Fachhochschule Münster University of Applied Sciences

Ceramic Converters for LEDs

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Inkohärente Lichtquellen

Overwiev

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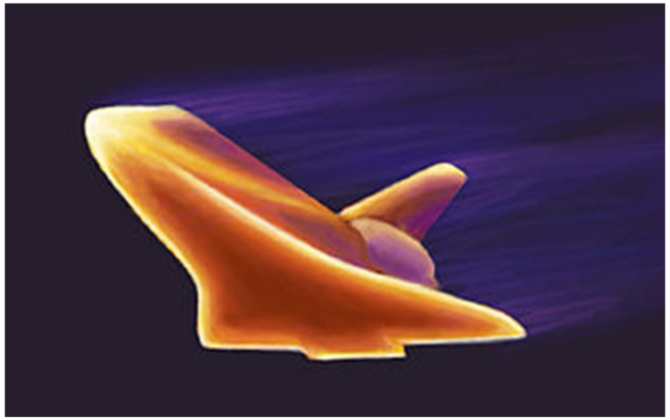
Introduction

What are ceramics?

- A ceramic is an inorganic, nonmetallic solid
- Prepared by the action of heat and subsequent cooling
- Crystalline or partly crystalline structure
- Many applications



Introduction

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LEDs in general

- A LED is a semiconductor light source
- Are used as indicator lamps
- Increasing use for other lighting
- Was introduced as a particular electronic component in 1962
- LEDs can emit in the visible- , IR- and UV-range

Introduction

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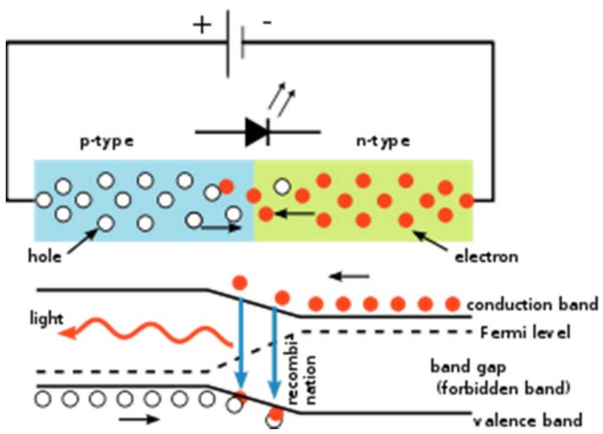
- Consists of a chip of semiconducting material doped with impurities to create a n-p junction
- Current flows from the anode to the cathode
- When an electron recombines with a hole, it falls down into a lower energy level $\longrightarrow$ release of energy
- Wavelength depends on the band gap energy



Ultraviolet and blue light LEDs

Blue LED

- GaN and InGaN $\longrightarrow$ wide band gap
- Wavelength between 420 to 480nm
- First blue LEDs were prepared in 1971, by J. Pankove

Ultraviolet LED

- Diamante and AlN
- Wavelength smaller than 400nm

Converting the LED light into white light

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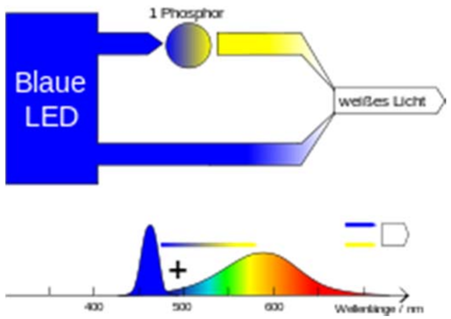
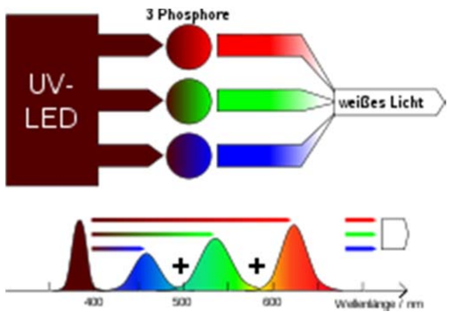
- Blue or UV-LEDs will be combined with a phosphor
- A blue LED has the highest efficiency; to convert the blue light, a yellow phosphor is used (using Ce^{3+})
- To convert the emission of a UV-LED more than one phosphor is needed.
- Most cases red (Eu^{2+}) , blue and green (Eu^{2+} or Ce^{3+}) phosphors





Converting the LED light into white light

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- In most cases the blue LED is used to prepare white light
- This is due to:

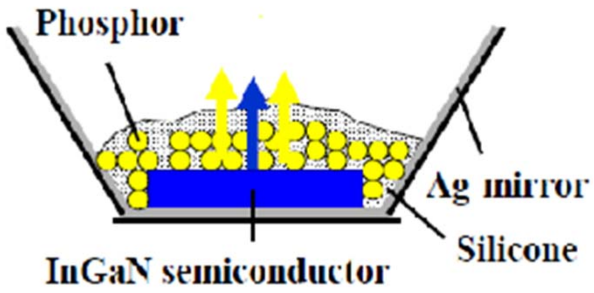
1. The high efficiency
2. Lower costs, because only one phosphor is needed instead of three like for the UV-LED

