



Materials and Technology for (LED) Lighting Applications

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 **BASF**

We create chemistry

BASF – We create chemistry

- Our chemistry is used in almost all industries
- We combine economic success, social responsibility and environmental protection
- Sales 2015: €70,449 million
- EBIT 2015: €6,248 million
- Employees (as of December 31, 2015): 112,435
- 6 Verbund sites and 338 other production sites



Chemicals remains a growth industry



Agriculture



Health & Nutrition



Energy & Resources



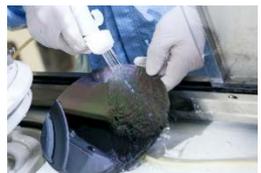
Construction & Housing



Consumer products



Automotive & Transport



Electric & Electronics

Chemistry as enabler for current and future needs

~10bn



...people by 2050

70%



...of the world population will live in cities by 2050

50%



...more primary energy consumption by 2050

30%



...more food needed by 2050

Global Know-How Verbund

Thanks to our close cooperation with numerous partners in science and industry worldwide, we have created an international and interdisciplinary Know-How Verbund.

- Expenditures for research and development
€1,953 million, world leader in chemical industry
- Approx. 10,000 employees in research and development worldwide
- Know-How Verbund with around 600 excellent universities, research institutions and companies



BASF Technology Incubator. Generate hypothesis, iterate, fail, pivot, test again, learn



Good Ideas are the wrong metric – test hypotheses and become action oriented

Materials and technology for (LED) lighting application

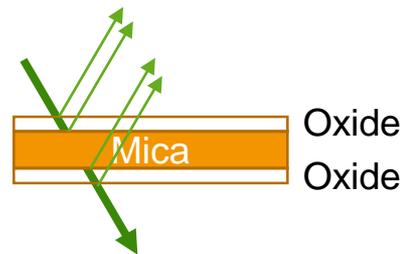
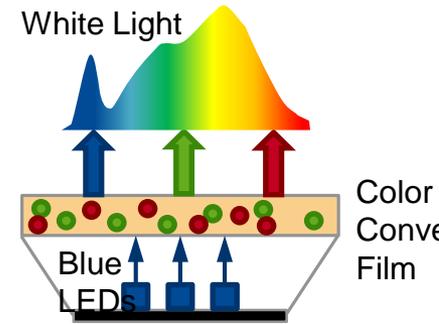
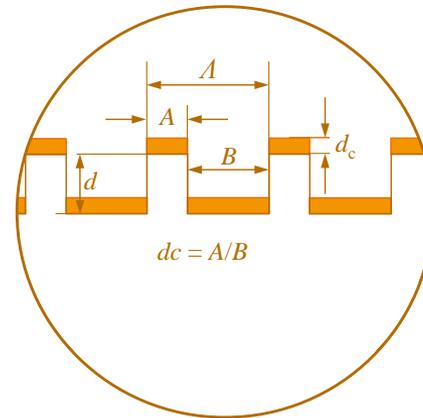
Color Conversion

Light management

By micro- and nanopattern

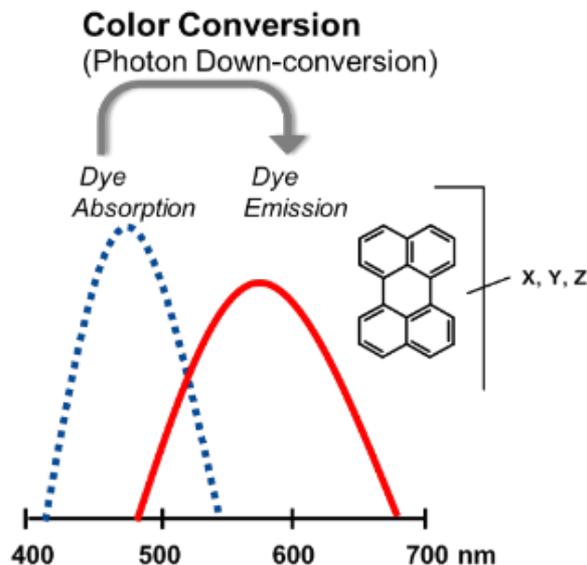
By interference layers

Eco Efficiency Analysis



Color conversion

- A **conversion material** (dye, phosphor, quantum dot) absorbs **short-wavelength photons** (e.g. blue) and re-emittes them at **longer wavelengths** (e.g. green) → **Fluorescence**
- Important parameters are the absorption coefficient, quantum efficiency, and emission band width



