Materials for LED packaging

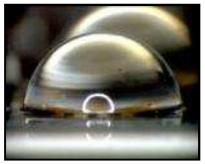
Dr. N. von Malm | June 2018 | Chemnitz

Agenda

1. Introduction: Materials for LEDs
2. Packaging Materials
3. Materials for color conversion (Phosphors)

Advanced materials for pcLEDs

What makes the difference?

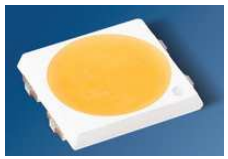


Encapsulation & Optic

- Transparency > 99% (>300 nm)
- Stable against light (**LM80**)
- Thermal conductivity (**Zth**)
- **High RI** (>1,54)

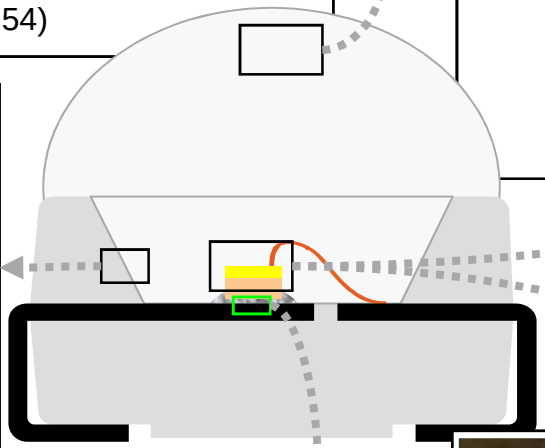
Phosphors

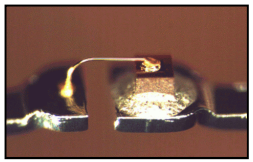
- High **QE**
- Low remission
- **low T-quenching**
- controlled scattering
- defined **spectral properties**



Reflective Housing

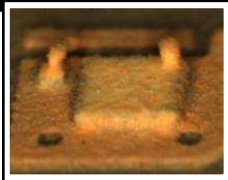
- **High reflectivity** (TiO_2 filled)
- Stable against light & temperature (**LM80**)





Thermal Managment

- **Low Rth** substrate
- Low Rth interconnect
- Corrosion stability

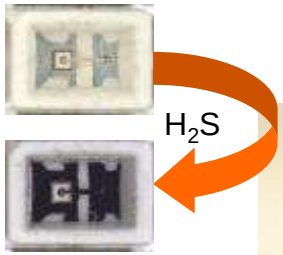


Conversion

- **Efficiency**
- **Optical performance** (CCT, angle distribution, etc.)
- **Thermal management**
- Color stability

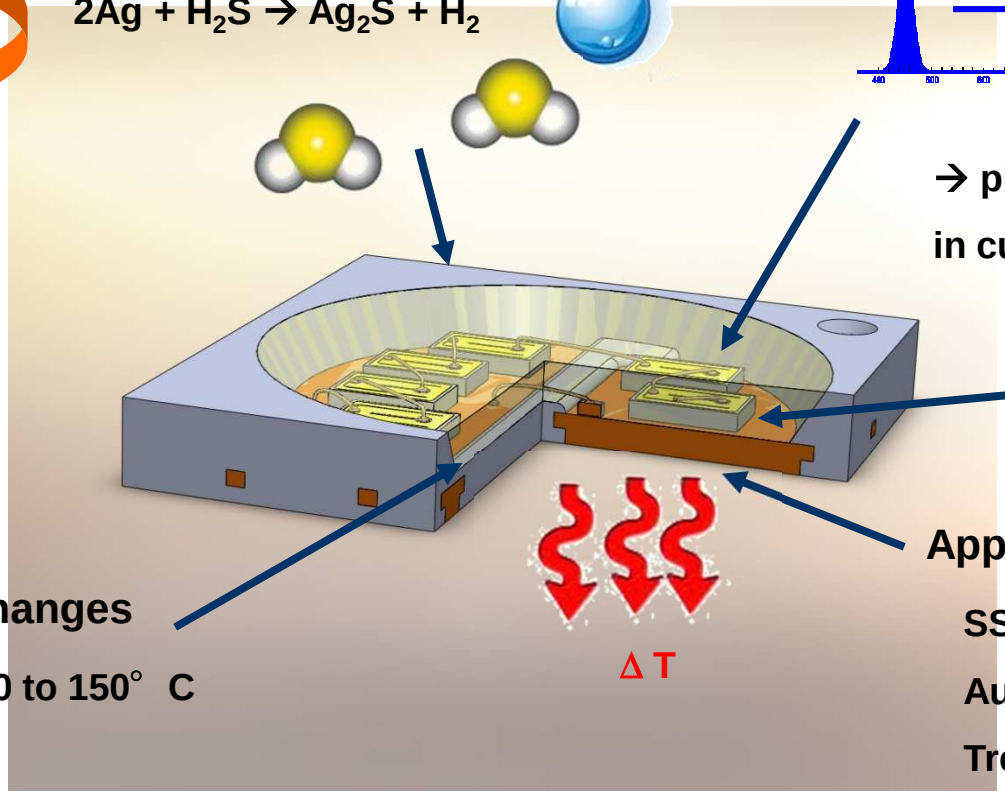
Today's challenges for a LED in modern environment…

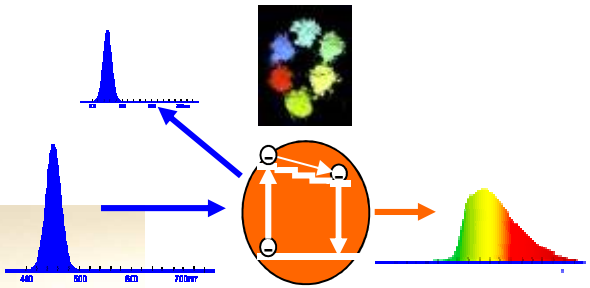
Moisture & corrosive gases



H_2S

$2Ag + H_2S \rightarrow Ag_2S + H_2$





Stokes Heat

→ phosphor can reach T>200° C in current applications.

High power InGaN radiation

Application temperature

SSL: T_{appl} ~ 85° C

Automotive: T_{appl} ~150° C

Trend: Increasing!

