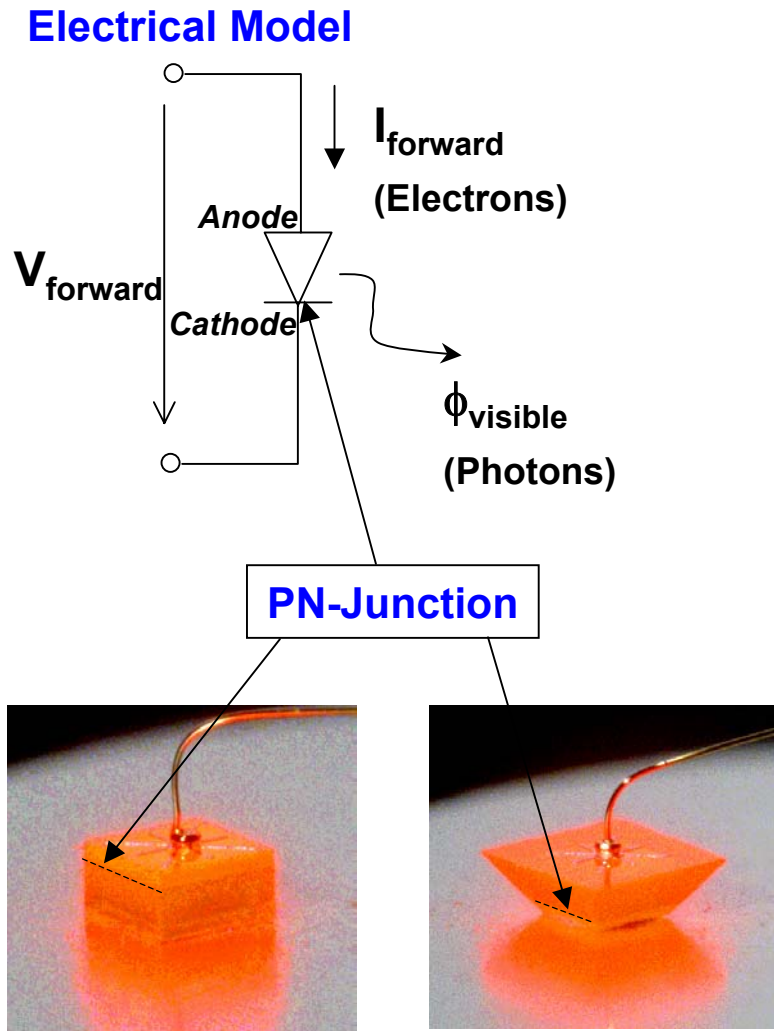
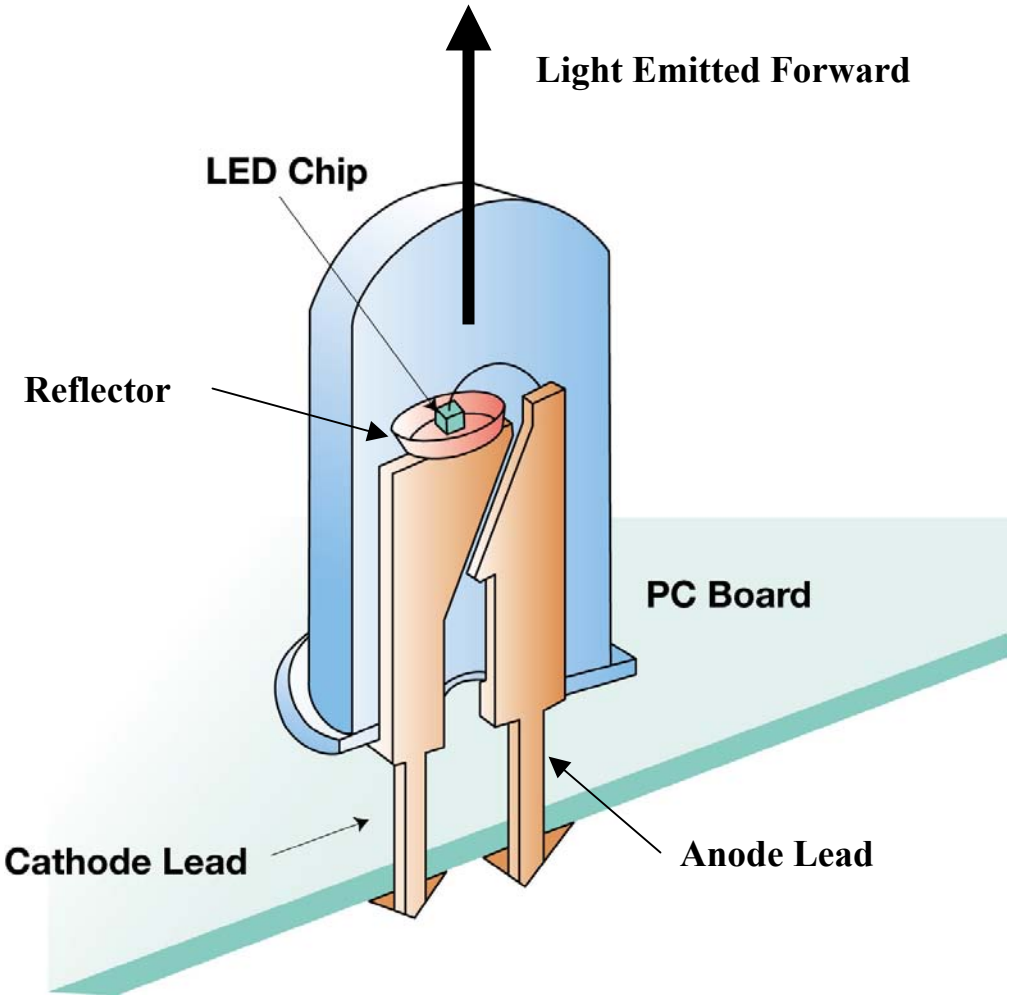
Language

