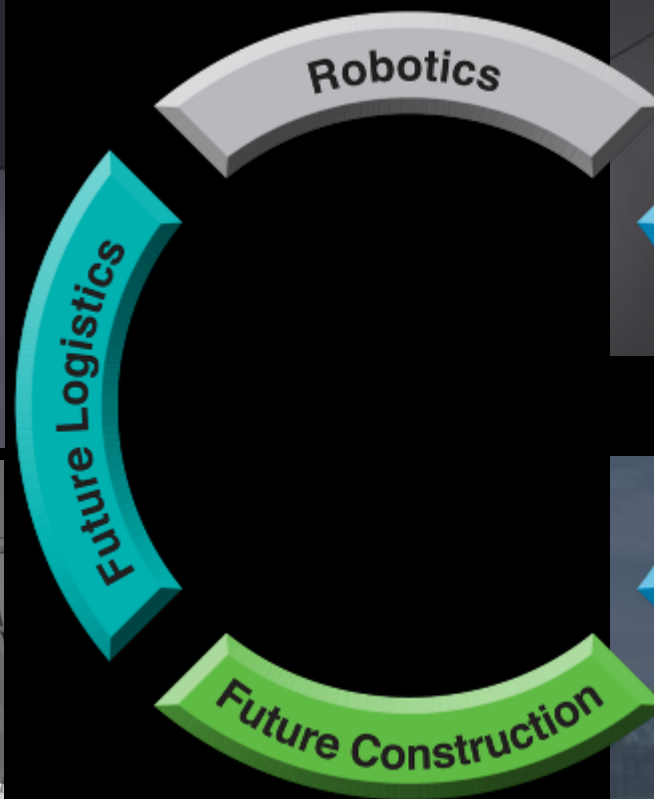


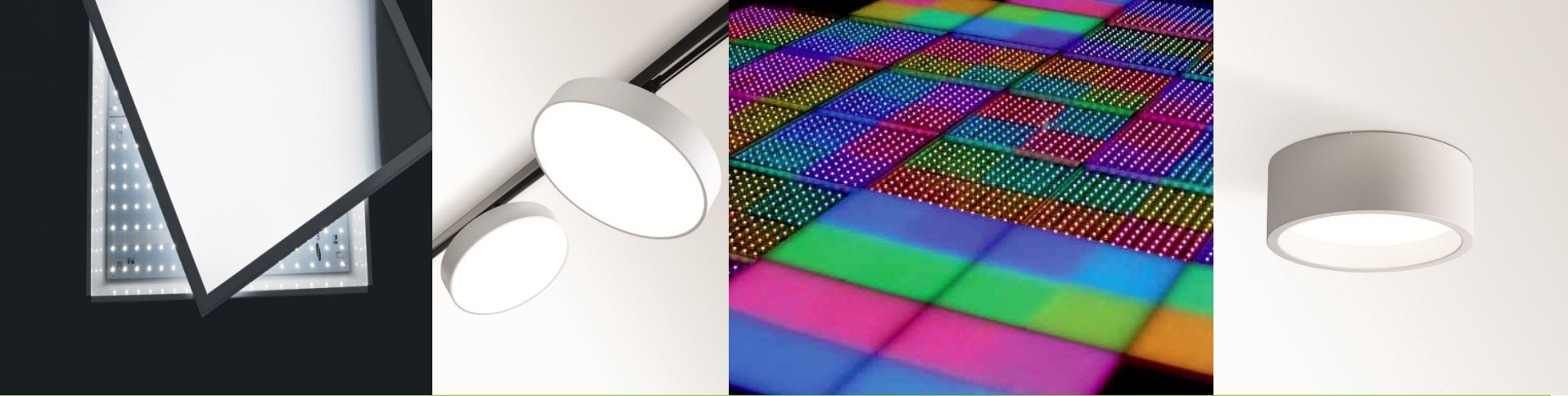
Supply alternative energy feedstocks such as biofuels to meet the increasing energy demand

energy

Reduce greenhouse gas emissions while economies are growing

emissions





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Sheet business @ BMS

Bayer MaterialScience develops, produces and sells high-value **plastic sheets made of Makrolon®** polycarbonate and thermoplastic polyester for the global market.

A broad range of **high-quality products and profound know-how** make the company a leading brand manufacturer of plastic sheets.





Global sheet business @ BMS

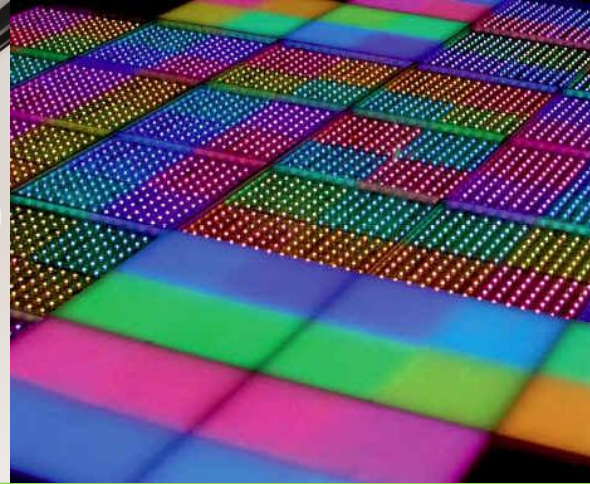
We are close to you

Offering a wide product range of high-quality polycarbonate sheet solutions around the world



● Bayer MaterialScience polycarbonate sheet companies

As of Sep 2012



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Diffusers for LED lighting

Performance requirements

❖ Light transmission

- Directly affects the energy efficiency of the fixture
- Manufacturers always desire maximum light transmission

❖ Light diffusion

- Different levels of diffusion are requested for different diffusion goals

❖ Color control

- CCT, CRI goals

❖ Application-driven functions

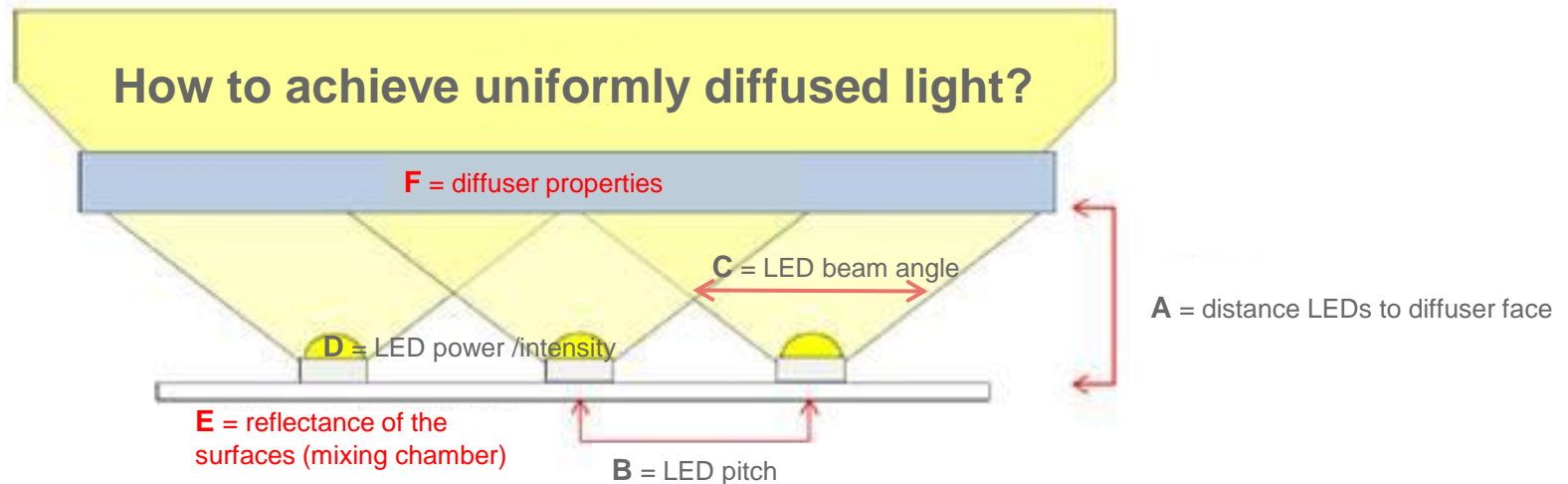
- weatherability, thermoformability, surface finish (matt/gloss)

❖ How to measure diffusion?