Temperature changes

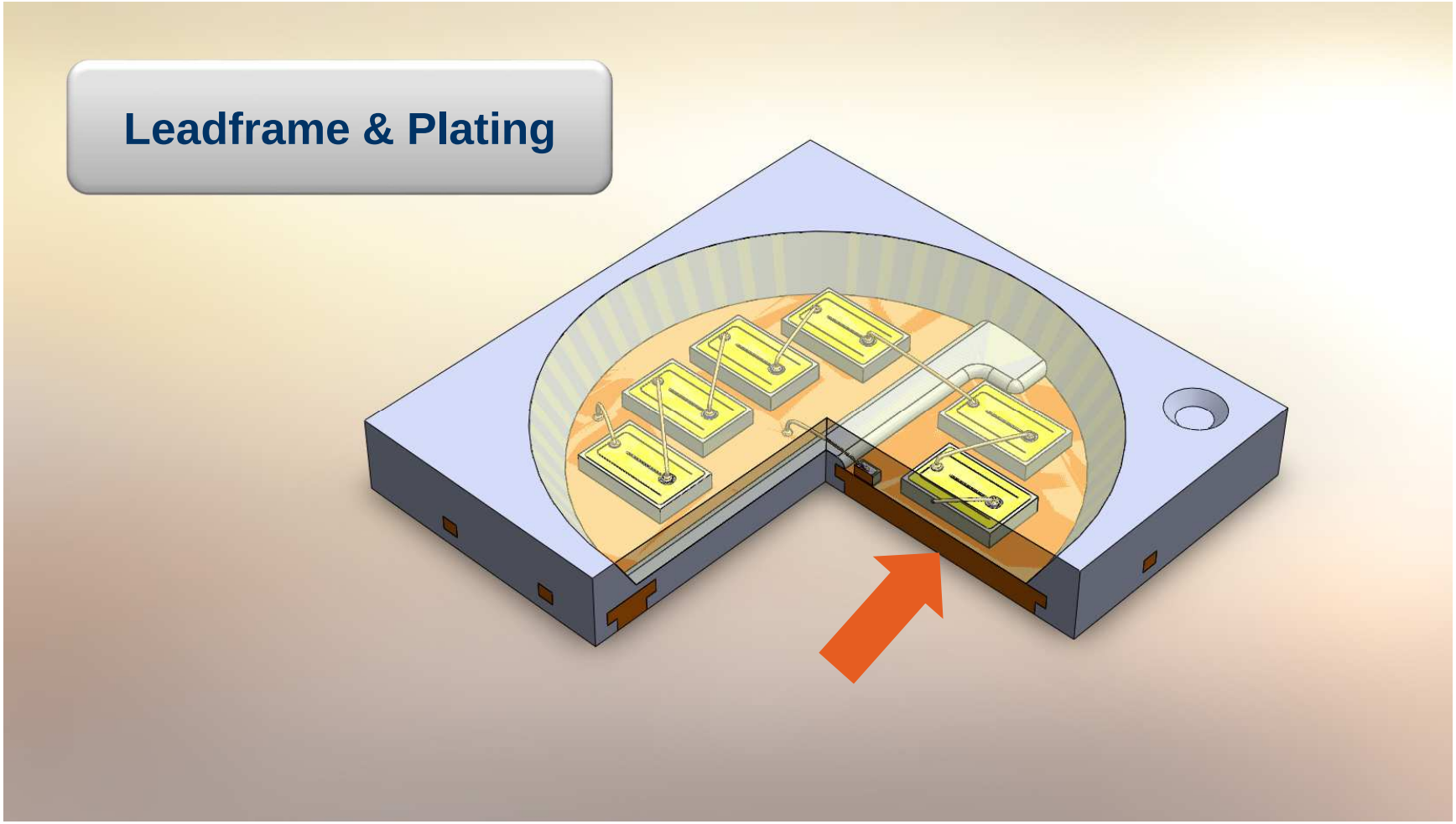
Automotive: -40 to 150° C

Δ T

Agenda

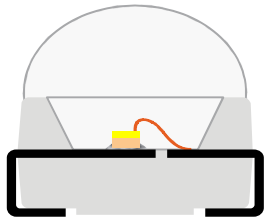
1. Introduction: Materials for LEDs
2. Packaging Materials
3. Materials for color conversion (Phosphors)

Leadframe and Plating



Leadframe and Plating

Requirements for Platings



Chip carrier:
mechanical properties

Electrical contact
metallurgy optimized for
die attach and wire bond techniques

Surface and layers
Reproducible quality,
free of contamination

Leadframe and Plating

SMT compatible
lead finish for mounting
component in LED system

Commercial aspect:
High volume + high speed
manufacturing

Robust and reliable
protection against climate,
corrosion, humidity…

Leadframe and Plating

Type of Package Substrates

Premolded leadframe

Advanced Power TOPLED

Power SIDELED

Stamped and plated Leadframe

Injection molding

Premolded Leadframe

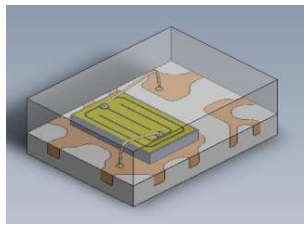
Quad flat no lead (QFN)

OSLON Black Flat

Duris S5 (3030)