- *Die* = chip: heart of the LED
- *LED* - chip in a package
- *PN Junction* - where the light is created in the chip
- *AlInGaP & AlGaS*: red - yellow technology
- *InGaN* - green – blue +white technology
- *Level 1* – the chip or die
- *Level 2* – the LED
- *Level 3* – a LED array; may include optics, heat sink and/or power supply
- *Level 4* – LED luminaire
- *Driver* = ballast
- *Thermal Resistance (C/W)* - a measure of the heat transfer capacity of the LED - lower is better
- *Binning* - subdivision of the manufactured "distribution" into common operating parts (color, flux, forward voltage)



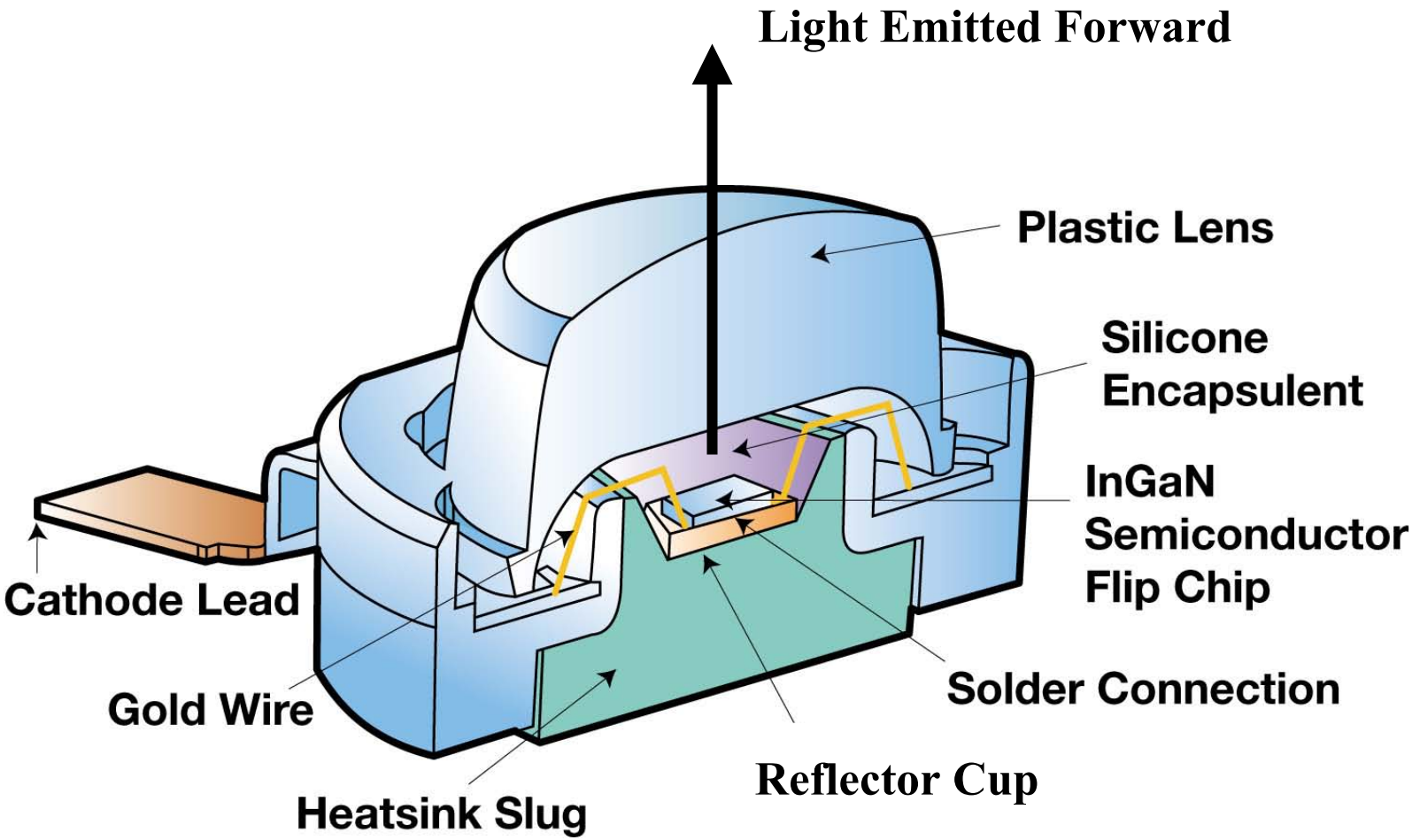
What is a LED?

Low Flux LED



LUMILEDS

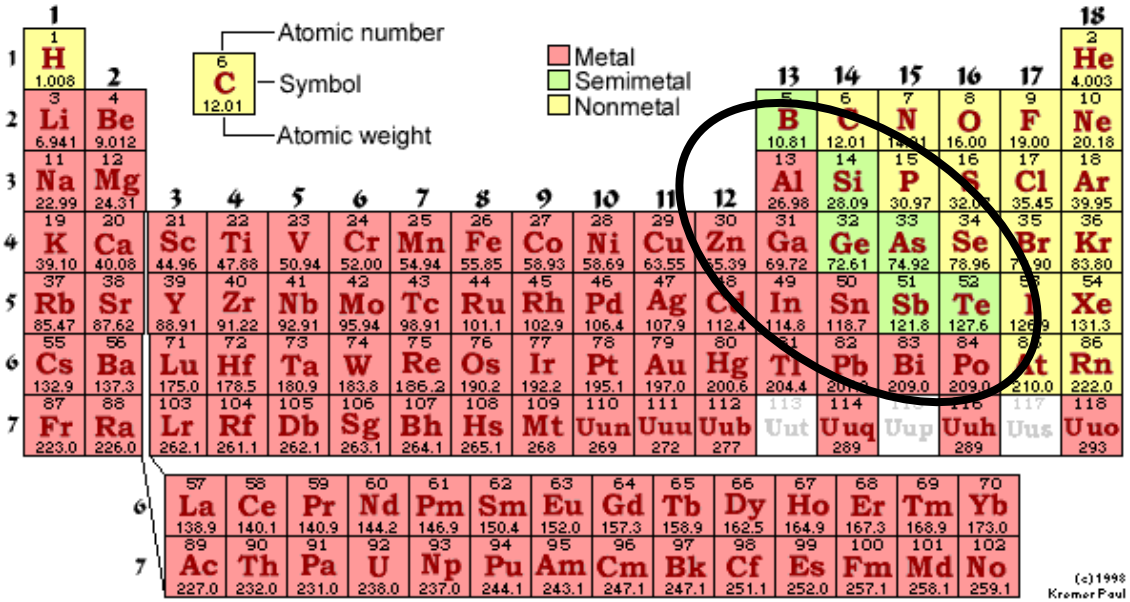
What is a LED?