- No industry accepted test procedure
- Standards vary

What is the optimal fixture design?

Quality of diffusion triggered by the variety of influence factors



Variables A-F are in lighting manufacturers' hands and have to be considered during the design phase.

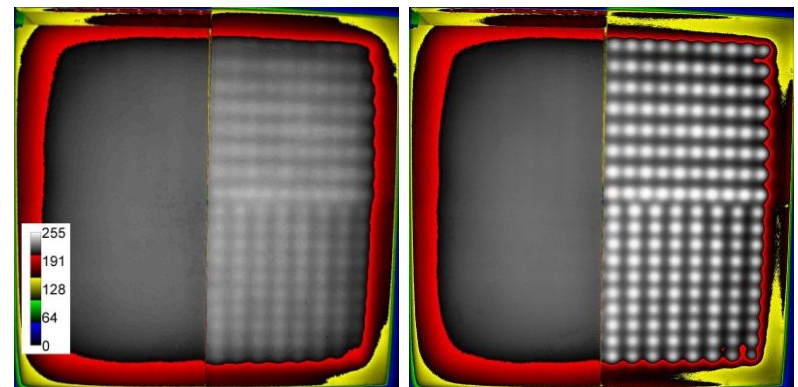
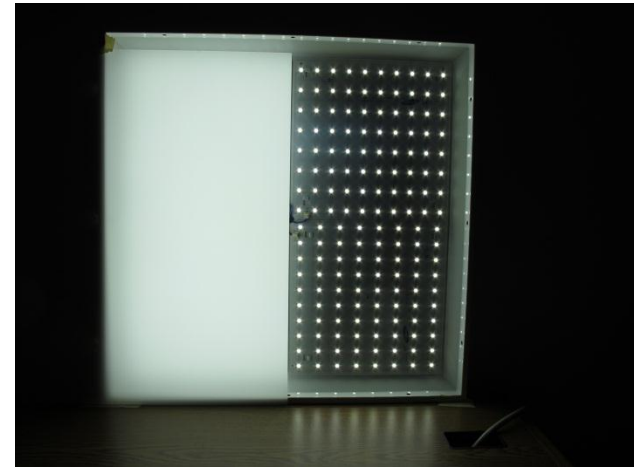
Observations:

- Diffusers (F) are very often specified last
- Reflectors (E) are often underestimated

Case study

Choosing a diffuser sheet

- ❖ Fixture producer's evaluation
 - Subjective, with mind of consumer
 - Example: small troffer
- ❖ Higher transmission levels do not sufficiently hide hot-spots
- ❖ False coloring – assign colors to different light intensities



Case study

Choosing a diffuser sheet

❖ Fixture producer's evaluation

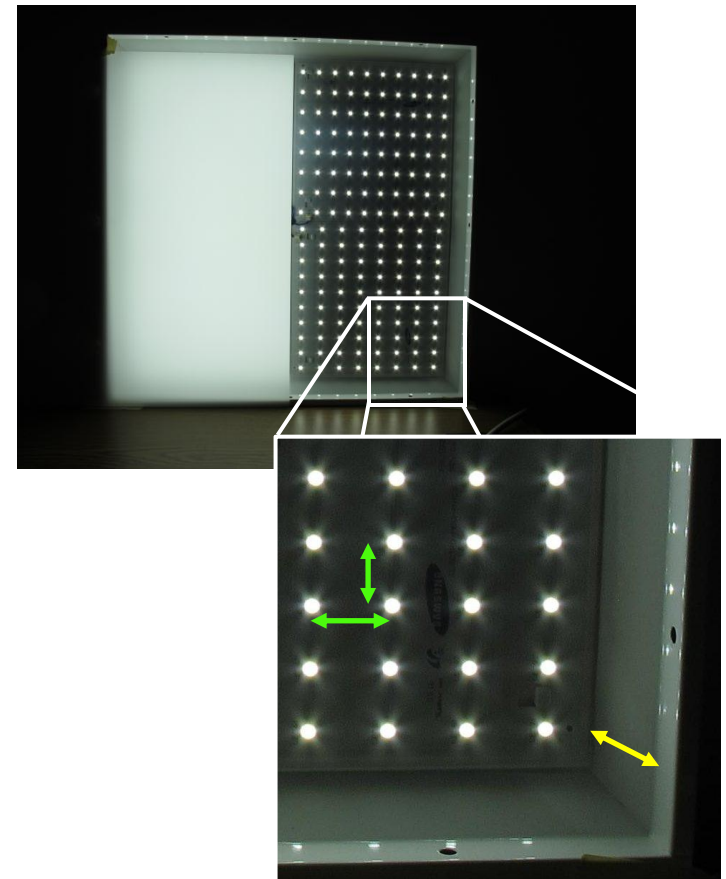
- Subjective, with mind of consumer
- Example: small troffer

❖ Higher transmission levels do not sufficiently hide hot-spots

❖ False coloring – assign colors to different light intensities

❖ What about other fixture geometries?

- LED to diffuser distance (A)
- LED spacing (B)
- LED beam angle (C)
- Different LED intensity (D)



Case study

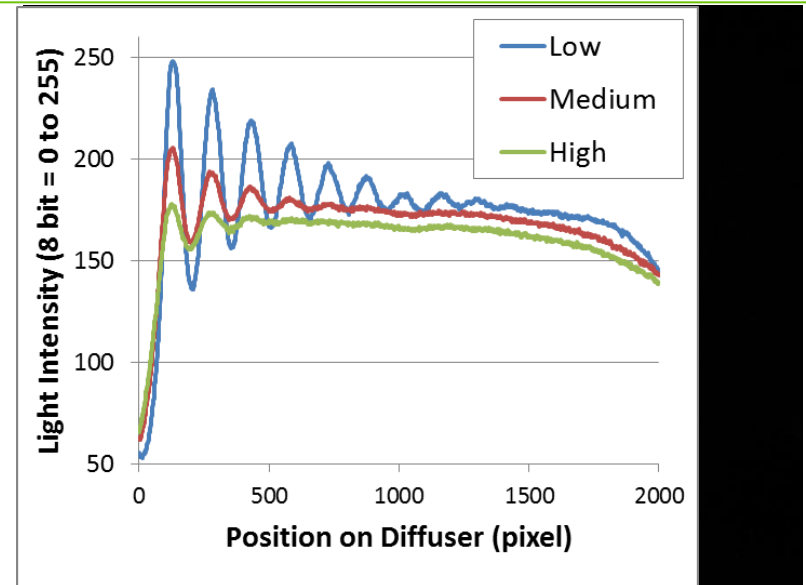
Choosing a diffuser sheet

❖ “Evaluation” Fixture

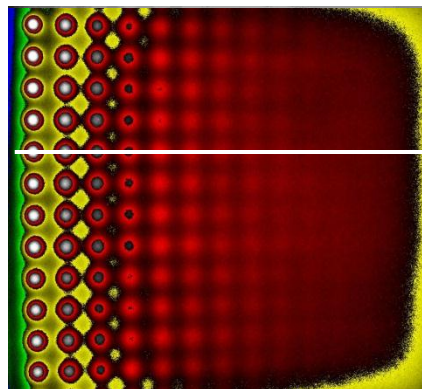
- LED board to diffuser distance varies from left to right

