Chemistry 4631

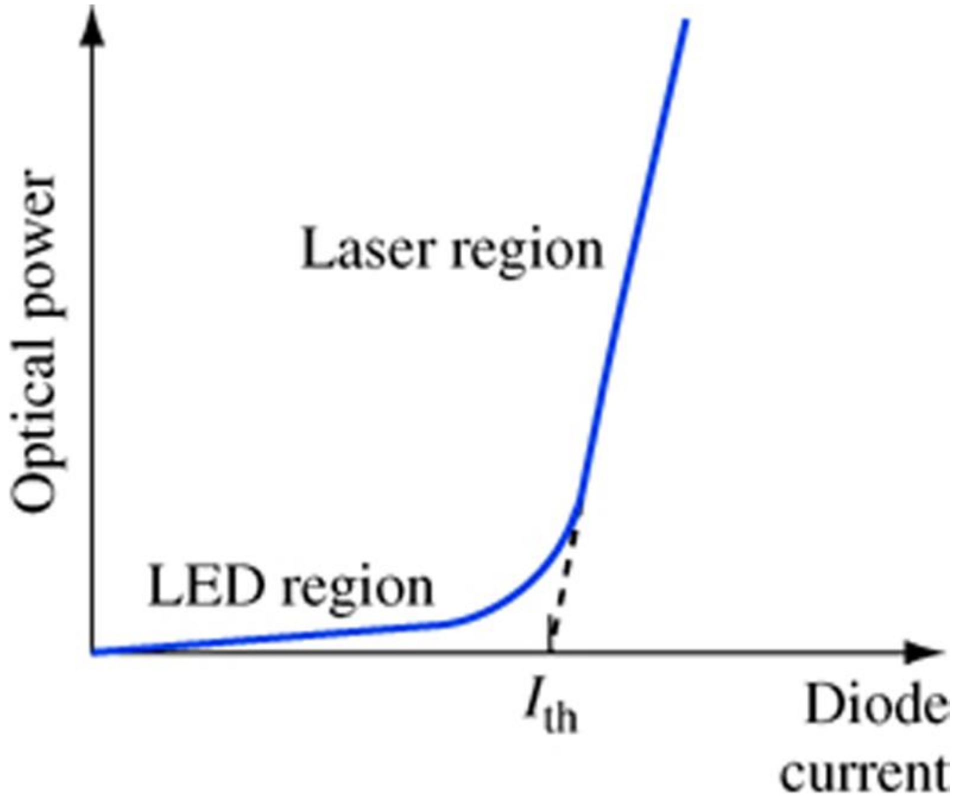
Instrumental Analysis

Lecture LEDs

Molecular Luminescence Spectrometry

Sources

Semiconductor LED vs LASER



Molecular Luminescence Spectrometry

Sources

- Blue light-emitting diodes (LEDs)

  Emit at 450-475 nm

  - Use a pn junction under forward bias to produce radiant energy
  - The diodes are made from gallium nitride (λ = 465 nm) or indium gallium nitride (λ = 450 nm)

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Advantages of Light Emitting Diodes (LEDs)

Longevity:

The light emitting element in a diode is a small conductor chip rather than a filament which greatly extends the diode's life in comparison to an incandescent bulb (10 000 hours life time compared to ~1000 hours for incandescence light bulb)

Efficiency: (Presently High 25--30 Lumens/Watt)

Diodes emit almost no heat and run at very low amperes

Lower energy consumption

Smaller size

Red 10x Better that (filtered) incandescent

White 2x better than incandescent

Potential efficiency 150+ Lumens/Watt (2x better than fluorescent)

Greater Light Intensity:

Since each diode emits its own light

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Advantages of Light Emitting Diodes (LEDs)

Cost:

Coming down

Robustness:

Solid state component, not as fragile as incandescence light bulb

No catastrophic failures

Environmentally friendly:

Minimal disposal required

No mercury

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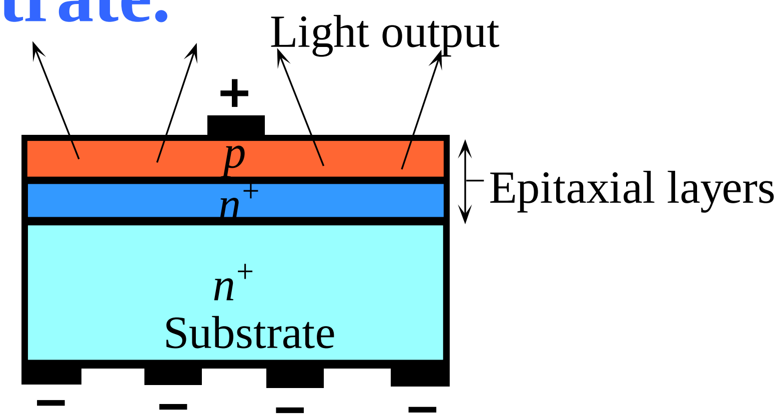
General Structure

A simple LED is a pn junction on a suitable substrate.



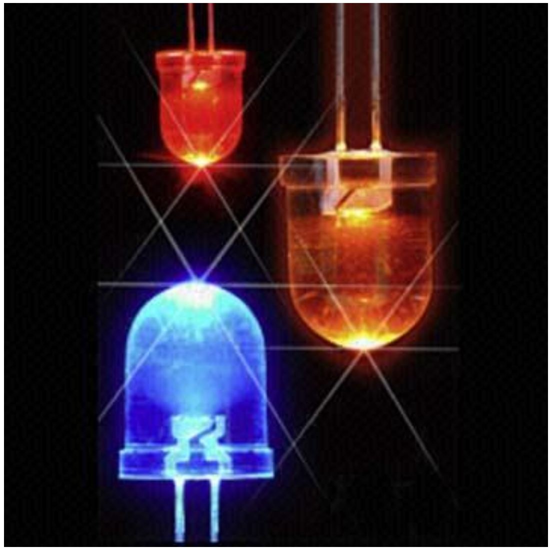


Fig. 6.44: A schematic illustration of one possible LED device structure. First n^+ is epitaxially grown on a substrate. A thin *p* layer is then epitaxially grown on the first layer.

From *Principles of Electronic Materials and Devices, Second Edition*, S.O. Kasap (© McGraw-Hill, 2002)
http://Materials.Usask.Ca

Molecular Luminescence Spectrometry

- LEDs are semiconductor p-n junctions that under forward bias conditions can emit radiation by electroluminescence in the UV, visible or infrared regions of the electromagnetic spectrum.

- When pn junction is forward biased, large number of carriers are injected across the junctions. These carriers recombine and emit light.

- The quanta of light energy released is approximately proportional to the band gap of the semiconductor.

- The emitted photons must escape without being reabsorbed, so the p-side has to be narrow.

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A typical LED needs a p-n junction

There are a lot of electrons and holes at the junction due to excitations

Electrons from n need to be injected to p to promote recombination

Junction is biased to produce even more e-h and to inject electrons from n to p for recombination to happen

Recombination produces light!!

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Efficient LED

- Need a **p-n junction** (preferably the same semiconductor material only different dopants).
- **Recombination must occur** → Radiative transmission to give out the correct color.
- Color of LED → $\mathbf{hc/\lambda = E_c - E_v = E_g}$
  → **so choose material with the right $\mathbf{E_g}$**
- **Direct band gap** semiconductors to allow efficient recombination.
- All photons created must be able to leave the semiconductor.
- Little or **no reabsorption** of photons.

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Visible LED

LED to emit visible light, the band gap of the materials that are used must be in the region of visible wavelength = 390 - 770nm. This coincides with the energy value of 3.18eV- 1.61eV which corresponds to the colour spectrum.