What is a LED?

LED's Defined

- The exchange of positive and negative charges between these materials results in the emission of photons.



The Periodic Table

Courtesy io Lighting

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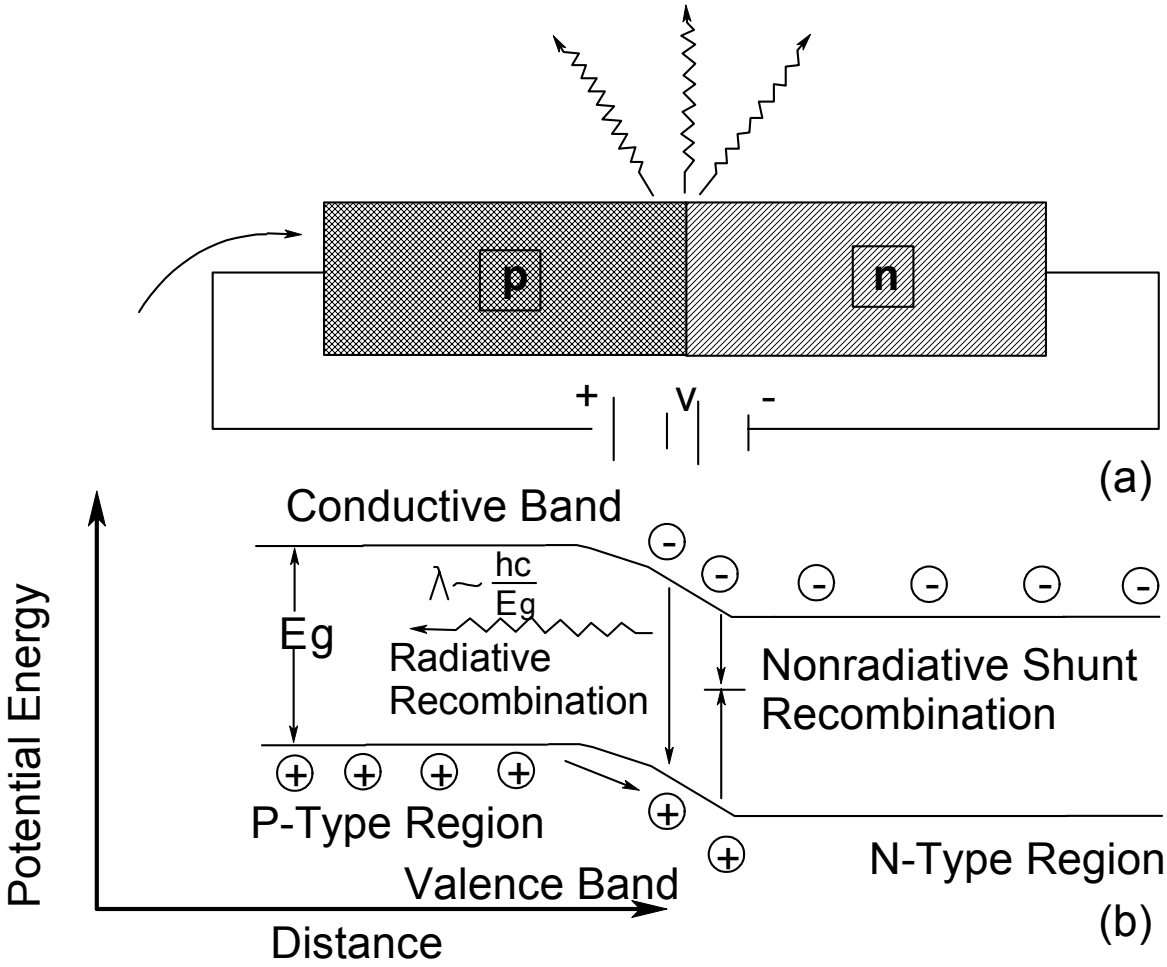
What is a LED – How does it work?