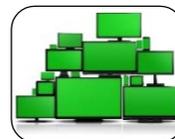
Photovoltaics

Conversion of the "wasted" sunlight radiation



LED Lighting

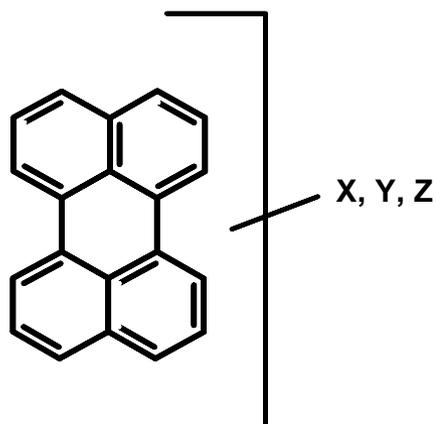
Conversion of Blue LEDs to White Light



Displays (LCD / OLED)

Brightness enhancement, Wide Color Gamut

BASF portfolio of fluorescent dyes Lumogen®



	Yellow 083	Yellow 170	Orange 240	Pink 285	Red 305
Chemical	Perylene	Perylene	Perylene	Perylene	Perylene
Absorption* (nm)	476	505	524	547	578
Emission* (nm)	490	528	539	580	613
FQY (%)	99	94	87	95	98

BASF - Lumogen® Fluorescent Dyes Technology Platform

- Additive for Polymer
- Brilliant Fluorescence
- Thermal Stable up to 300 °C

BASF offers a complete solution for large area LED illumination systems

Optimized Solution

BASF product is a polymeric diffusing film

Highest CRI

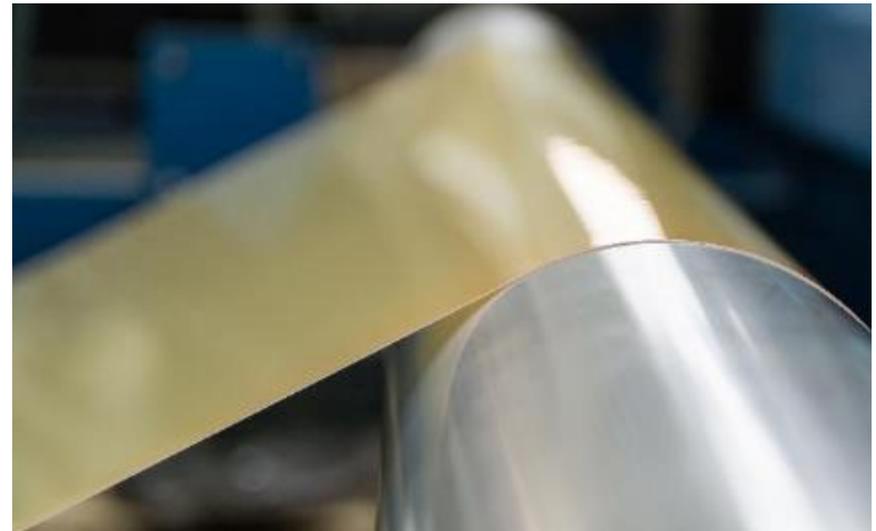
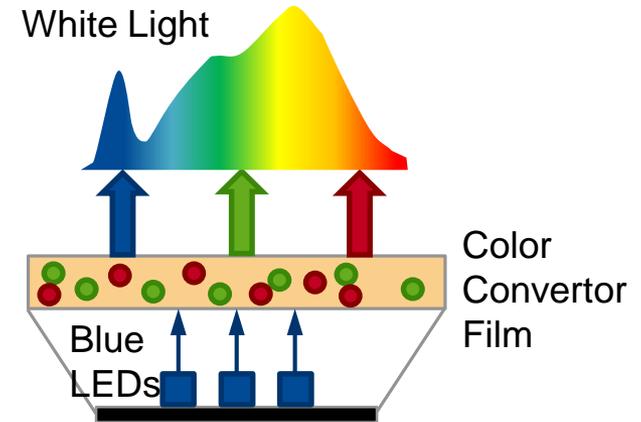
CRI > 90, all CCTs (1900 – 6500 K already tested)

Lowest System Cost

Side bin / broad bin LEDs are usable
Film is changeable for different specs

High Efficiency

Conversion efficacy as high as inorganic remote phosphor, less thermal droop from remote design