❖ False coloring

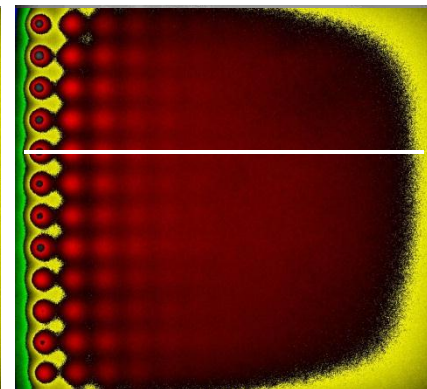
❖ Light intensity as a function of position



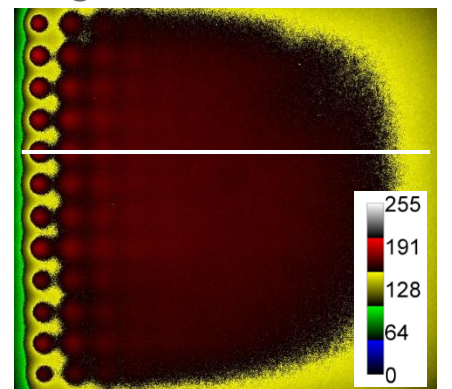
Low Diffusion



Medium



High

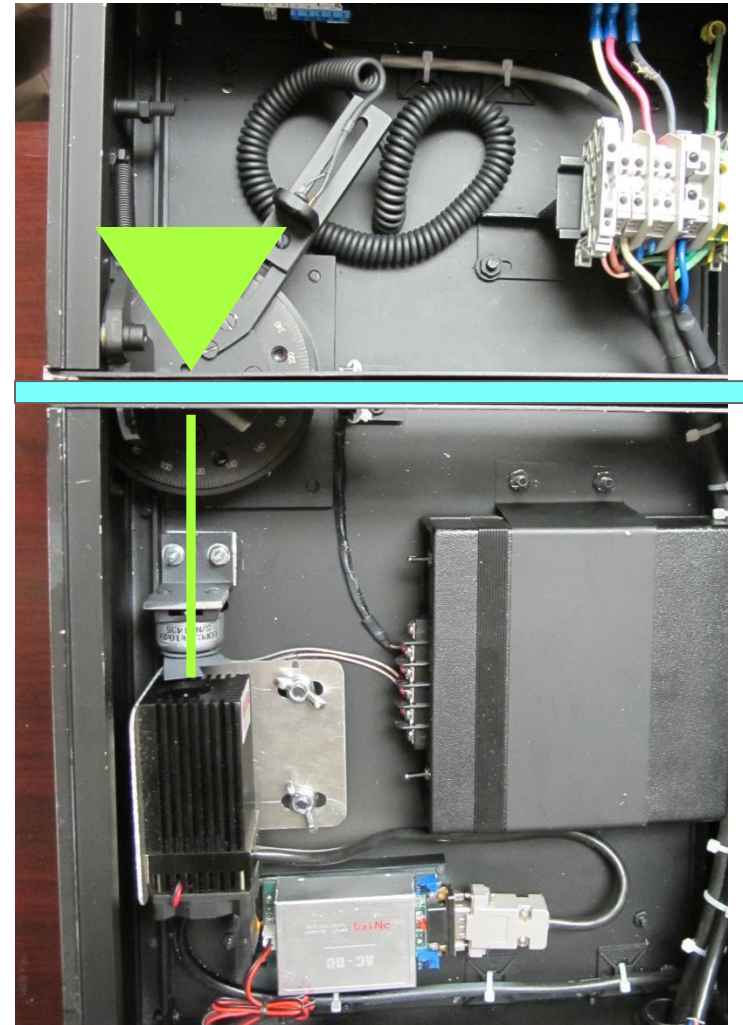


How to communicate about diffusion?

Quantitative diffusion measurement

❖ Measure spread of collimated light

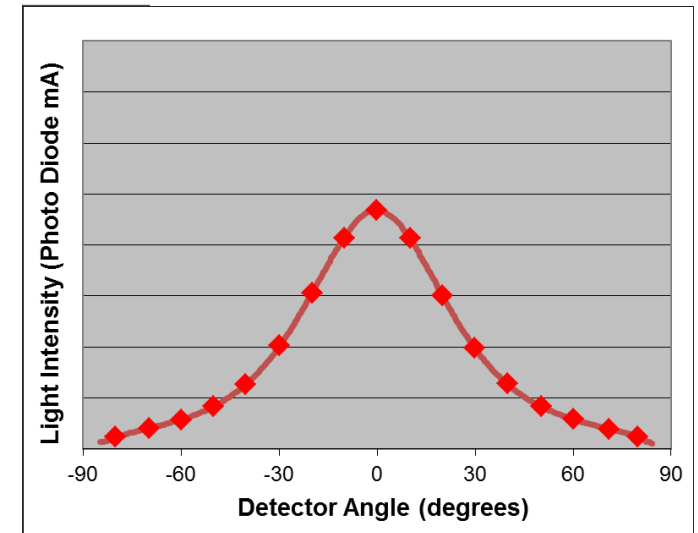
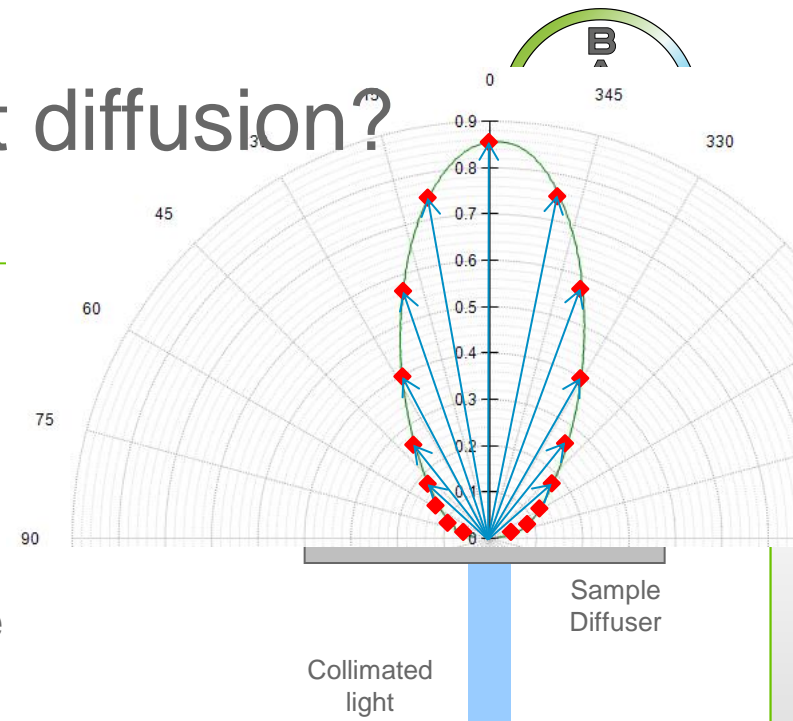
- Collimated light = laser
- Light detector = photodiode



How to communicate about diffusion?