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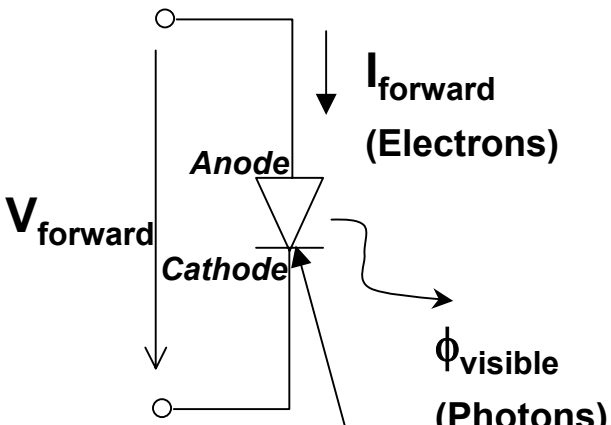
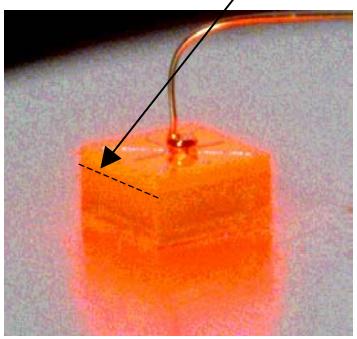
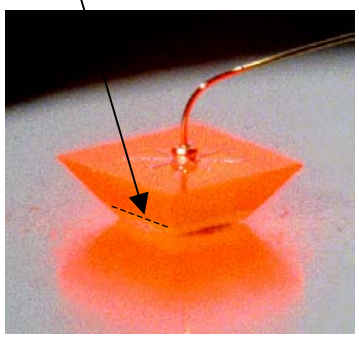
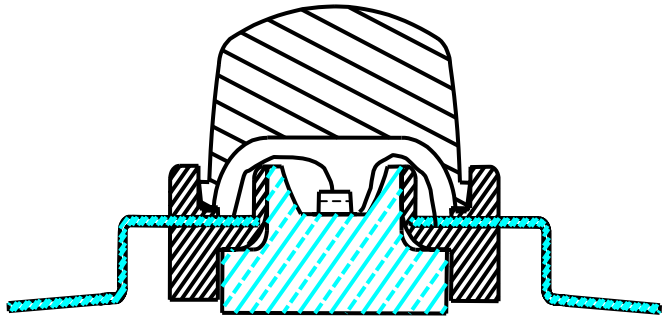
Working Principle of an LED