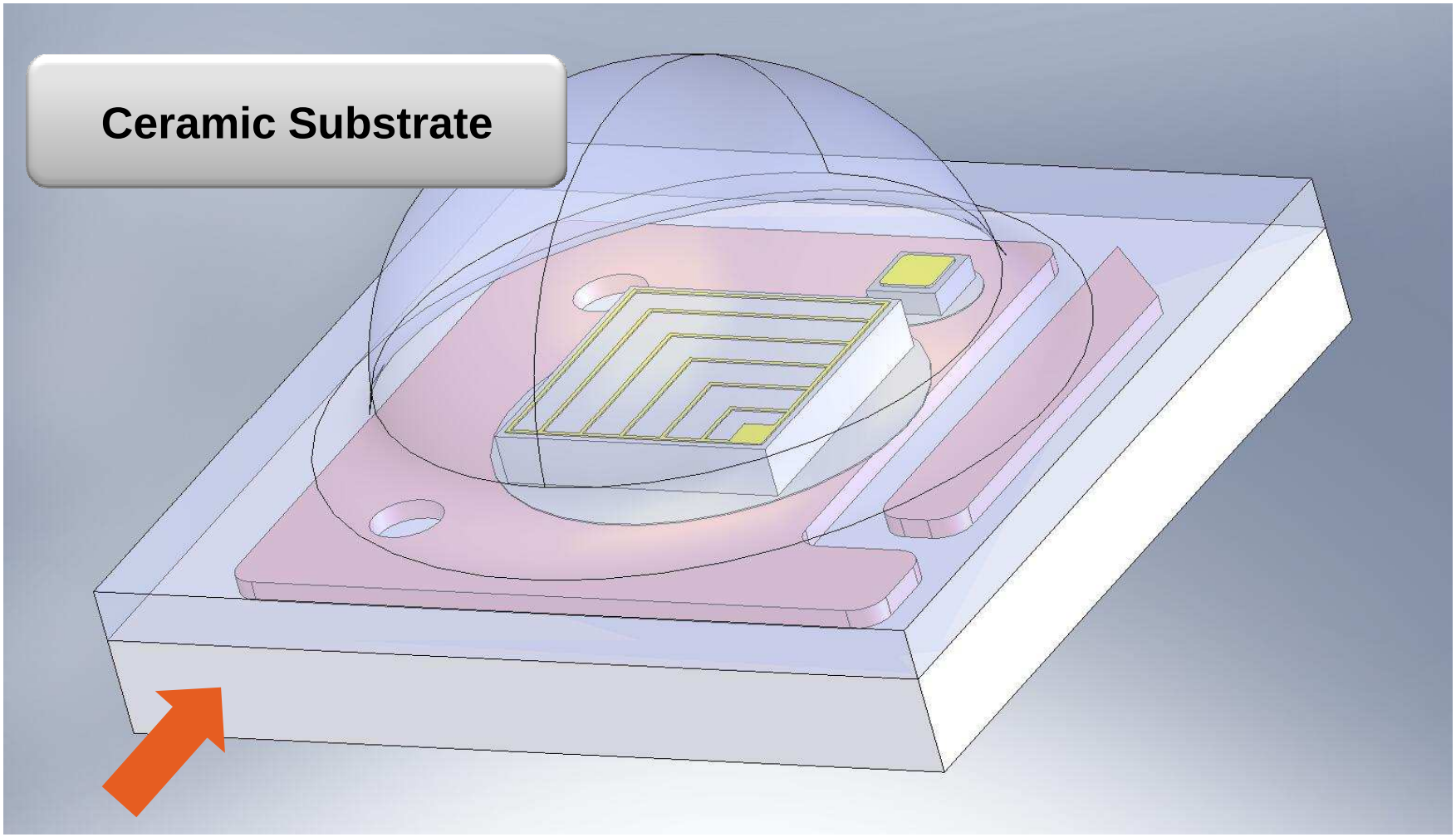
Etched and plated Leadframe

Transfer molding



Electro-plating: Cu/Ni/Pd/Ag or Cu/Ni/Pd/Au

Ceramic Substrates



Ceramic Substrates

Material Basic Functions

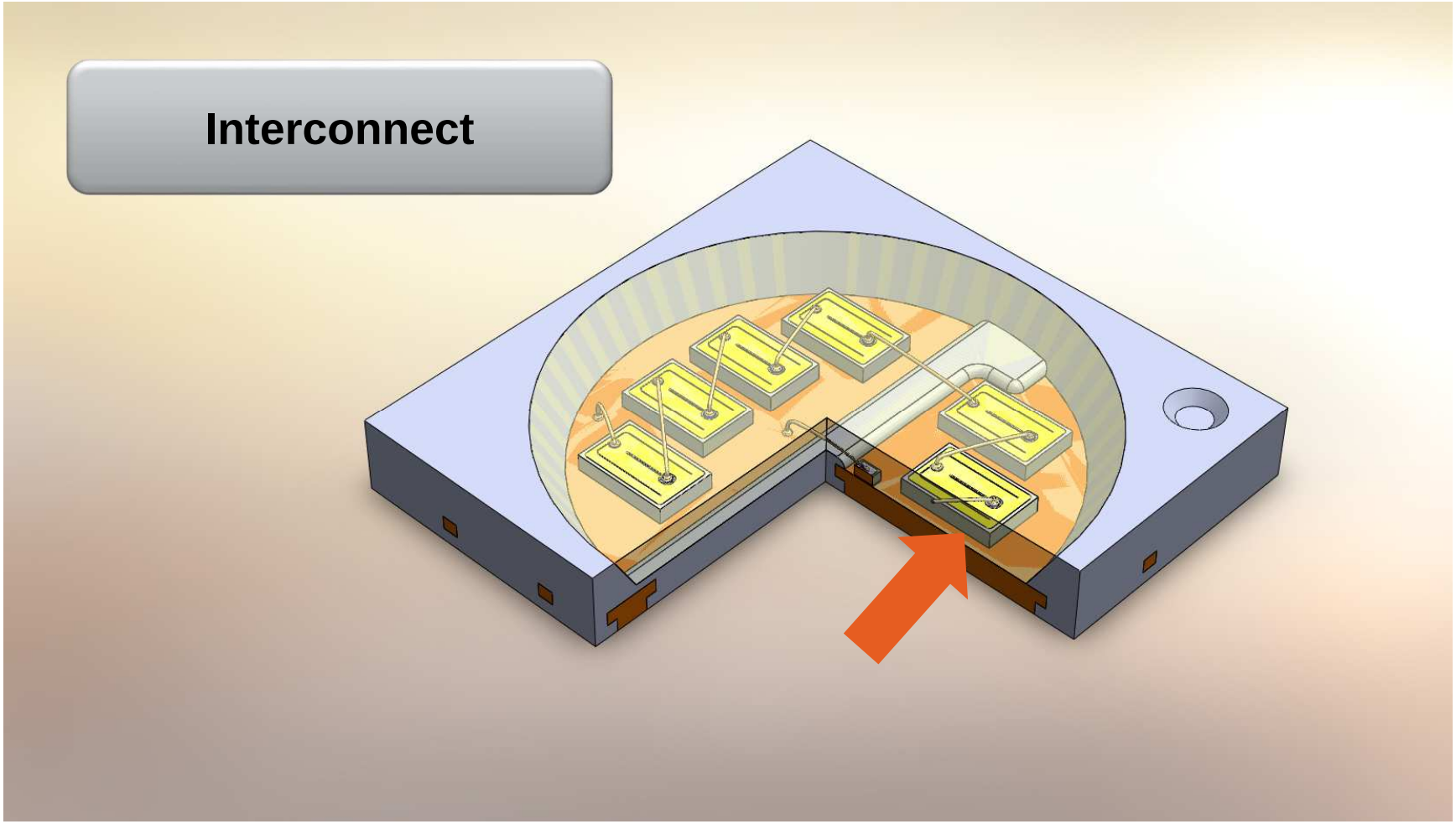
Used Ceramics for LED

- Al_2O_3 — Trigonal Crystal Structure **25 W/mK**
- AlN — Wurtzite Structure **180 W/mK**

Ceramic properties :