Product forms possible with

Tubes



Troffers



Luminaires



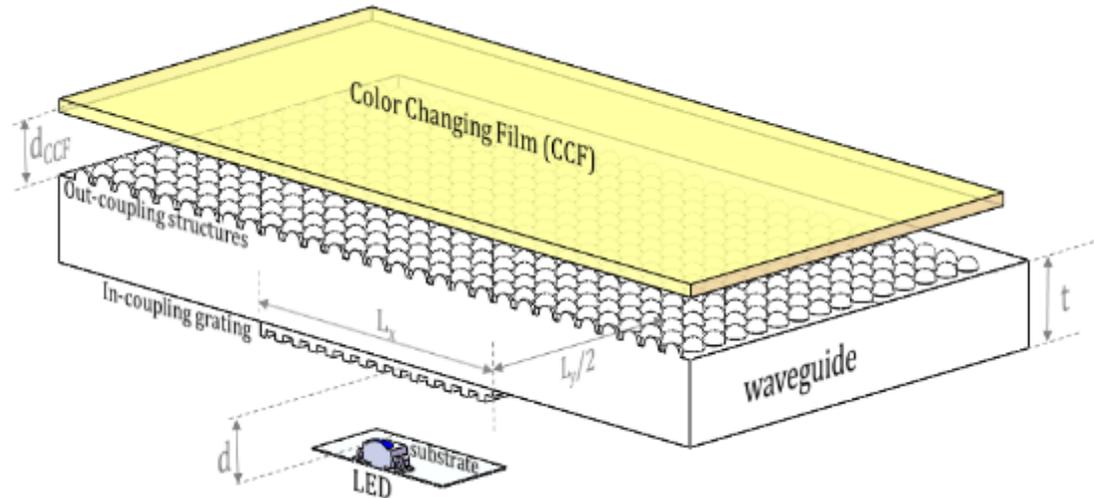
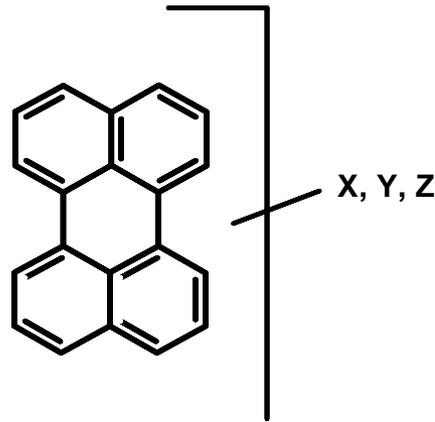
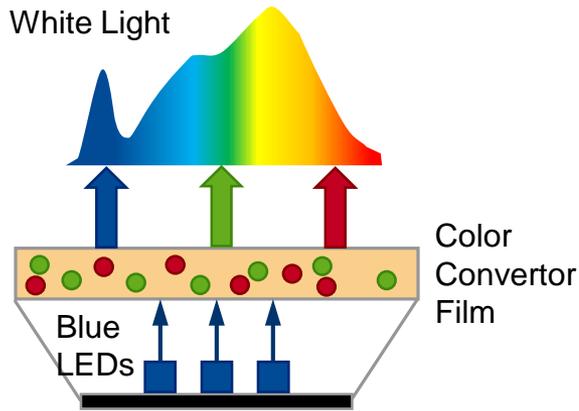
LASSIE-FP7

Panels



LASSIE-FP7

LASSIE-FP7 Color and Light Management

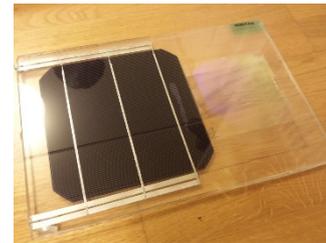
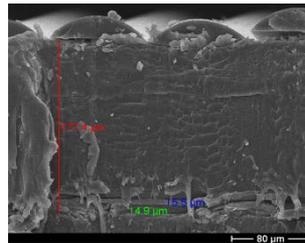
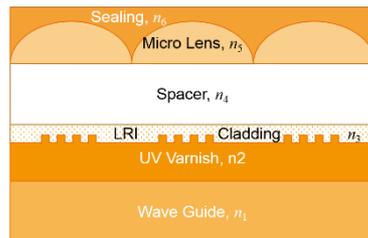