Electrical Model





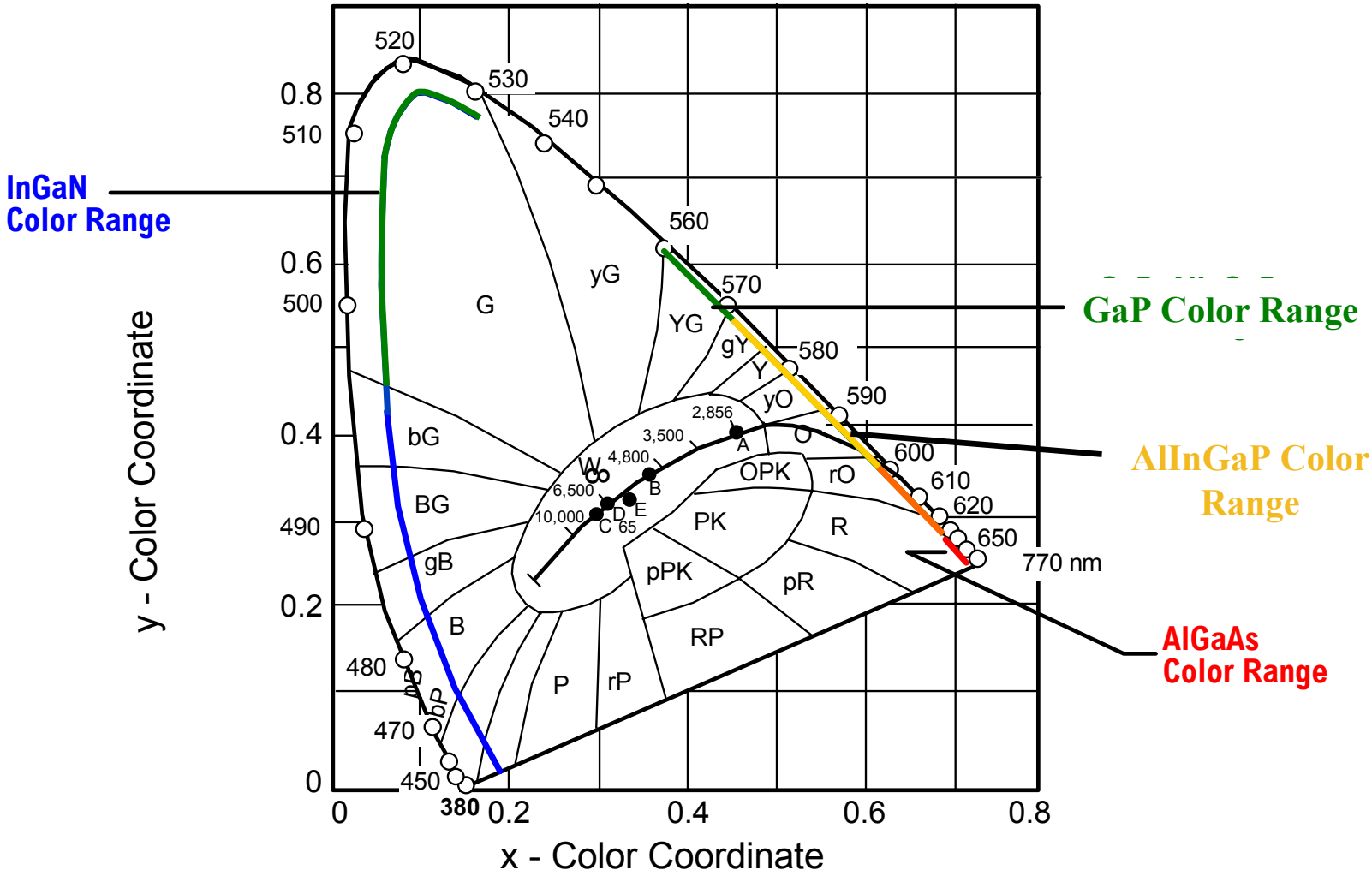




- Same principle for all colors (AlInGaP & InGaN)
- Power dissipation:1-5 Watt
- Package Extraction Efficiency: >95%

- Maximum Ratings
  - $T_{junction-max}$ = 120°C
  - $I_{forward-max}$ = Product dependent

LED Color Ranges



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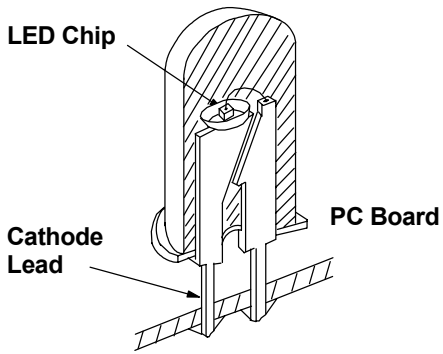
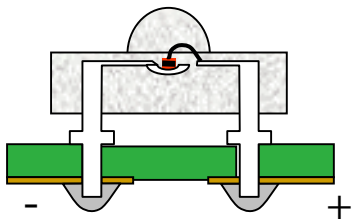
Historical Development of LEDs