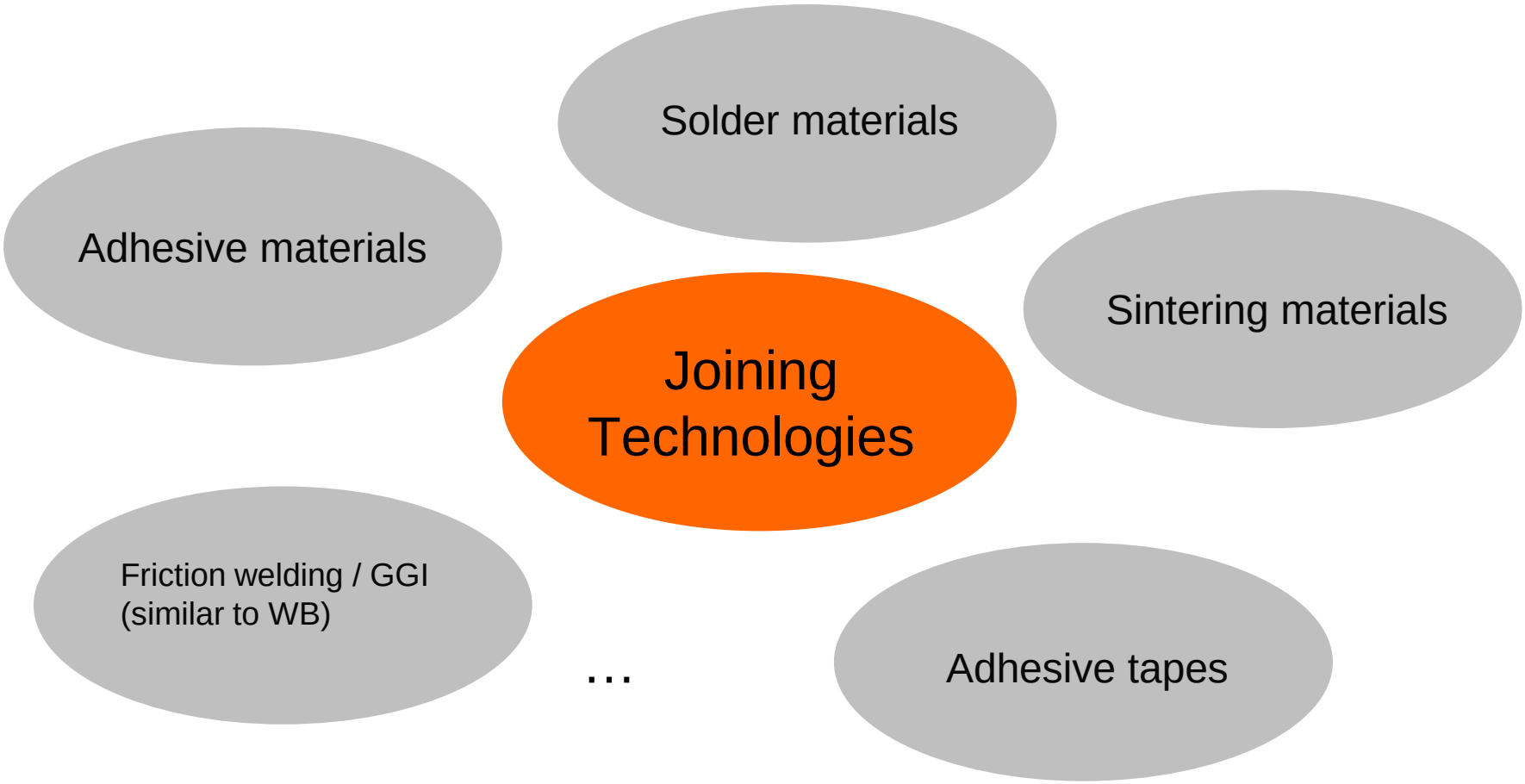
- **Base substrate** (Metallization area Ag or Au).
- Electrical **insulation**: insulated backside
- High **thermal conductivity**: dissipating heat in high Power LEDs.
- **Thermal stability**: Long term reliability at high temperature.
- Similar **expansion coefficient**: ceramic substrate 5-8ppm/K, LED chip 5-6ppm/K
- **Reflective** surface for LED chip

Interconnect Materials



Interconnect Materials

Joining Technologies & Material

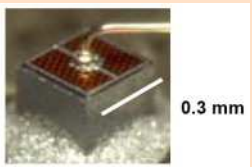


Interconnect Materials

Materials for die attach

Electrically conductive glues — λ 1-7 W/mK

- Adhesives for die attach: LED, ESD
- Adhesives for submout & heatsink attach

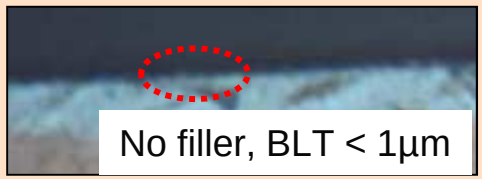


Cross section

Electrically non-conductive glues ~0.1 W/mK

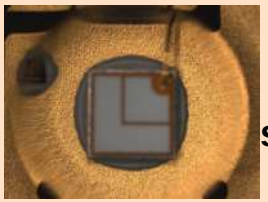
- Adhesives for sapphire die attach (transparent)
- Adhesives for optics attach: Lens, reflector

Cross section

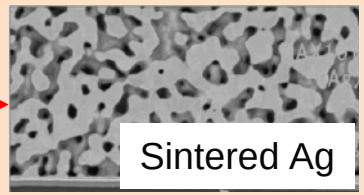


Sintering material — λ 50-100 W/mK

- Sintering material for die attach
- Sintering for submout & heatsink attach



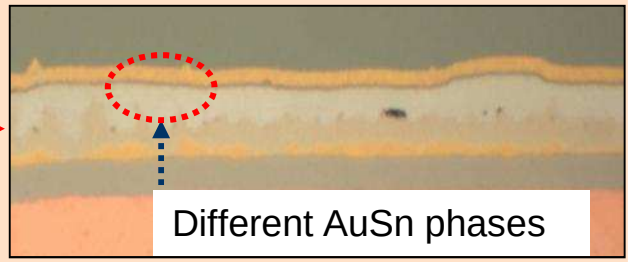
Cross section



Solder material — λ 40-60 W/mK

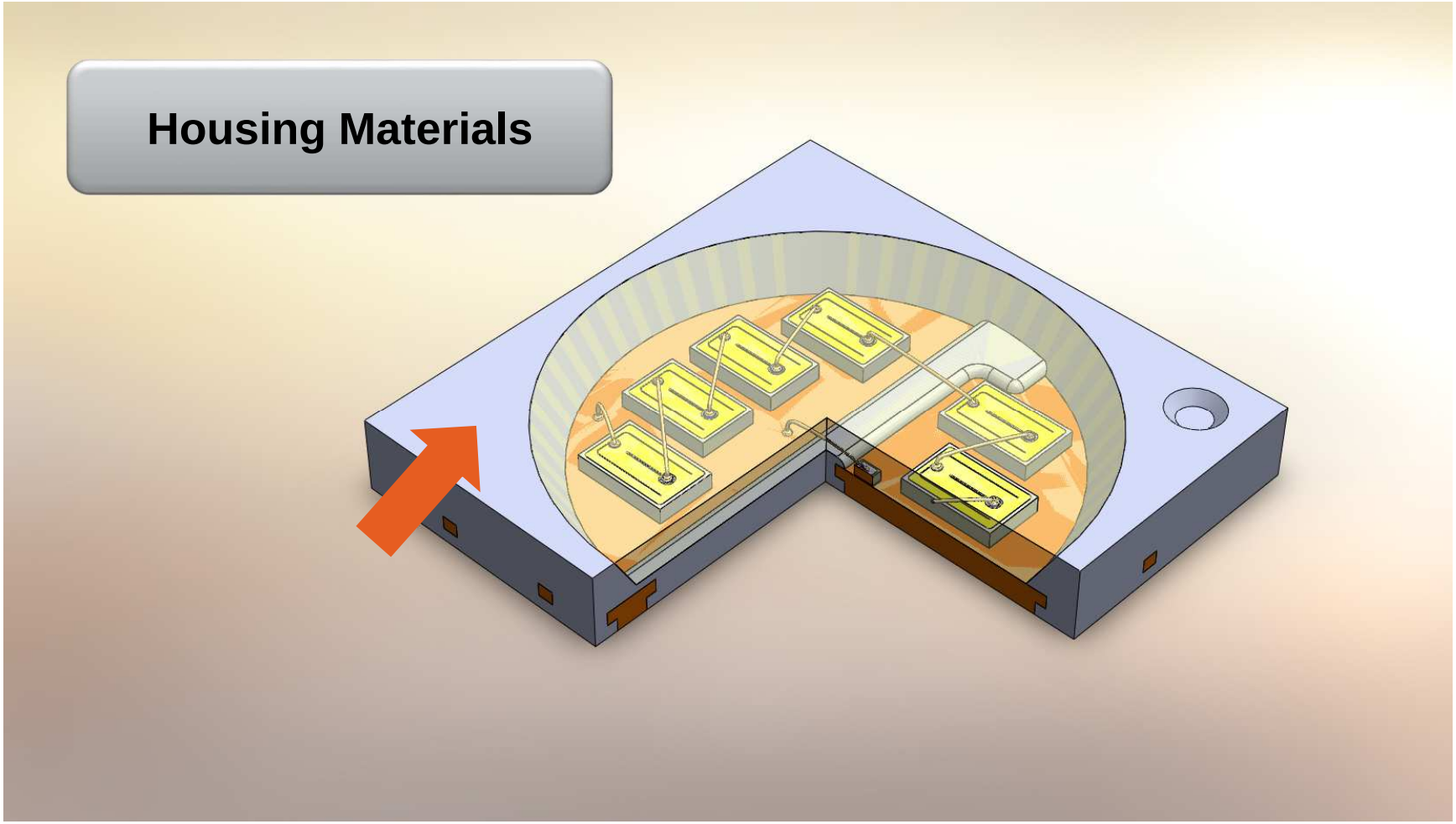
- Solder materials for die attach e.g. AuSn