Light Management by micro- and nanopattern

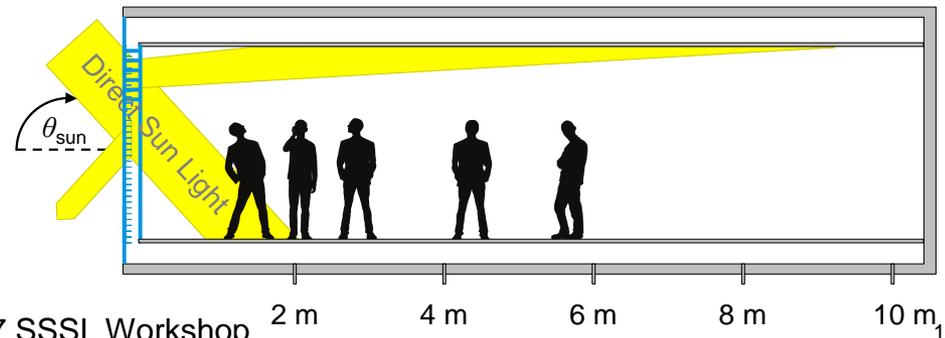
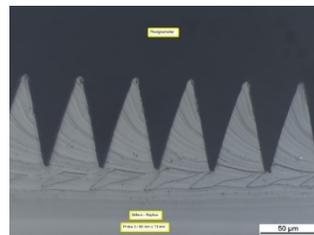
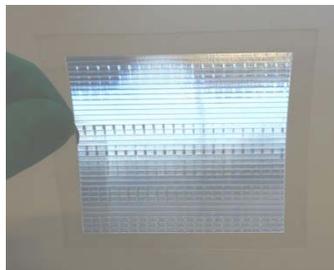
■ Diffraction grating



