UV – LED based on AlGaN

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History of Light Emitting Diodes

1907 - The British experimenter J.H. Round of Marconi Labs discovered, that some inorganic materials start to glow if a current is applied. Today known as electroluminescence.

1927 - The Russian physicist Oleg Vladimirovich Losev rediscovered Rounds phenomenon and did further research until 1942. He reported on the first LED, but no practical use was made of it.

1955 - Rubin Braunstein observed infrared light emission generated by simple semiconductor structures using GaAs, GaSb, InP and SiGe.

1961 - Robert Biard and Gary Pittman of Texas Instruments found out that GaAs emitts infrared light if a electrical current is applied. They received a patent for the infrared LED.

History of Light Emitting Diodes

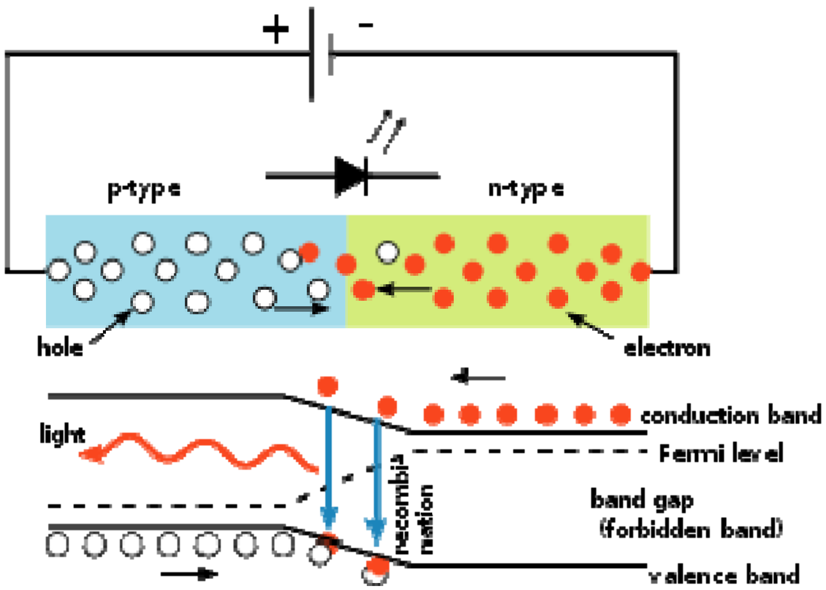
1962 - Nick Holonyak, Jr., while working at General Electric Company developed the first red LED as is seen as the "father of the light-emitting diode“.

1972 - M. George Craford invented the first yellow LED and improved the brightness of red and red-orange LEDs by a factor of ten.

1994 - The first high-brightness blue LED was demonstrated by Shuji Nakamura of Nichia Corporation and was based on InGaN.

1995 - First white LED is presented, which emits white light by light conversation from UV to broadband spectra using phosphorus.

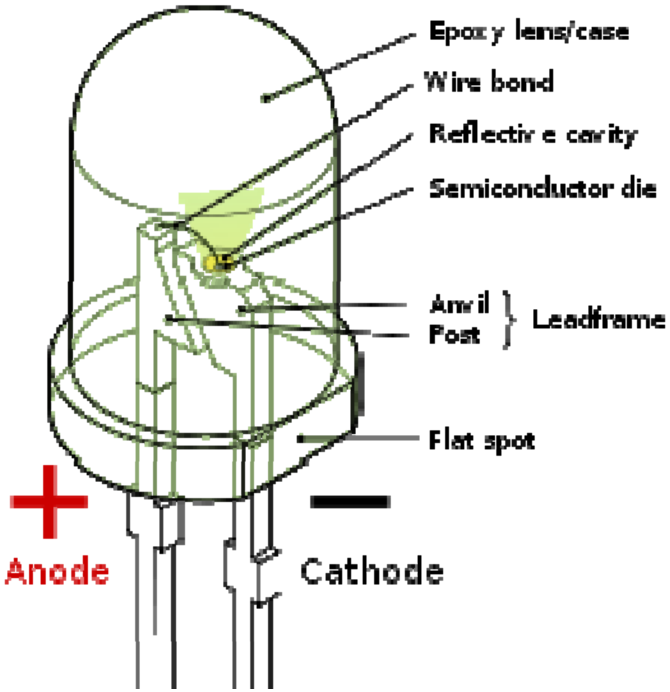
Working principle



- basic material: doped semiconductor with a p-n junction
- The applied current flows, like in other diodes, easily from p-side to n-side
- In the junction area the charge carriers, electrons and holes, combine and drop down to a lower energy level by emitting a photon
- The wavelength of the photons corresponds to the energy of the band gap