Quantitative diffusion measurement

- ❖ Measure light intensity as function of angle
 - Highest intensity at 0°
 - Decay in intensity with angle
- ❖ Symmetric diffuser – Gaussian type response
- ❖ Polar coordinates

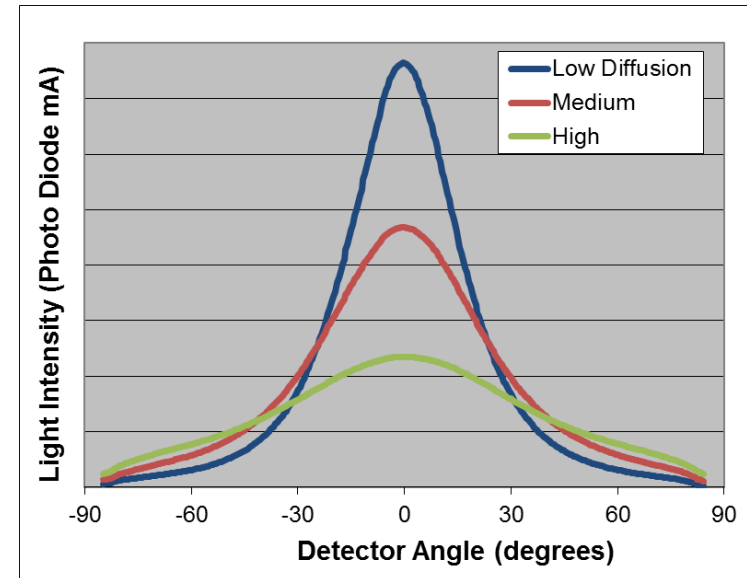


How to communicate about diffusion?

Quantitative diffusion measurement

❖ Amount of diffusion can be described by the intensity vs. angle plot

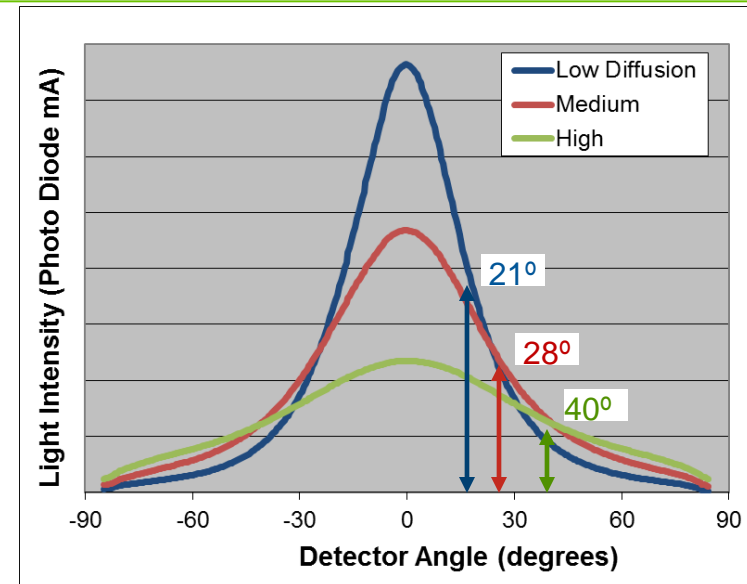
- Width of plot
- Wider = more diffusion



Half-value angle

Quantitative diffusion measurement

- ❖ Amount of diffusion can be described by the intensity vs. angle plot
 - Width of plot
 - Wider = more diffusion
- ❖ Width is often described by a single number
 - Half-value angle
 - Angle where intensity is half of the peak intensity
 - Low diffusion, half-value angle = 21°
 - Medium diffusion, half-value angle = 28°
 - High diffusion, half-value angle = 40°
 - Used in PDS but also as manufacturing QC parameter or a KPI



How to achieve light diffusion?

Two technologies are available: separately or combined

- **Scattering** → bulk diffusion

↳ Scattering additive within the bulk (“opal diffuser”)

- **Refraction** → optically active surface

↳ “Frosted” or “sanded” materials with irregular (statistical) surface structure

Makrolon® DX

Scattering by means of modern additives

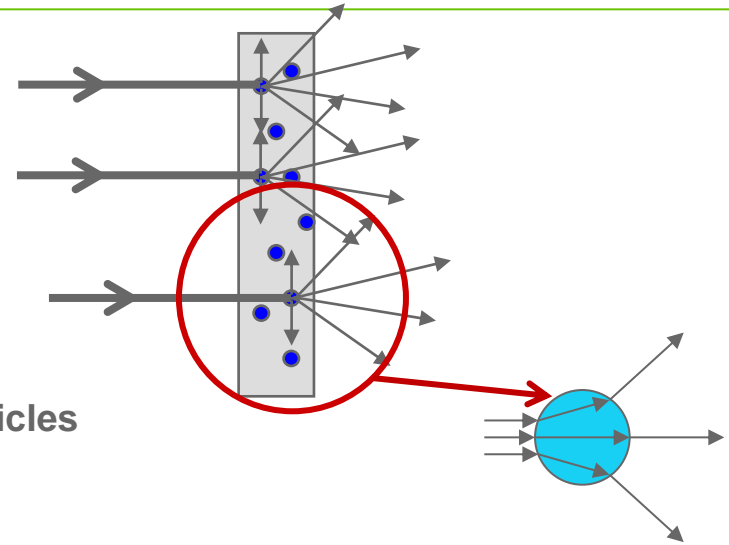
- **Scattering** → bulk diffusion

↳ Clear particles with different index of refraction

↳ Much more forward scattering than reflective particles

↳ Decisive factors are: material (index of refraction), size and shape of particle, loading

↳ Technology also available in Makrolon® resin and Makrofol® films



Makrolon® DX

Benefits of DX warm and DX cool

Makrolon®
DX
Diffusion
eXcellence

DX cool:
higher hiding power and
diffusivity provide higher
luminance uniformity

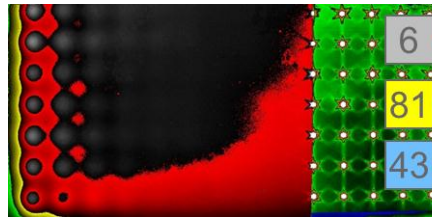


DX cool 1,5 mm

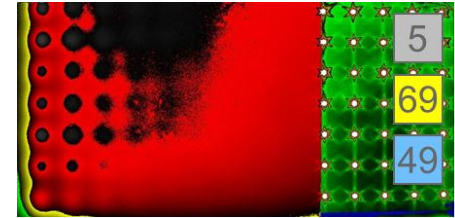


DX cool 3,0 mm

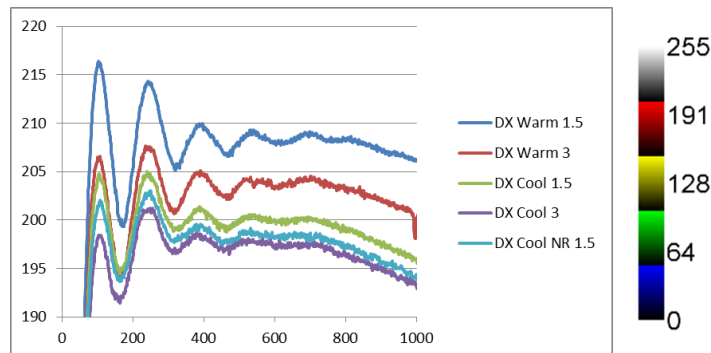
DX warm:
higher light transmission
provide higher brightness



DX warm 1,5 mm



DX warm 3,0 mm



Makrolon® DX

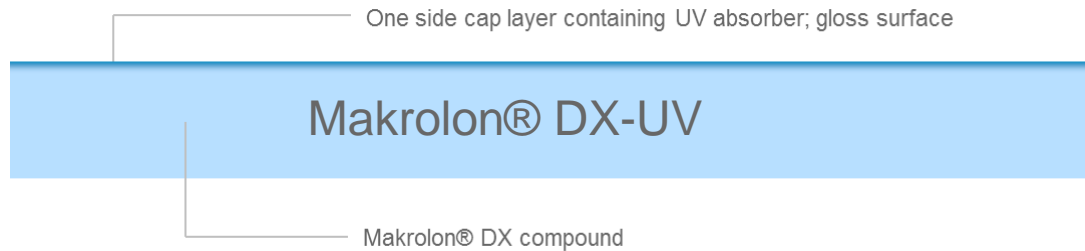
Flexible approach to surface

Makrolon®
DX
Diffusion
eXcellence

UV protection =weatherable

Applications:

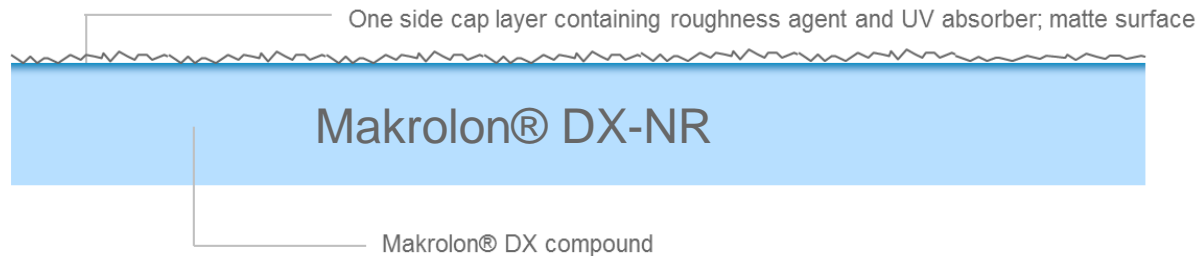
Outdoor fittings
Indoor use with fluorescent neon
tubes possible



Matt / Satin =non-reflective

Applications:

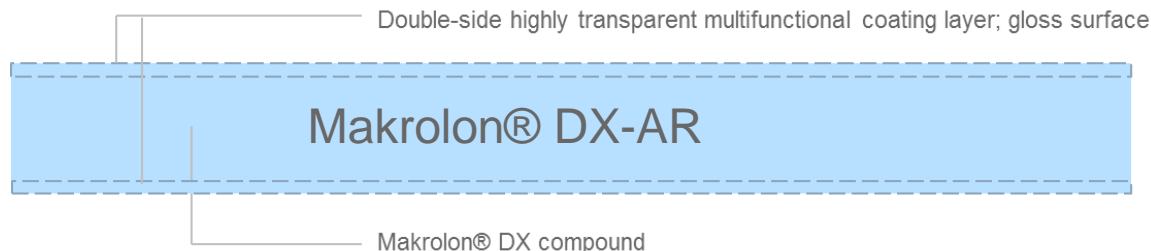
Office lighting (low surface glare)
Design / decorative lighting
Outdoor fittings



Hard-coat =abrasion+chemical +UV resistant

Applications:

Heavy-duty industrial lighting
(food preparation, agriculture)
Vandal-proof outdoor lighting



Coextrusion
(online)

Coating
(offline)

Makrolon® Lumen XT

Two scattering technologies in one



- **Scattering** → bulk diffusion, like Makrolon® DX

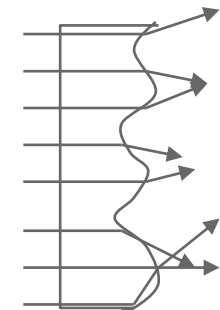
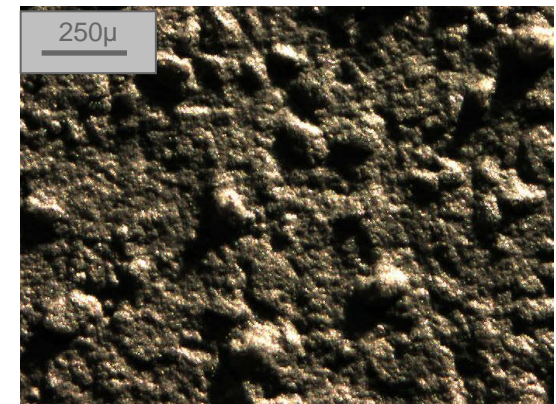
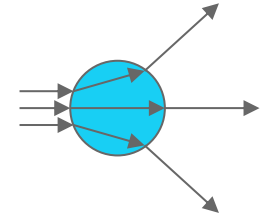
&

- **Refraction** → optically active surface

↳ Any surface that is not perpendicular to the light will refract (scatter) the light

↳ Polycarbonate to air interface is also a change of index of refraction

↳ Technology also available in Makrofol® films

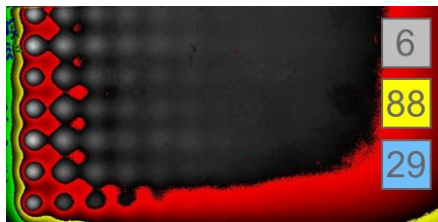


Makrolon® Lumen XT

Additional diffusion levels to increase light output

Makrolon®
Lumen XT

Lumen XT diffusion level 5: lower hiding power and diffusivity provide higher brightness



Lumen XT LC5 1,5 mm



Lumen XT LC5 3,0 mm



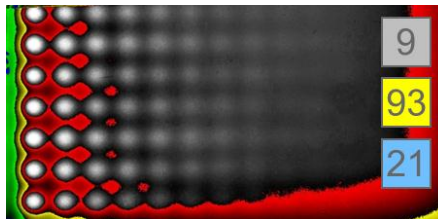
Lumen XT LW5 1,5 mm



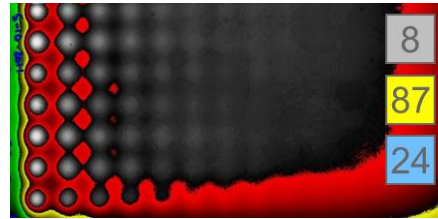
Lumen XT LW5 3,0 mm



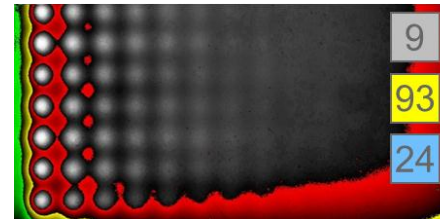
Lumen XT diffusion level 3: the lowest hiding power provide the highest brightness



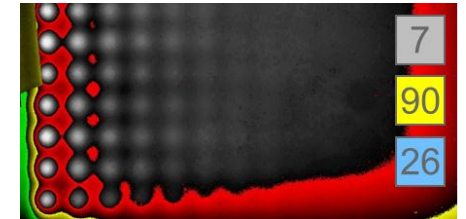
Lumen XT LC3 1,5 mm



Lumen XT LC3 3,0 mm



Lumen XT LW3 1,5 mm



Lumen XT LW3 3,0 mm

LC = light cool (higher hiding power)