Cross section



OSRAM Opto Semiconductors

Housing Materials

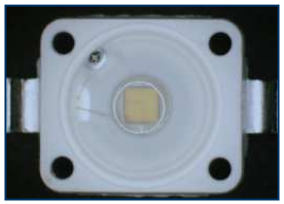


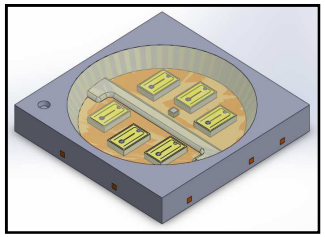
Housing Materials

Basics

Requirements for housing materials:

- high reflectivity > 90 % at 440 nm
- superior heat and light stability
- crack resistance and good adhesion (LFr, encapsulant)
- resistance to solder heat (>260°C)





Used material classes:

Semi-crystalline thermoplastics:
- PPA (PA 6T/6I, PA9T PA 10T), PCT, LCP, PEEK, PEI

Thermosettings:
- white or black Epoxy (EMC, 1-component frozen product)
- epoxy resin with anhydride hardener
- high dimensional, mechanical and environmental strength

Silicones:
- high mechanical, heat and light durability
- high reflectivity

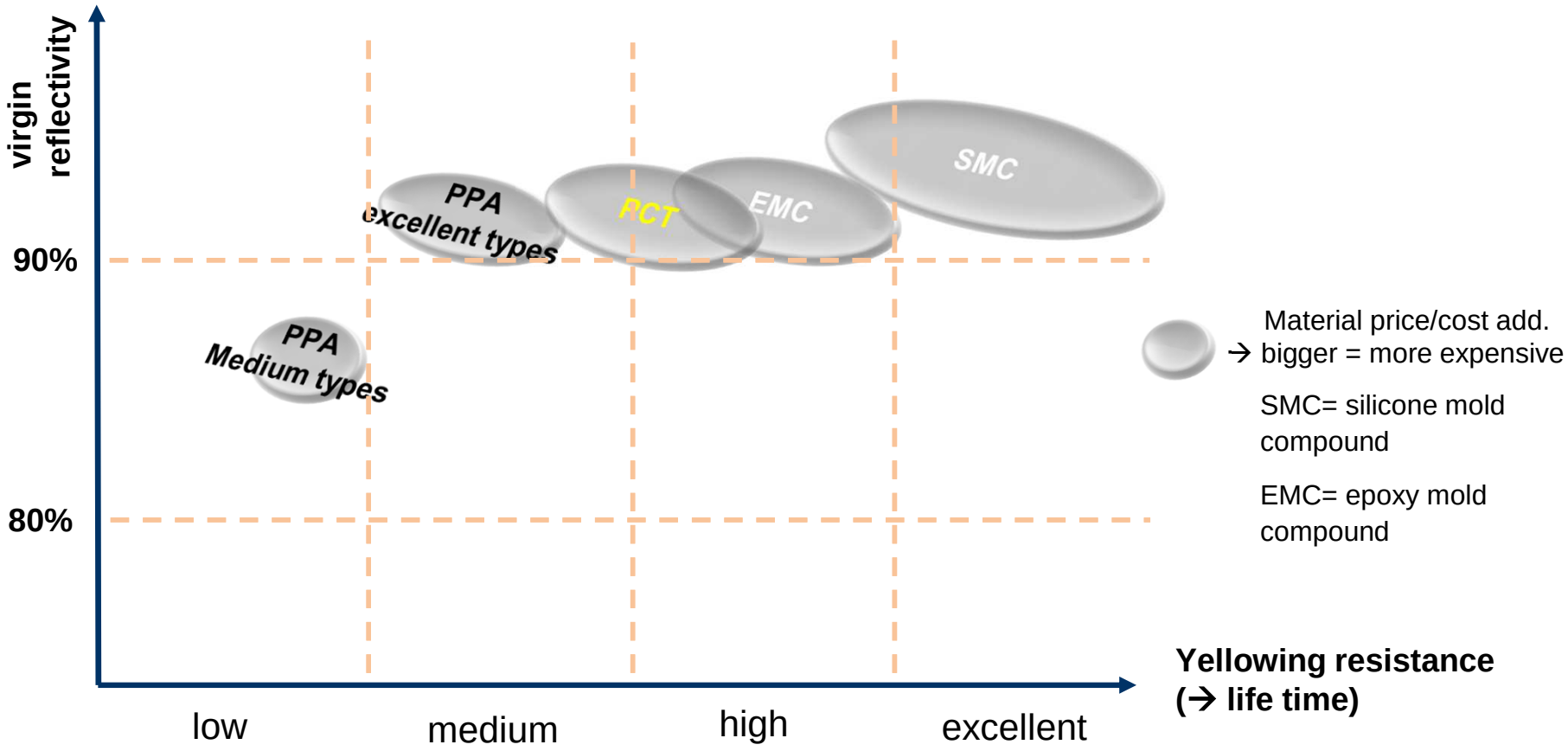
Hybrids
- epoxy network with silicone structures
- silicone network with epoxy structures
- high heat and light resistance