Types of LEDs

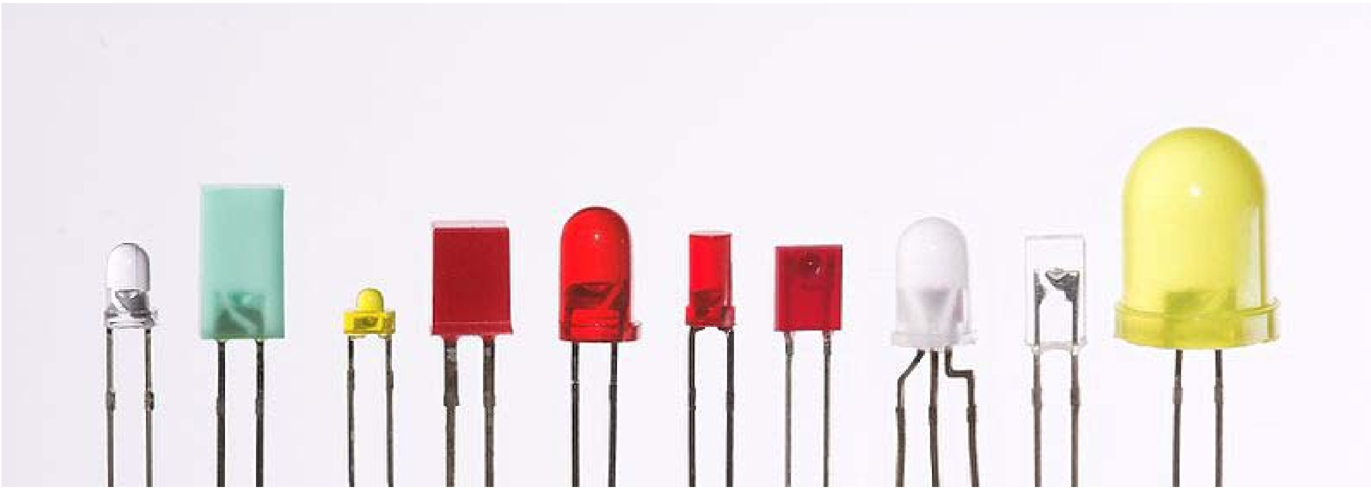
schematic setting:



real setting:

Types of LEDs

Various types of LED shapes:



Types of LEDs

	Color	Wavelength [nm]	Voltage drop [ΔV]	Semiconductor material
	Infrared	$\lambda > 760$	$\Delta V < 1.63$	Gallium arsenide (GaAs) Aluminium gallium arsenide (AlGaAs)
	Red	$610 < \lambda < 760$	$1.63 < \Delta V < 2.03$	Aluminium gallium arsenide (AlGaAs) Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
	Orange	$590 < \lambda < 610$	$2.03 < \Delta V < 2.10$	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
	Yellow	$570 < \lambda < 590$	$2.10 < \Delta V < 2.18$	Gallium arsenide phosphide (GaAsP) Aluminium gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
	Green	$500 < \lambda < 570$	$1.9 < \Delta V < 4.0$	**Traditional green:** Gallium(III) phosphide (GaP) Aluminium gallium indium phosphide (AlGaInP) Aluminium gallium phosphide (AlGaP) **Pure green:** Indium gallium nitride (InGaN) / Gallium(III) nitride (GaN)
	Blue	$450 < \lambda < 500$	$2.48 < \Delta V < 3.7$	Zinc selenide (ZnSe) Indium gallium nitride (InGaN) Silicon carbide (SiC) as substrate Silicon (Si) as substrate—under development
	Violet	$400 < \lambda < 450$	$2.76 < \Delta V < 4.0$	Indium gallium nitride (InGaN)
	Purple	multiple types	$2.48 < \Delta V < 3.7$	Dual blue/red LEDs, blue with red phosphor, or white with purple plastic
	Ultraviolet	$\lambda < 400$	$3.1 < \Delta V < 4.4$	Diamond (235 nm) Boron nitride (215 nm) Aluminium nitride (AlN) (210 nm) Aluminium gallium nitride (AlGaN) Aluminium gallium indium nitride (AlGaInN)—down to 210 nm
	Pink	multiple types	$\Delta V \sim 3.3$	Blue with one or two phosphor layers: yellow with red, orange or pink phosphor added afterwards, or white with pink pigment or dye.
	White	Broad spectrum	$\Delta V = 3.5$	Blue/UV diode with yellow phosphor