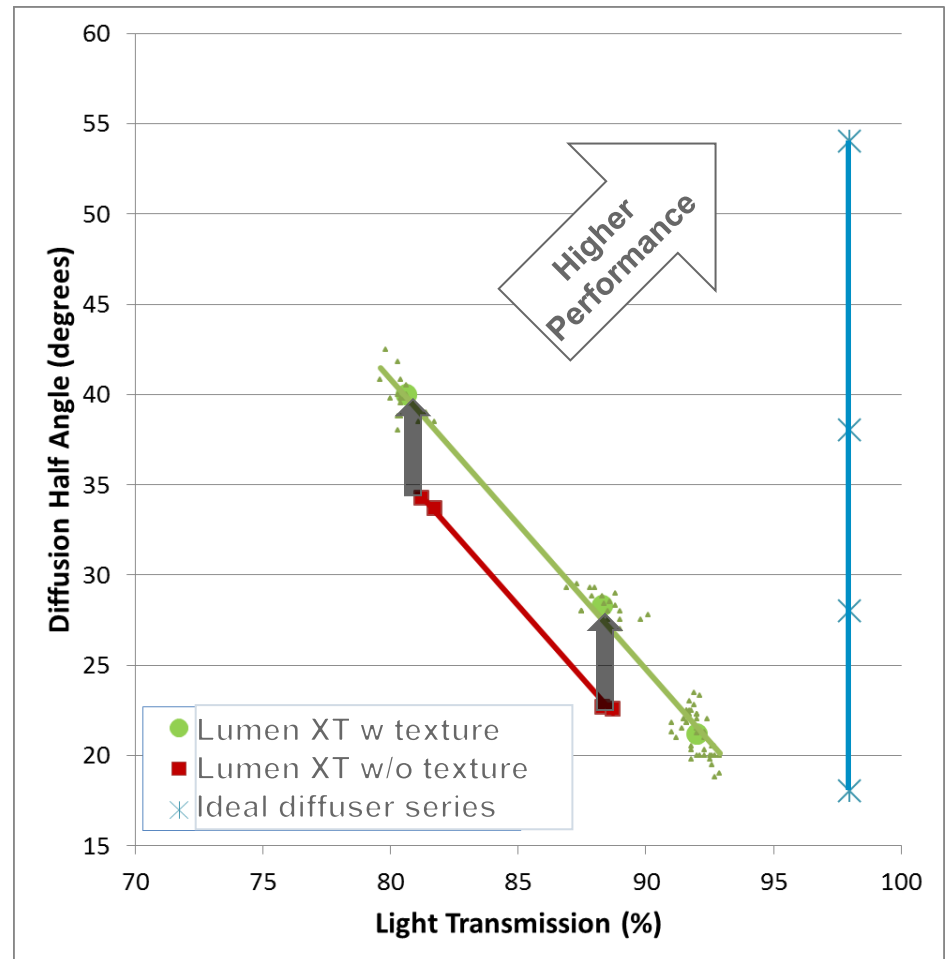
LW = light warm (higher brightness)

Important performance trade-off

Diffusion vs. light transmission

Makrolon®
Lumen XT

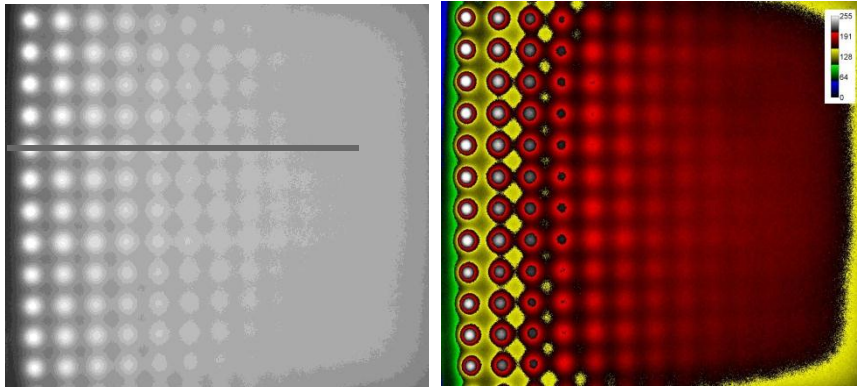
- ❖ Adding more bulk additive increases diffusion but lowers first pass light transmission
- ❖ The texture on the Lumen XT sheet adds to the diffusion performance
- ❖ Fixture manufacturers desire diffusion level options but would prefer to not sacrifice light transmission
- ❖ Higher performance is toward the upper right corner



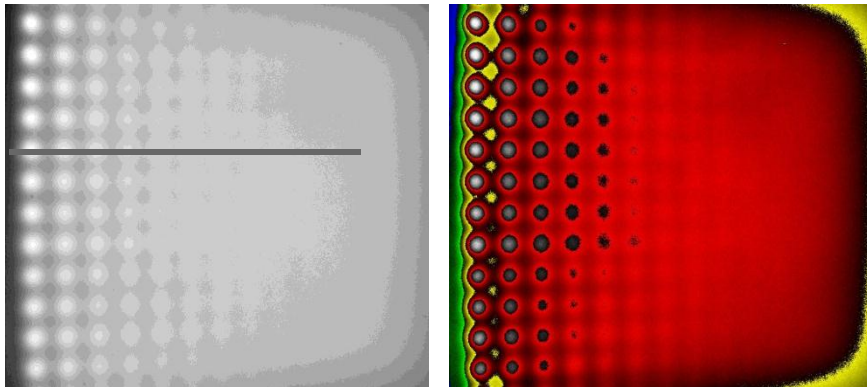
Makrolon® Lumen XT

Specially designed surface texture to offer a better diffusion

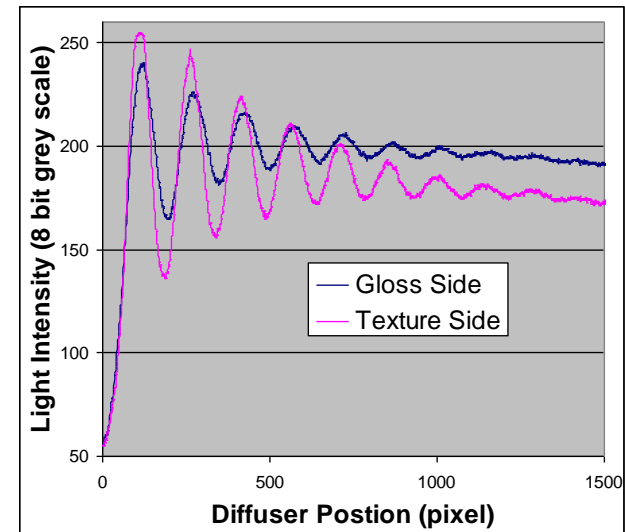
Makrolon®
Lumen XT



Texture Side



Gloss Side

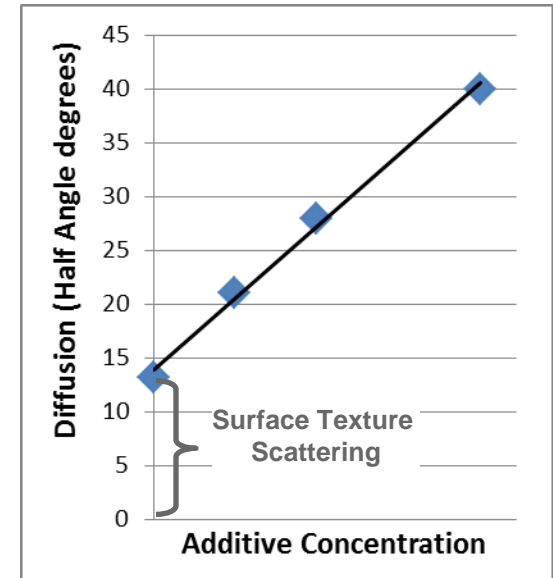
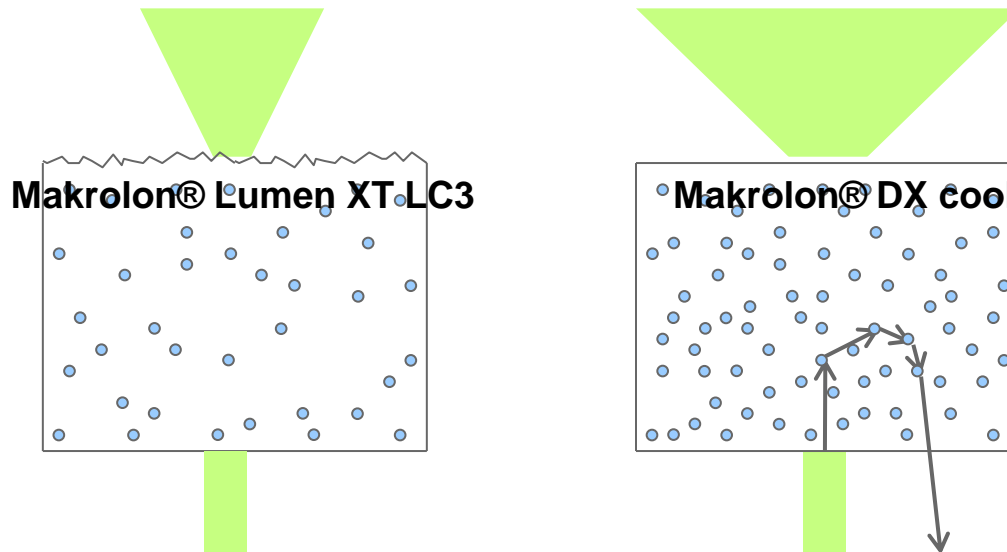