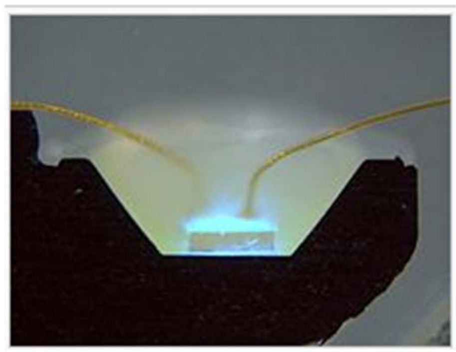
Yellow Phosphor

- In most cases YAG:Ce ($Y_3Al_5O_{12}:Ce^{3+}$) is used
- A fraction of the LED emission between 420 – 480 nm is absorbed by the YAG: Ce and down converted to yellow light
- Combined with a blue LED light source the emitted light has a color temperature of 5000K

YAG:Ce combined with a blue emitting LED

- The not converted blue light of the LED and the yellow emission is mixed and white light can be obtained
- In case of the upper picture, the yellow phosphor was inset into a epoxy / silicon matrix
- Due to aging effects and heat dissipation, scientist tried to find another way…



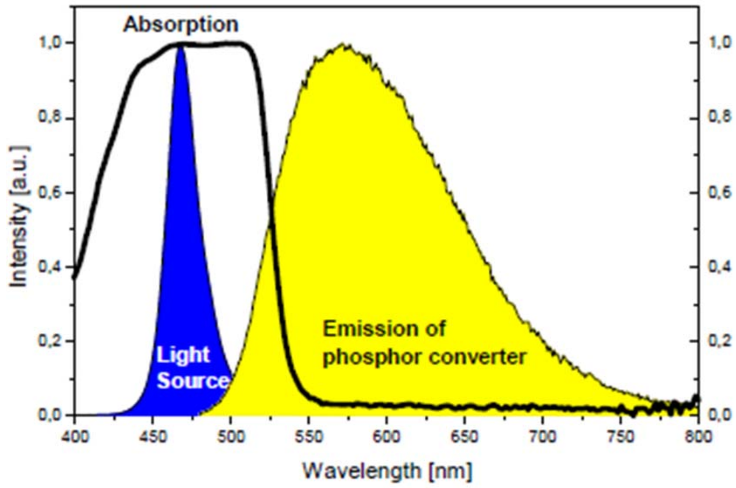


YAG:Ce ceramics as converters for LEDs

- Preparation of YAG: ceramics
- Polycrystalline ceramic plate
- YAG has a cubic crystal structure $\longrightarrow$ optical isotropic and thus transparent in the visible
- yellow body color, due to absorbing Ce^{3+}
- a well known YAG:Ce ceramic is the Lumiramic™ by *Philips*

White Emission

- black curve is the absorption
- blue peak is the emission of the LED
- and the yellow curve is the emission of the phosphor (YAG:Ce)
- the whole emission spectra shows the emission of the white light from a pcLED (phosphor converted LED)
- the correlated color temperature (CCT) is higher than 4000K (“cool white”)

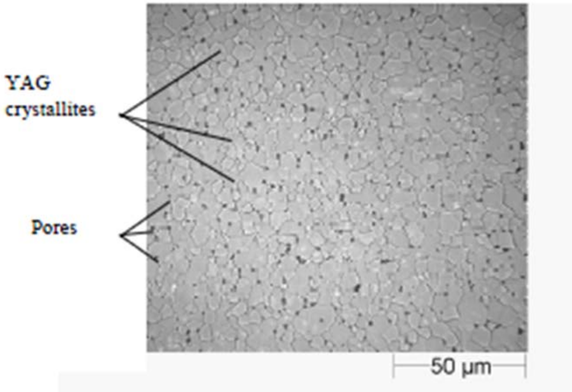


Scattering

- providing light extraction from a ceramic it needs scattering centers
- scattering centers can be produced by:

1. variation of the starting materials
2. variation of the sintering process

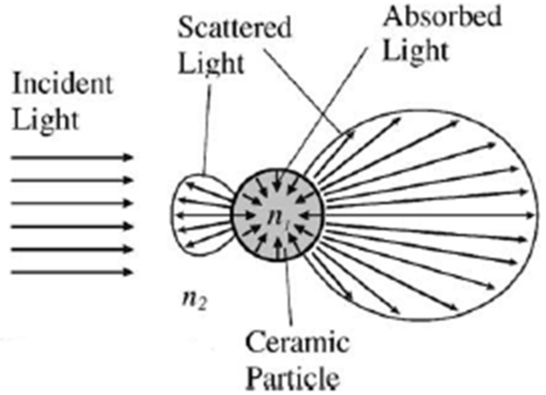
⟶ leads to variations in density of the ceramic, due to pores remaining within the structure