UV-LEDs

Ultraviolet light:

- Wavelength: λ < 400 nm
- Band gap energy: 3,1 – 4,4 eV
- Materials:

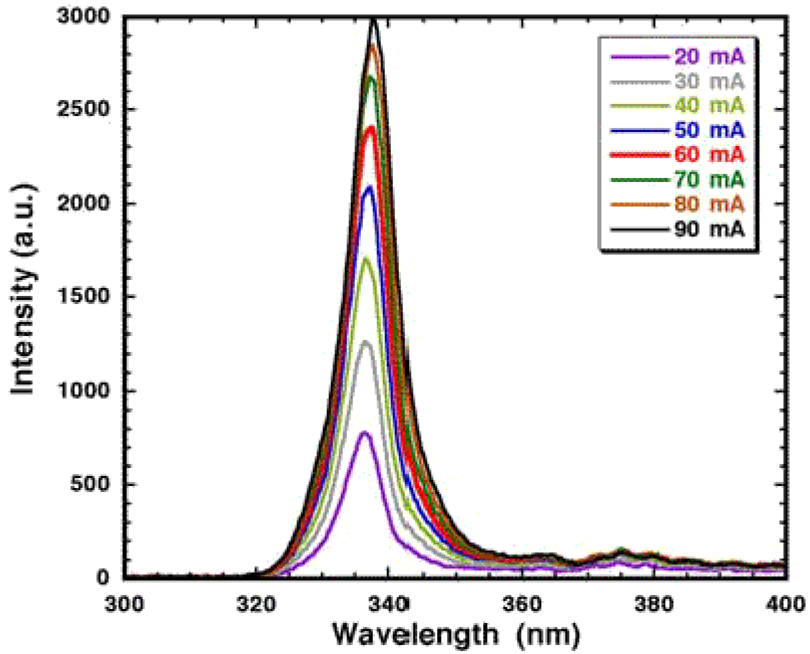
  - Diamond (235 nm)

  - Boron nitride (215 nm)

  - Aluminium nitride (AlN) (210 nm)

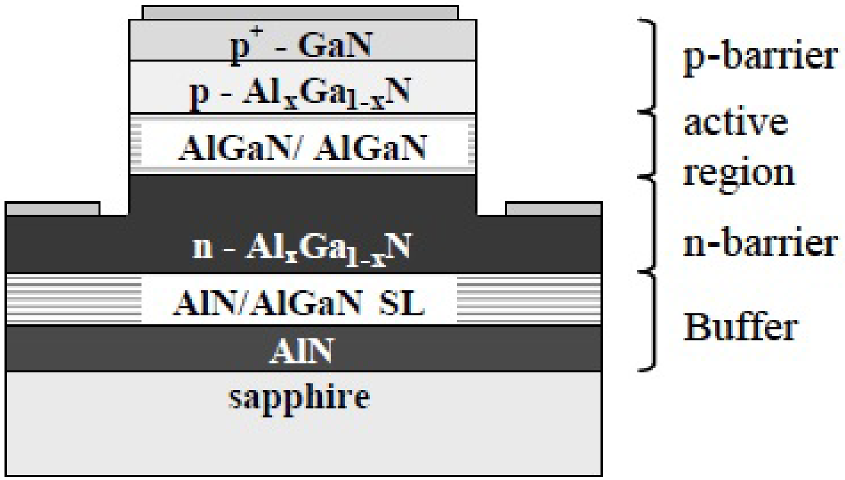
  - Aluminium gallium nitride (AlGaN) (340 nm)