Fillers
- glass fibers
- pigments
- SiO_2
- TiO_2
- other mineral fillers

Housing Materials

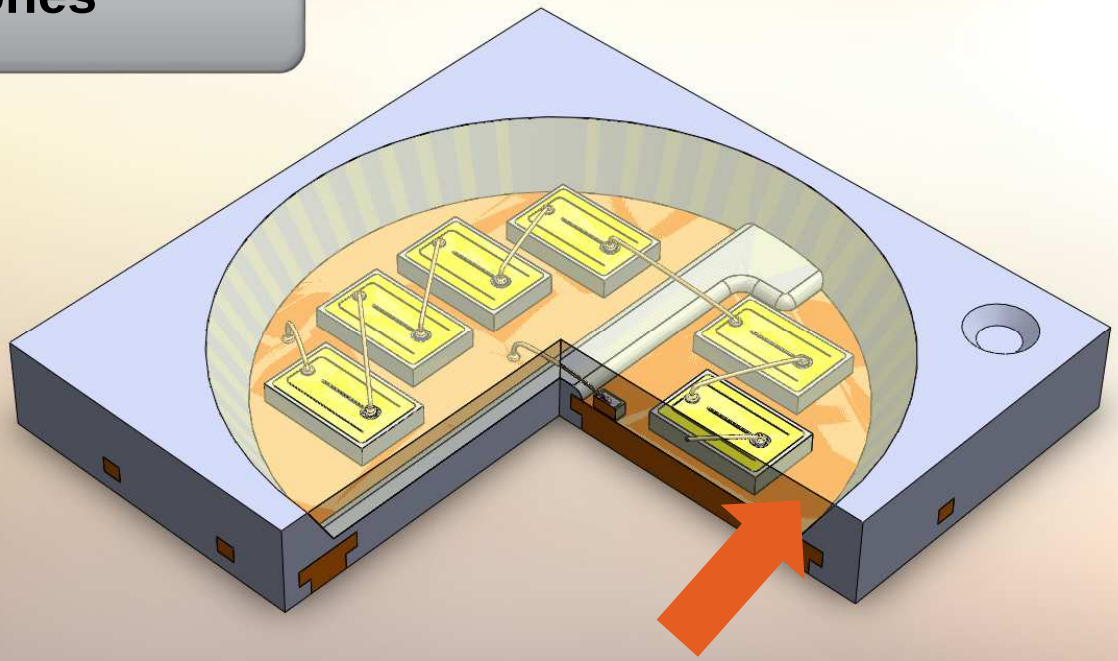
Comparison

Proper selection of adequate material stronger demanded since more and better materials are available!



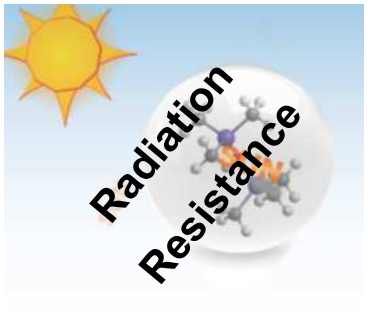
Encapsulation Materials

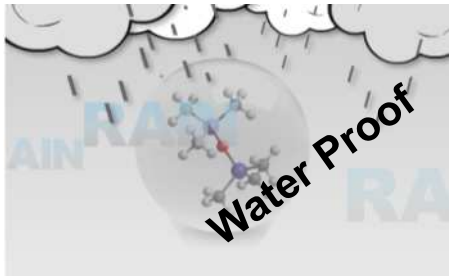
Silicones

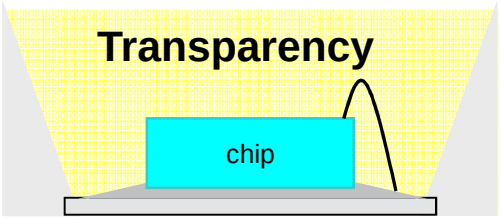


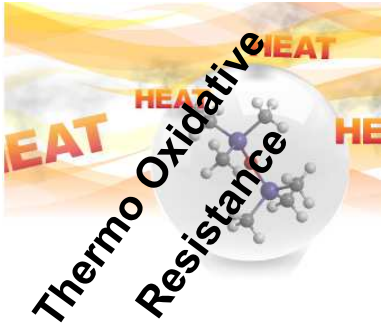
OSRAM
Opto Semiconductors

Advantages of using silicone as an encapsulant

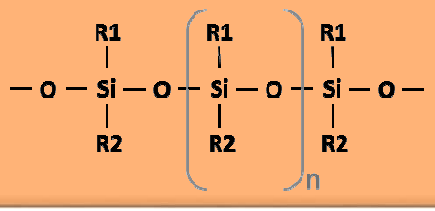








chemical structure:

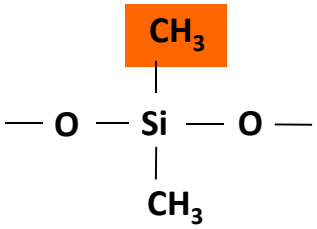


bond energy:

C – C	345 kJ/mol
Si - O	452 kJ/mol

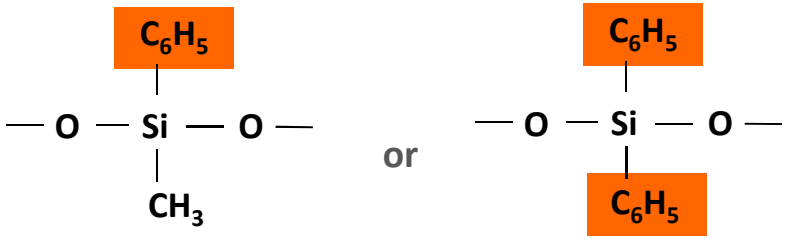
Types of silicones

Methyl-Silicones:



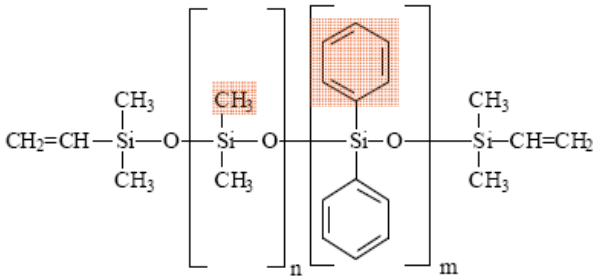
Methyl side group
low refractive index (LRI)

Phenyl-Silicones:



Phenyl side group
high refractive index (HRI)