Makrolon® DX + Lumen XT

Different levels of diffusion

Makrolon®
DX
Makrolon®
Lumen XT

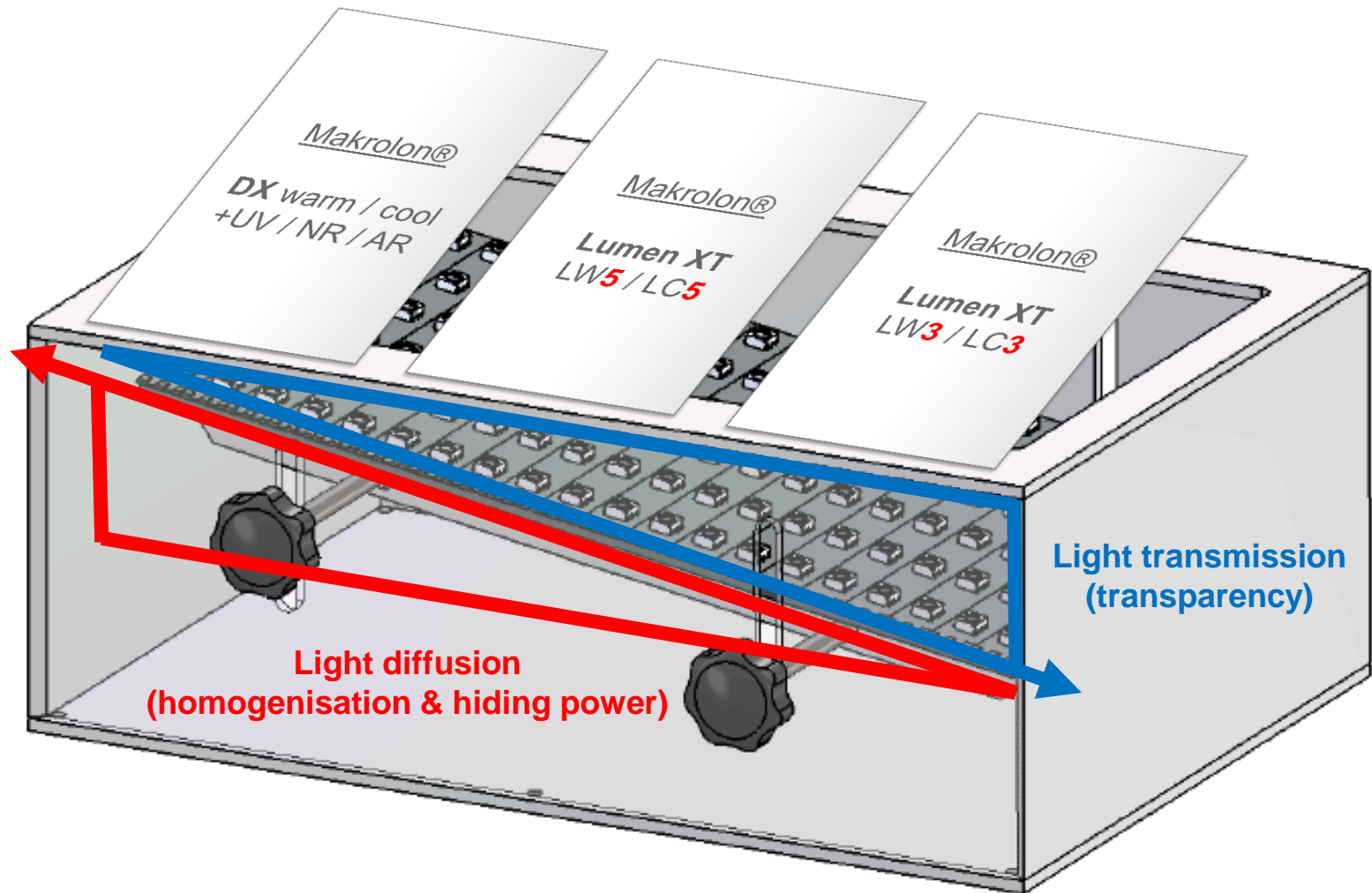
- ❖ Different levels of light diffusion are achieved by varying the bulk additive
 - More and multiple scattering events cause wider beam spread
- ❖ Surface structure alone has appreciable diffusion
 - If applied, other surface functions (UV, NR, AR) are not possible



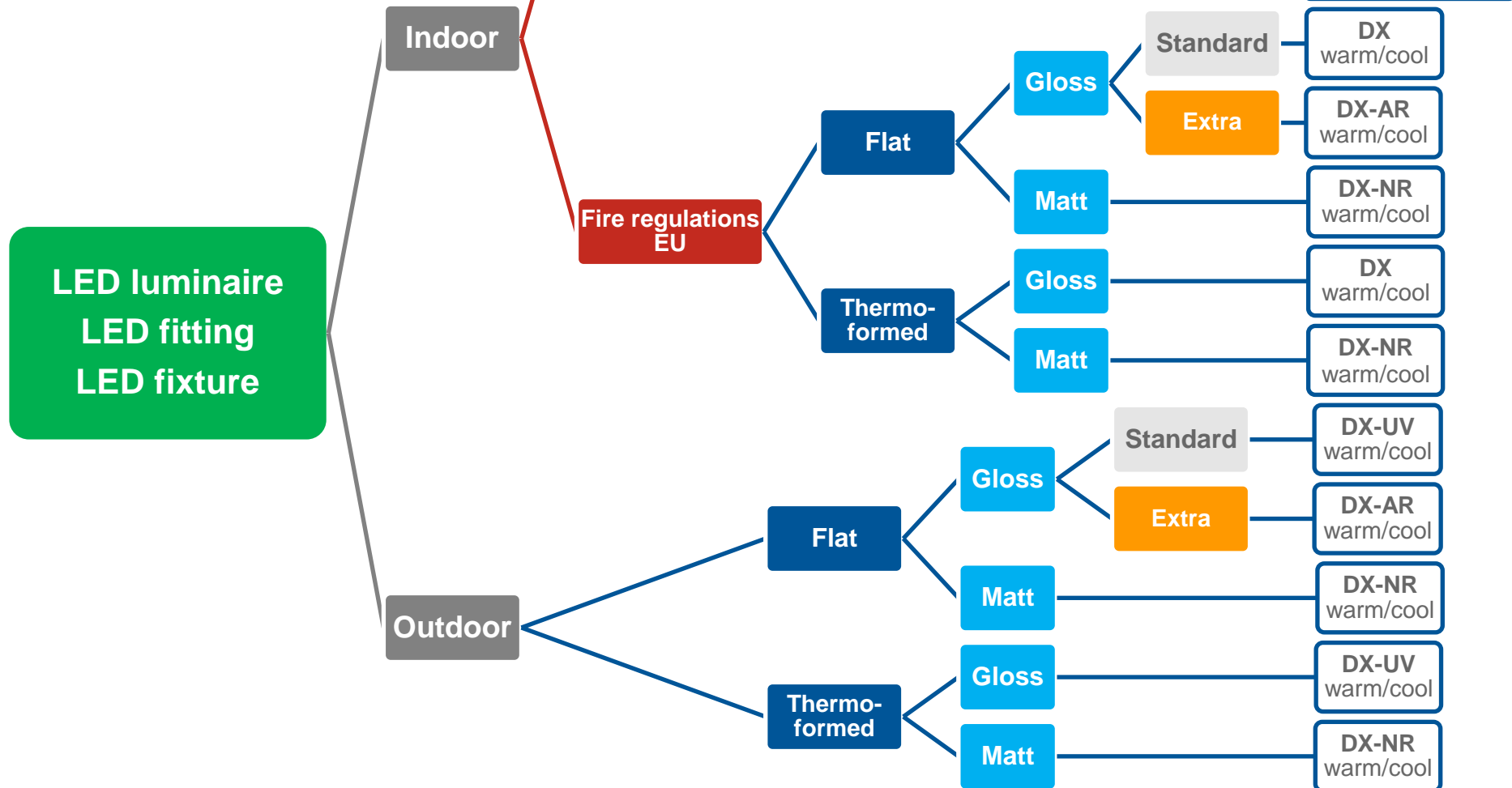
- ❖ Multiple scattering events can also direct light back to light source
 - Lower first pass light transmission