■ Light Harvesting structure

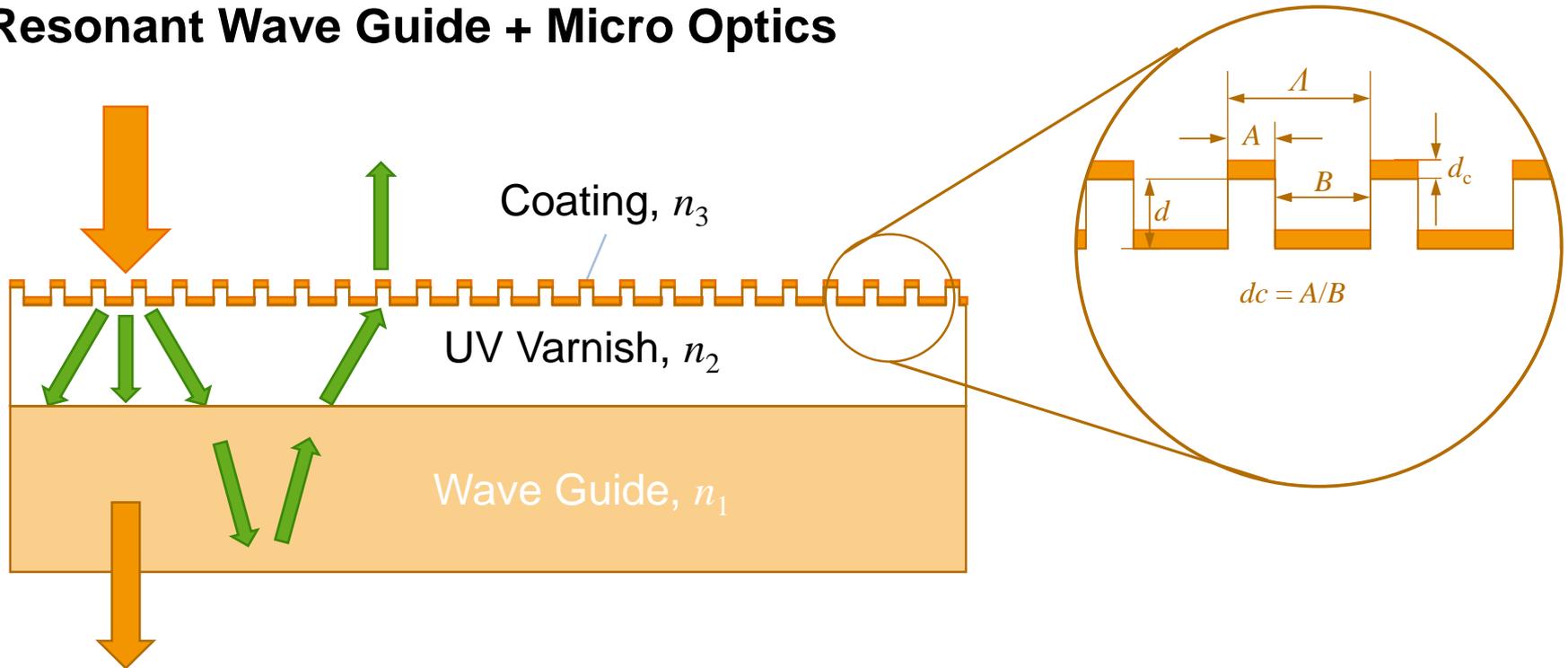


■ Daylighting structure



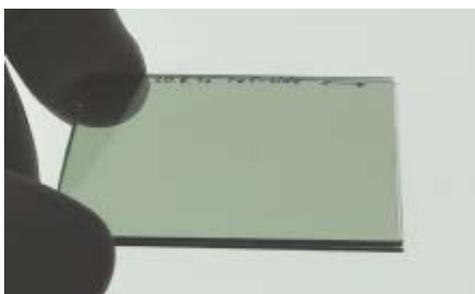
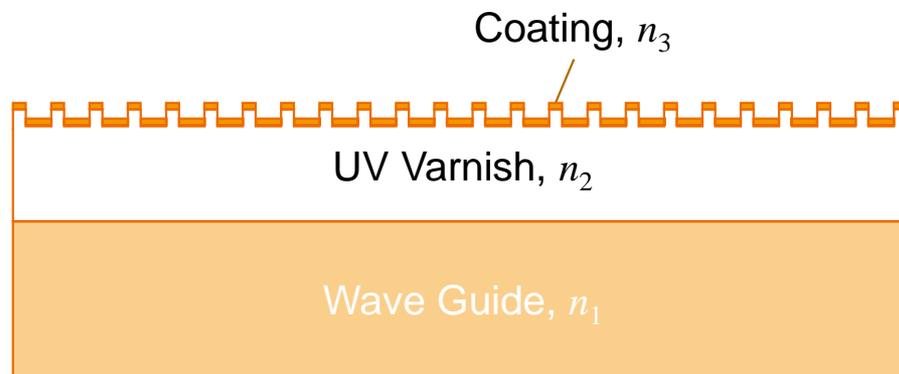
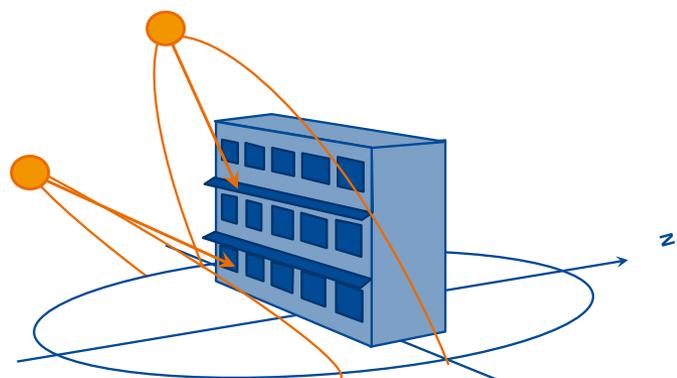
How do we manage light with micro- and nano patterns?

Resonant Wave Guide + Micro Optics

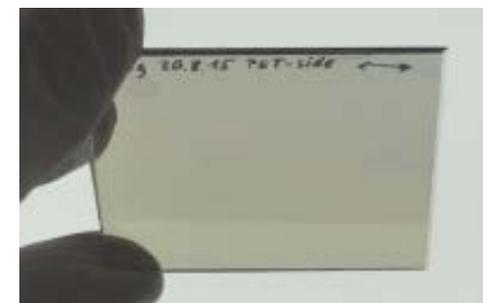
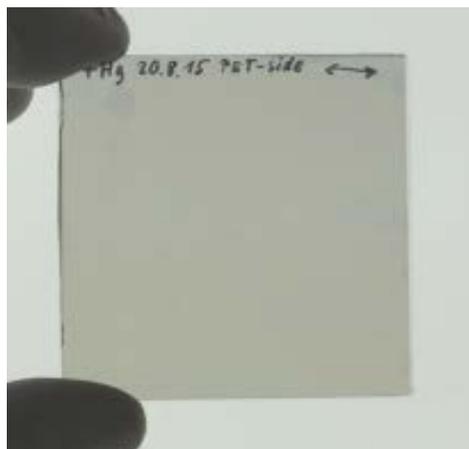