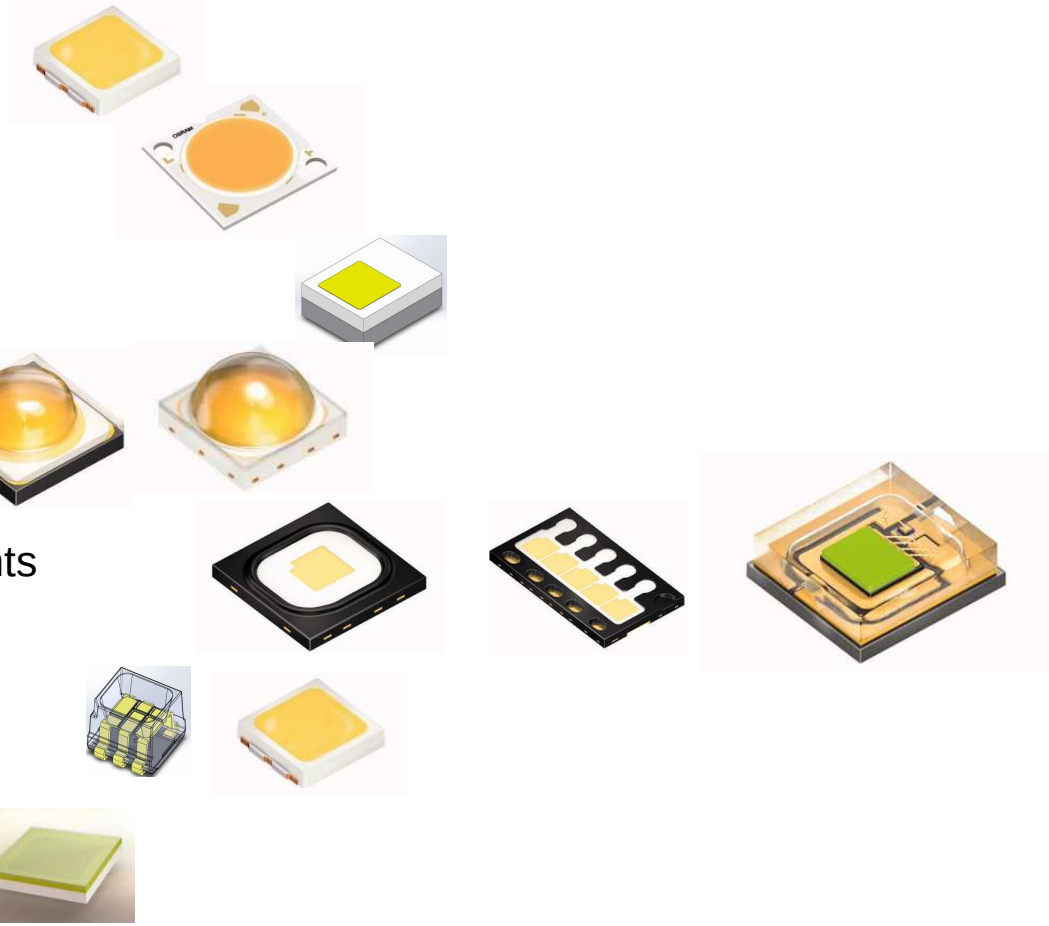
actual polymer composition:



OSRAM
Opto Semiconductors

Applications for silicones

- Volume conversion
- Sedimentation
- TiO_2 matrix
- Lens material
- Glue for conversion elements
- Glue for Sapphire Chips
- Phosphor sheets