LED hotspots obscuration at different fixture profiles through various diffusion levels

Makrolon®
DX
Makrolon®
Lumen XT



Makrolon® sheet solutions for all kinds of diffusion applications

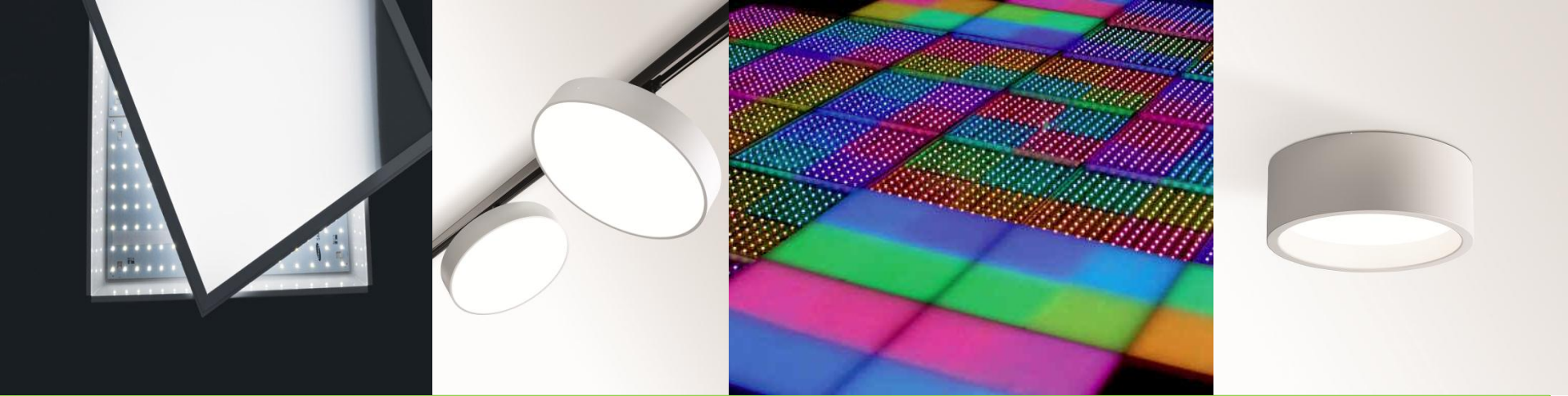


Makrolon® DX and Lumen XT

A success story in progress

Makrolon®
DX
Makrolon®
Lumen XT

- ❖ Makrolon® DX was launched in 2011 for the EU market
- ❖ Makrolon® Lumen XT was launched in 2011 for the US market and last week (Strategies In Light Europe in Munich) for the EU market
- ❖ Check soon for the optical data in lighting software libraries like Photopia, Radiant Zemax, Optis
- ❖ Look for more information in the forthcoming issue of LEDs Magazine and come to visit us at Light & Building in 2014
- ❖ Samples are available for your convenience



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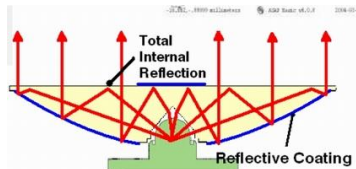
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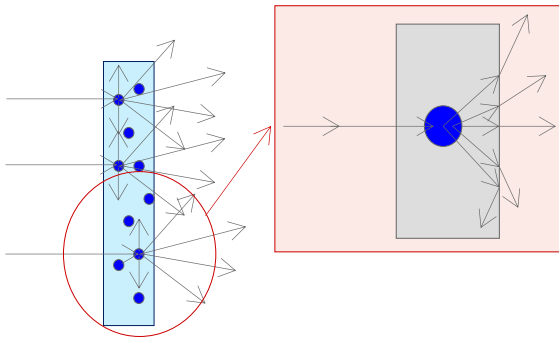
Bayer MaterialScience's focus on LED

LED lighting requires multiple solutions



<http://img166.imageshack.us/img166/1659/700oh7.jpg>

Light focusing and guiding



Light diffusion



<http://diy-community.de/attachment.php?attachmentid=52551&stc=1&thumb=1&d=1284748266>

Light reflection



Thermal conductivity



Advanced plastics for LED lighting

Material offer from Bayer MaterialScience

Part	Requirements	Lighting applications	Thermoplastics from Bayer
Secondary optics	<ul style="list-style-type: none">• High brightness• Focused light• Design freedom	<ul style="list-style-type: none">• Street lighting• Spot lights• Wall washers• Task lighting	<ul style="list-style-type: none">• Optical resin grades (up to 90%)• Available with additional flame retardant or UV-stable packages
Diffusers	<ul style="list-style-type: none">• No “hot spots”• Soft and flat light• Low glare• Light uniformity• Cost vs. quantity	<ul style="list-style-type: none">• Commercial lighting (offices)• Retail lighting• Residential lighting	<ul style="list-style-type: none">• Resin grades with individual color packages according to requirement• Sheet grades (opal and lenticular)• Film grades (opal and lenticular)
Reflectors	<ul style="list-style-type: none">• Focused light• Increased output via light recycling• No “hot spots”	<ul style="list-style-type: none">• Commercial lighting (offices)• Retail lighting• Residential lighting	<ul style="list-style-type: none">• Resin grades for white diffuse reflectors 96% and grades suitable for metallization for specular reflectors• Sheet grades (diffuse refl. 96-97%)• Film grades (diffuse refl. 96-97%)
Heat sink	<ul style="list-style-type: none">• Thermal conductivity• Processability	<ul style="list-style-type: none">• Fixtures based on high power / high brightness LEDs	<ul style="list-style-type: none">• Thermally conductive injection molding resin grade (15-20 W/m*K)



Forward-Looking Statements

This presentation may contain forward-looking statements based on current assumptions and forecasts made by Bayer Group or subgroup management.

Various known and unknown risks, uncertainties and other factors could lead to material differences between the actual future results, financial situation, development or performance of the company and the estimates given here. These factors include those discussed in Bayer's public reports which are available on the Bayer website at www.bayer.com.

The company assumes no liability whatsoever to update these forward-looking statements or to conform them to future events or developments.



Science For A Better Life

Thank you!