M. Gale, K. Knop, R. Morf, SPIE Proc. 1210, 83 (1990)

Diffraction Grating based angle dependent mirror



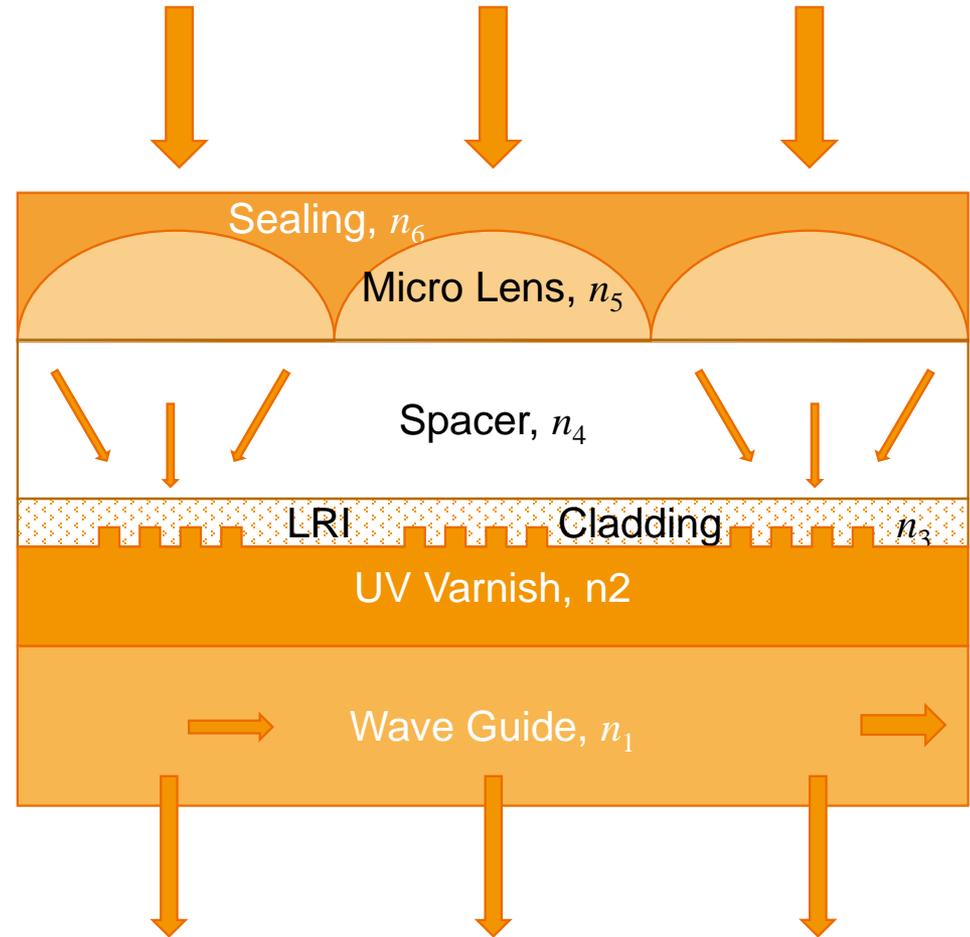
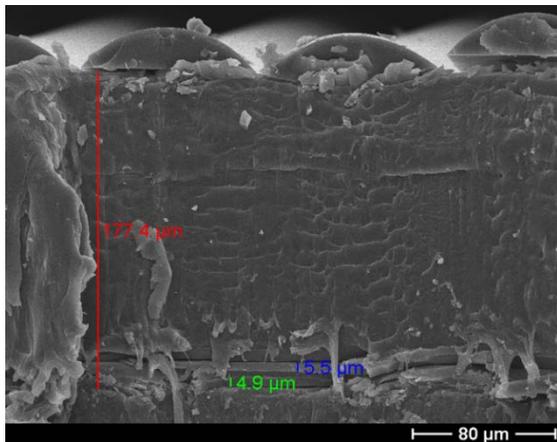
- tilted



+ tilted

Light Harvesting Foil comprising aligned micro- and nanopatterns

- Concentrate Light
6 suns
- No Tracking
 ± 10 Degree Angle of Acceptance
- Foil Based Approach
3 mm Thickness