Source: Philips – Lumiramic ™

Scattering

- scattering is described by Mie`s theory for spherical particles
- Mie scattering: scattering on particles with the approximately size of the wavelength of the incident light
- $\longrightarrow$ nm scale
- to “use” all of the scattered light, the ceramic is embedded into mirrors, for example Ag-mirrors

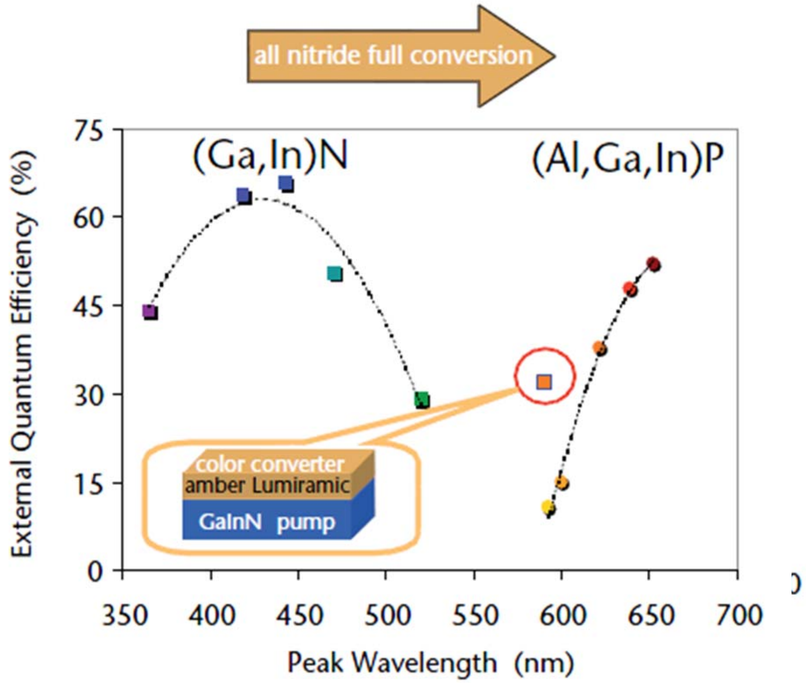


General requirements on the used phosphor

- needs to absorb at the emission wavelength of the LED
- allowed transition (spin and parity),
- compatibility to the LED production process
- high quantum yield
- stability against O_2, CO_2 and H_2O
- emitting wavelength depends on the host lattice for Ce and Eu

Ceramic converter closes the yellow gap

- high efficient LEDs for the blue light using nitride-diodes and for the red range phosohide-diodes
- no high efficient LEDs for the range around 590nm ⟶ yellow gap
- scientist of *Philips Lumileds* now invented a monochromatic nitride-diode, which closes the yellow gap at 595 nm



Source: R. Müller-Mach/ Philips Lumileds/ pps

Ceramic converter closes the yellow gap

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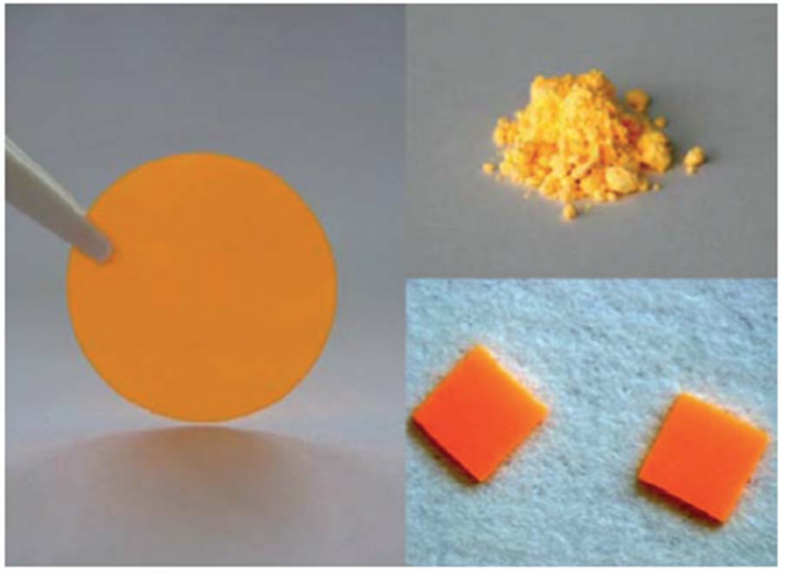
- Lumiramic –Wafer™
- $M_2Si_5N_8:Eu^{2+}$, M = Ba - Sr
- by changing the M ratio, different emission wavelength can be obtained
- brightness up to 70 lumen
- combined with a high efficient blue LED

⟶ close of the yellow gap



Source: Philips Lumileds

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