- 1962 – first LED, a novelty in the lab
- Late 60s – low output red LEDs (< 1 mcd) find commercial applications as indicator lamps
- mid 70s – Green LEDs
- Early 90s – Blue (Nakamura), completing spectrum
- Late 90s + - commercialization of high brightness LEDs

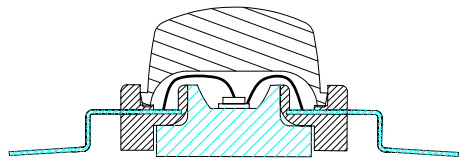
Historical Development - Design Evolution of LED Packages



5mm Lamp
Circa 1970
2-3 lumens
If = 30 mA



SuperFlux
Circa 1992
4-8 lumens
If = 70 mA



Luxeon
Circa 1997
20-40 lumens
If = 350 mA

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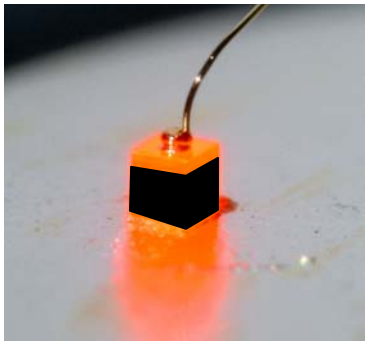
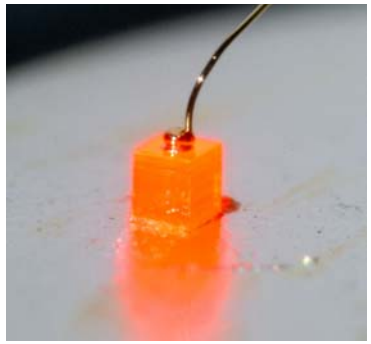
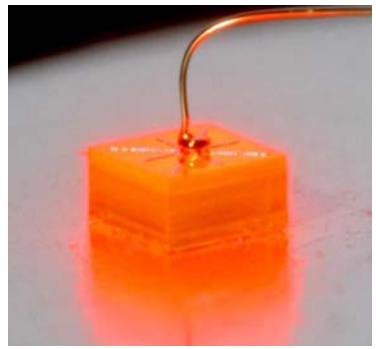
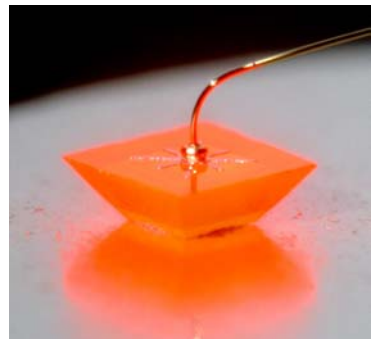
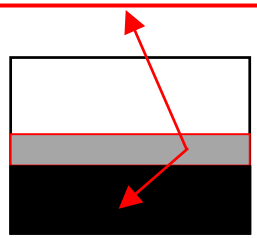
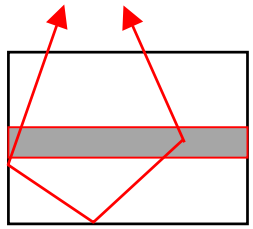
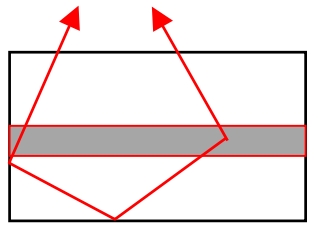
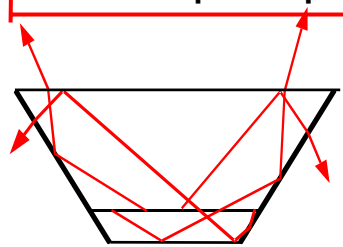
Historical Development - Better Light Extraction

Absorbing Substrate (1991)	Transparent Substrate (1994)	Batwing (1998)	Lambertian (mid 2001)
			
	Increase surface area		Re-shape Chip
			
	~ 3x flux improvement	~ 15x flux improvement	~ 30x flux improvement