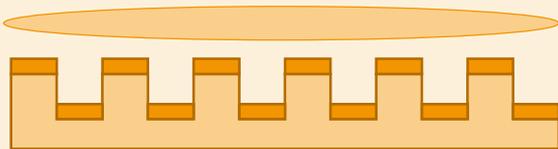


Light Management by micro- and nano-patterns



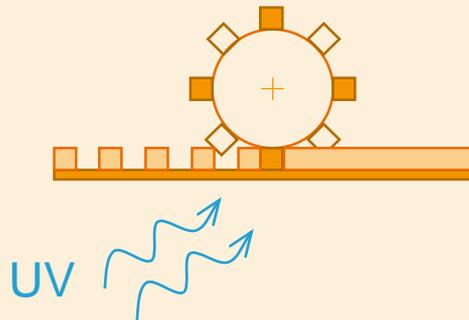
Design & Optimization

- Design & Simulate Function
- Micro Optics (mm)
- Diffraction Gratings
- Interference Layers



Processes & Patterning

- Gravure printing
- Slot die casting
- Spin coating
- UV NIL (reel-to-reel)
- SCIL (wafer based)



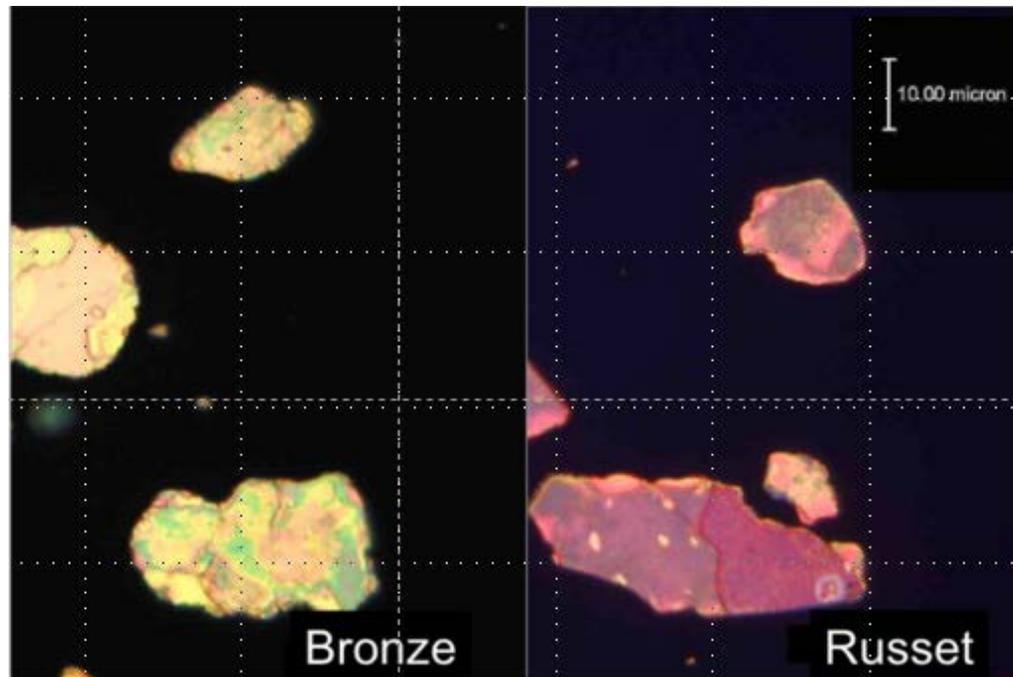
Material Optimization & Coating

- Develop & Formulate
- UV – curable resins
- Low and High refractive index
- Optical quality