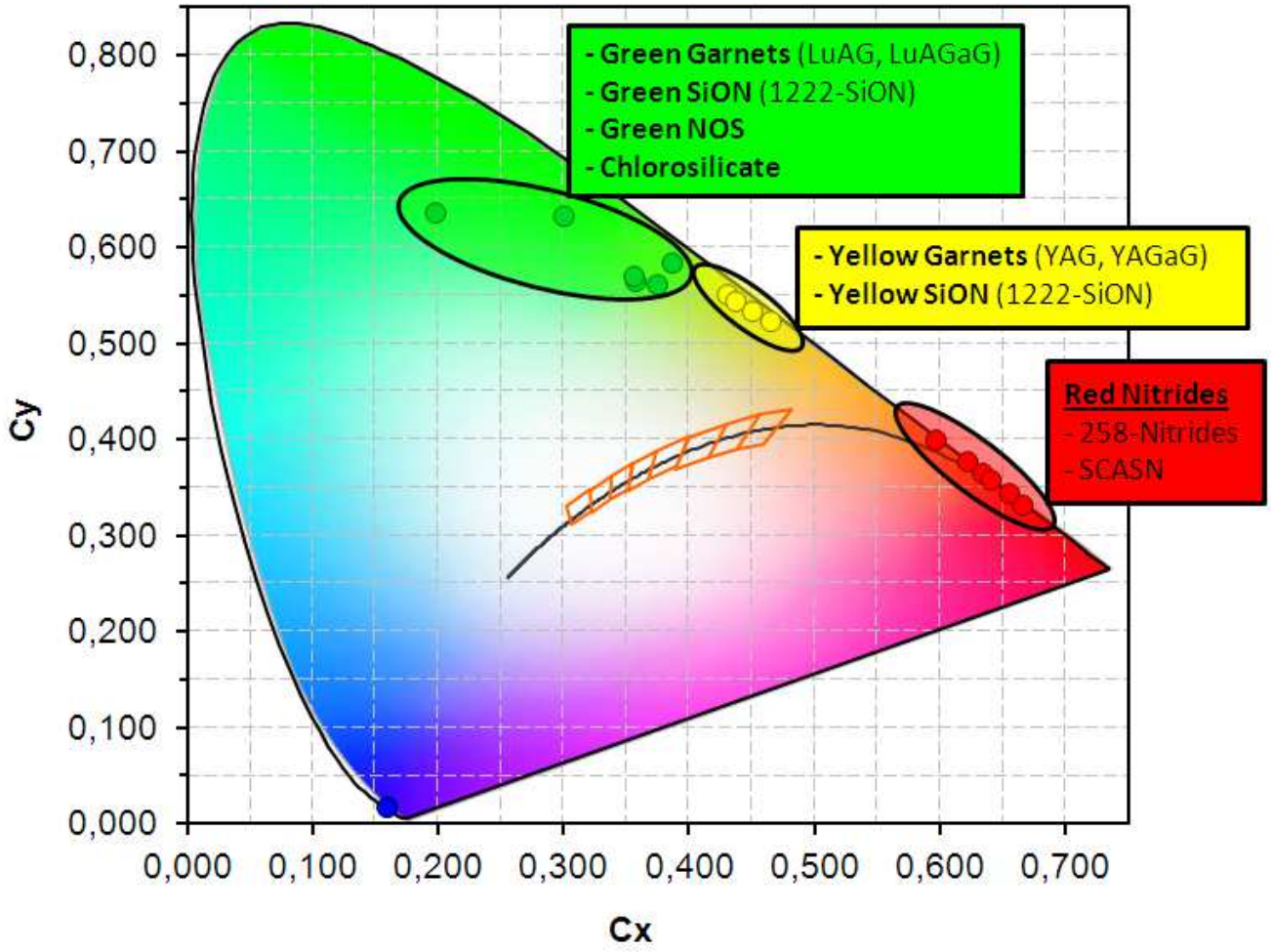


Agenda

1. Introduction: Materials for LEDs
2. Packaging Materials
3. Materials for color conversion (Phosphors)

Phosphor Materials

Chemistry – Material Classes



Phosphor Materials

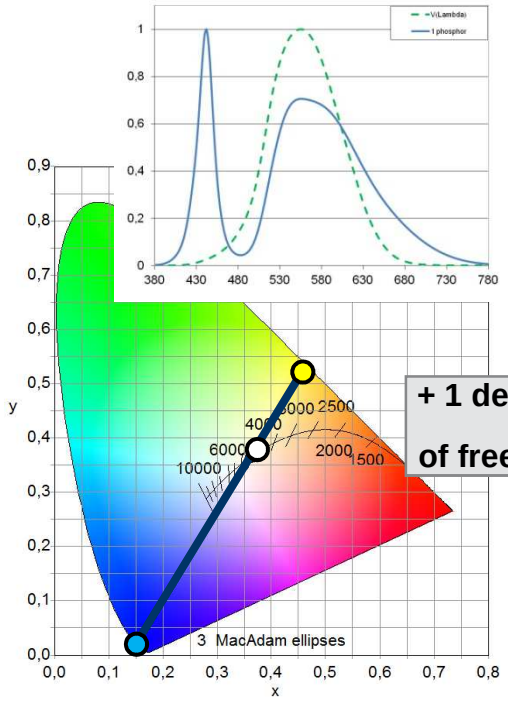
Major Phosphor parameters

Spectral emission	**λ(dom)**	dominant emission wavelength
	FWHM	spectral emission width
	Cx, Cy	color coordinate
Spectral absorption	**λ_{Rmin}**	wavelength position of remission minimum
	$R_{\lambda ex}$	remission at excitation wavelength
Phosphor efficiency	**QE**	quantum efficiency
Grain characteristic	**Size**	nm-particle → LED eff. ↓, homogeneous scattering, uniform color
		µm-particle → LED eff. ↑, forward scattering, color dependant on angle
	Shape	spherical, rough etc. impact on eff. and conversion
Chemical composition (example YAG)	**c(Ce)**	low concentration → less t-quenching, less absorption, green shift
	c(Ga)	high conc. → green shifted emission and absorption
	c(Gd)	high conc. → red shifted emission

→ All parameters are important at the same time

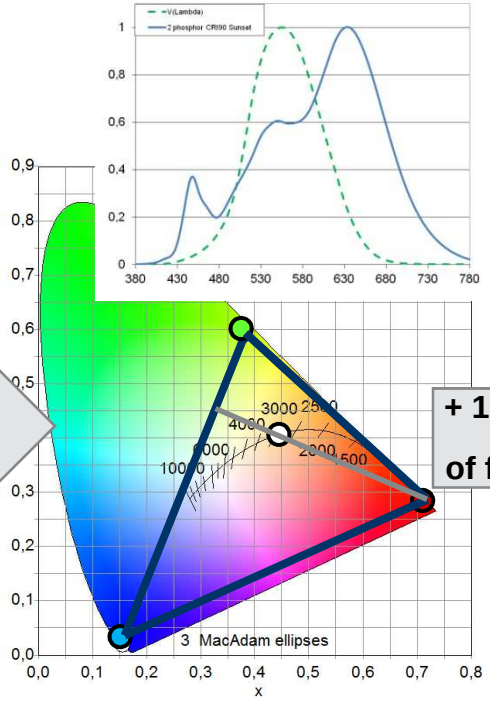
Multi-Phosphor Solutions:
1, 2, 3 or even more?

1 Phosphor: Cold White



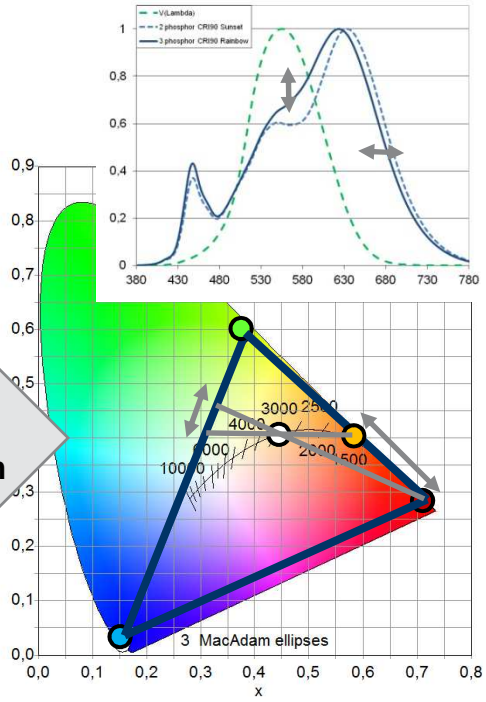
+ 1 degree of freedom

2 Phosphors: Warmwhite



+ 1 degree of freedom

3 Phosphors: LED3



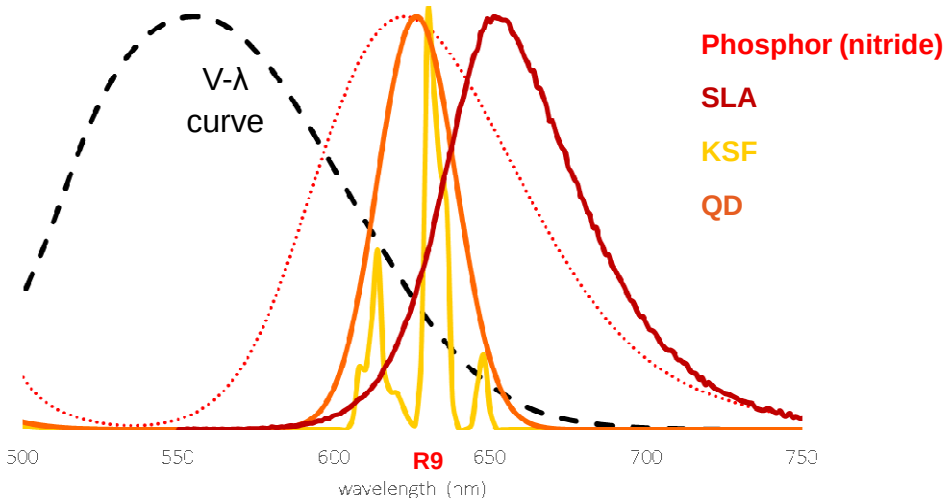
- 1 CCT on Planck
- adjustable CCT
- CRI fixed with CCT
- adjustable CCT
- fine-tuned CRI

⇒ Better fine-tuning with more phosphors

→ gain of efficacy

OSRAM
Opto Semiconductors

Outlook: narrow-band converters



SLA = $SrLiAl_3N_4$:Eu
KSF = potassium fluorosilicate K_2SiF_6: Mn^{4+}
QD = Quantum Dots
(nanoscale semiconductor particles)

- SLA: wavelength too long
- KSF: low absorption, long decay time
- QD: flexible wavelength and FWHM but limited stability

Summary

- Many different material classes are used and needed for different LED packages
- Each material has to fulfill many requirements at the same time
- **Interaction of the materials and the LED chip is key for LED development**


OSRAM
Many Thanks.