  - Aluminium gallium indium nitride (AlGaInN)—down to 210 nm

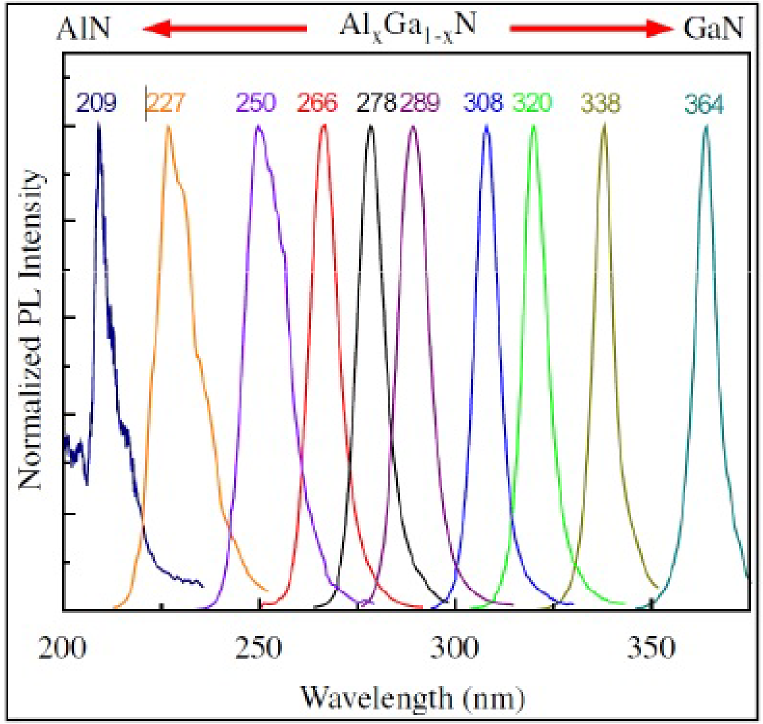


Spectrum for an AlGaN-based UV LED

AlGaN-LED



Schematic structure order



Wavelength dependency
on material composition

Comparison to low pressure Hg-Lamp

AlGaN UV-LED:		Hg low pressure Lamp*:	
Efficiency:	5-15%	Efficiency:	40%
Lifetime:	> 15.000 h	Lifetime:	16.000 h
Output Power:	30 mW (100 mA)	Output Power:	4 W (100mA)

- no risks of environmental pollution by UV-LEDs
- LEDs have no time delay by warming up,

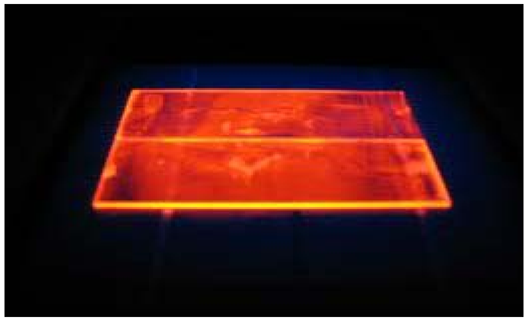
  -> good for applications with fast on/off switches
- LEDs have no wide spectral power distribution
- LEDs have no dropping in UV output over lifetime

* standart quartz lamp

Applications

- Adhesive/lacquers hardening
- Quality control
- Sterilisation / Disinfection (liquids, air)
- Medicine (light therapy)
- Microscopy (Fluorescence)
- Light conversion (UV on

  various types of phosphorus)



Thank you for your attention!

Sources:

- Wikipedia: Light-emitting Diode (english)
  http://en.wikipedia.org/wiki/Led#Ultraviolet_and_blue_LEDs
- UV LEDs ramp up the quiet side of the LED market
  http://ledsmagazine.com/features/9/2/5
- AlGaN deep ultraviolet LEDs on bulk AlN substrates
  (Zaiyuan Ren1, Q. Sun1, S.-Y. Kwon1, J. Han,1, K. Davitt2, Y. K. Song2, A. V. Nurmikko2,W. Liu3, J. Smart 3, and L. Schowalter 3)*
- Efficiency Increase For Deep UV LEDs
  http://www.compoundsemiconductor.net/csc/features-details/19735467/Efficiency-increase-for-deep-UV-LED.html
- HG low pressure lamps data
  http://www.light-sources.com/