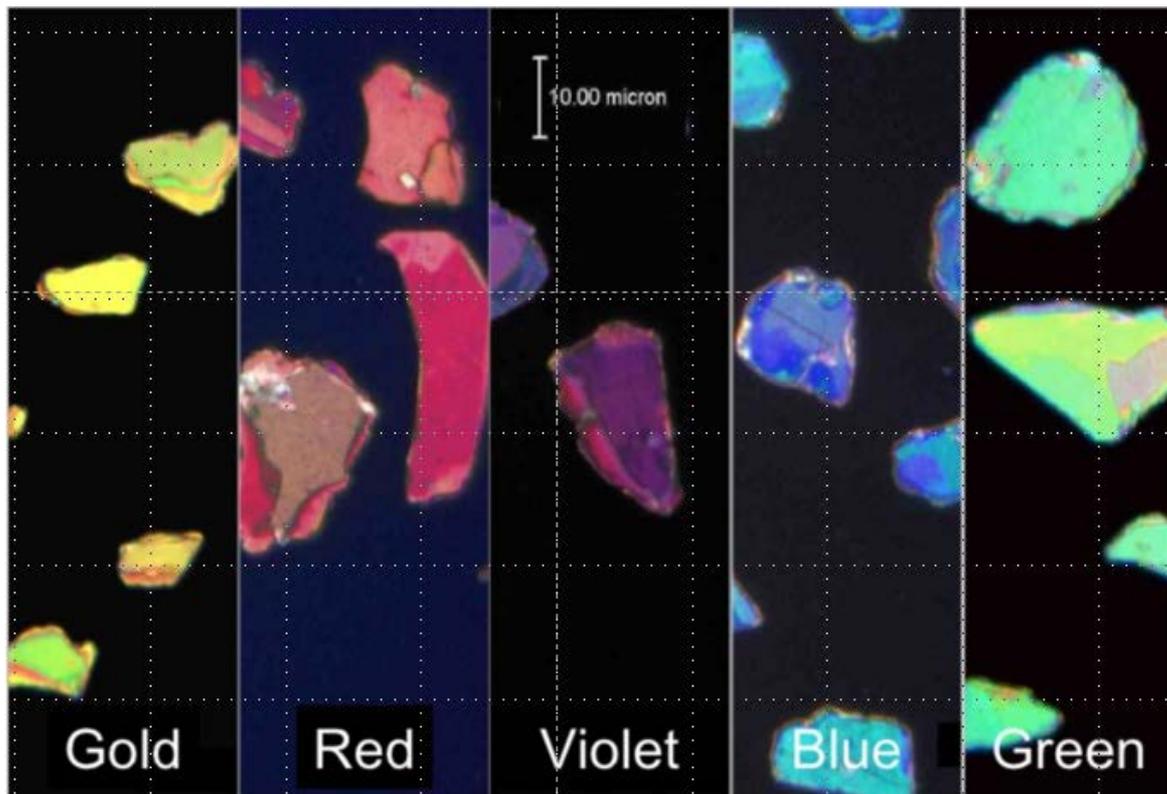


Light management by interference layers

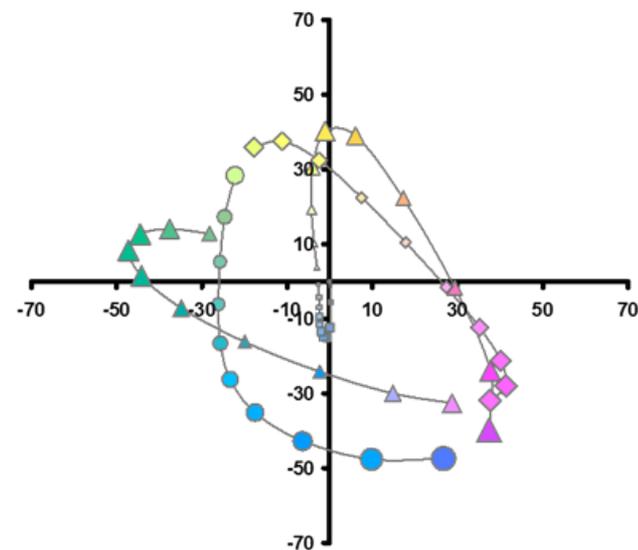
- Mica flakes with oxide nano-layers on top



Light management by interference layers



CIE-64 a*b calculation



Increasing oxide thickness by 5 nm

BASF Toolbox for Measuring Sustainability



Eco-Efficiency Analysis

- life cycle-based
- evaluation of environmental impacts
- includes life cycle costs

Conclusions

- Materials and Systems
 - Color Conversion Film (CRI > 90%, CCT between 1'800 and 6'500 K)
 - UV NIL Micro- and Nano-Replication
 - Pitch from 200 nm – 200 µm
 - Multilayer integration of micro- and nano-patterns with 5 µm registration
 - Interference pigments ranging from brilliant white (pearl) to colors
- Cradle-to-Cradle Sustainability analysis SEEBALANCE®
- Holistic light management approach

Thank you!



Federal Department of Economic Affairs,
Education and Research EAER
Commission for Technology and Innovation CTI
Innovation Promotion Agency



Questions?



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