Colour the LED should emit

Violet ~ 3.17eV
Blue ~ 2.73eV
Green ~ 2.52eV
Yellow ~ 2.15eV
Orange ~ 2.08eV
Red ~ 1.62eV

The band gap, E_g that the semiconductor must possess to emit each light

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The nitrides and blue LED

- **Difficulties:**
  - to find suitable substrates for the nitrides
  - to get p-type nitrides

- **But with constant R&D work, better materials are produced**
- **GaN, InGaN, AlGaN → high efficiency LEDs emitting blue/green part of the spectrum.**
- **First blue LED 1994 Shuji & Nakamura (10 000 hours lifetime)**
- **SiC can also be used as blue LED - SiC on GaN substrate**

Molecular Luminescence Spectrometry

Sources

- **Blue light-emitting diodes (LEDs)**

Important parameter -quantum efficiency (η): a number of photons generated per electron-hole pairs

Factors which determine quantum efficiency

Efficiency of radiative recombination

Internal losses (due to recombination in the depletion region)

Molecular Luminescence Spectrometry

Sources

- **Blue light-emitting diodes (LEDs)**

The quantum efficiency

- Internal quantum efficiency of some LEDs approaches 100% but the *external efficiencies* are much lower. This is due to reabsorption and TIR (Total internal reflectance).

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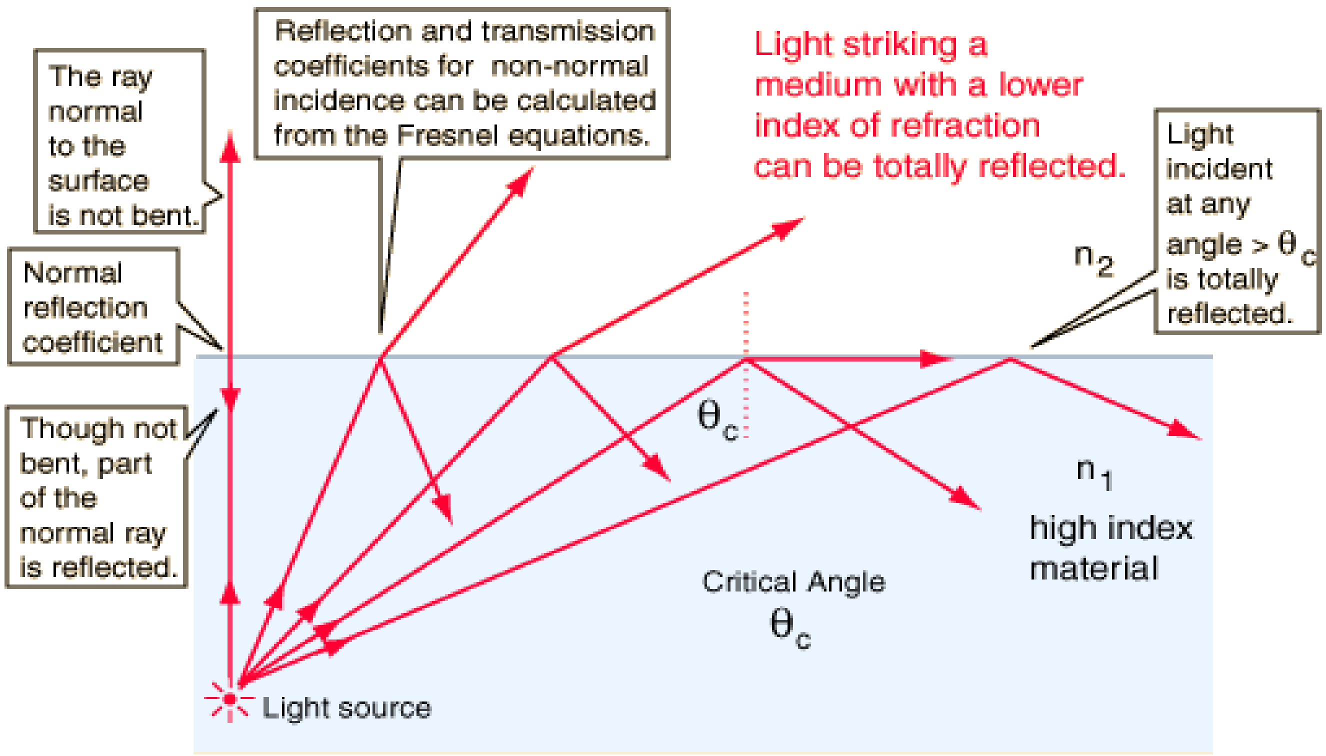
Total Internal Reflection



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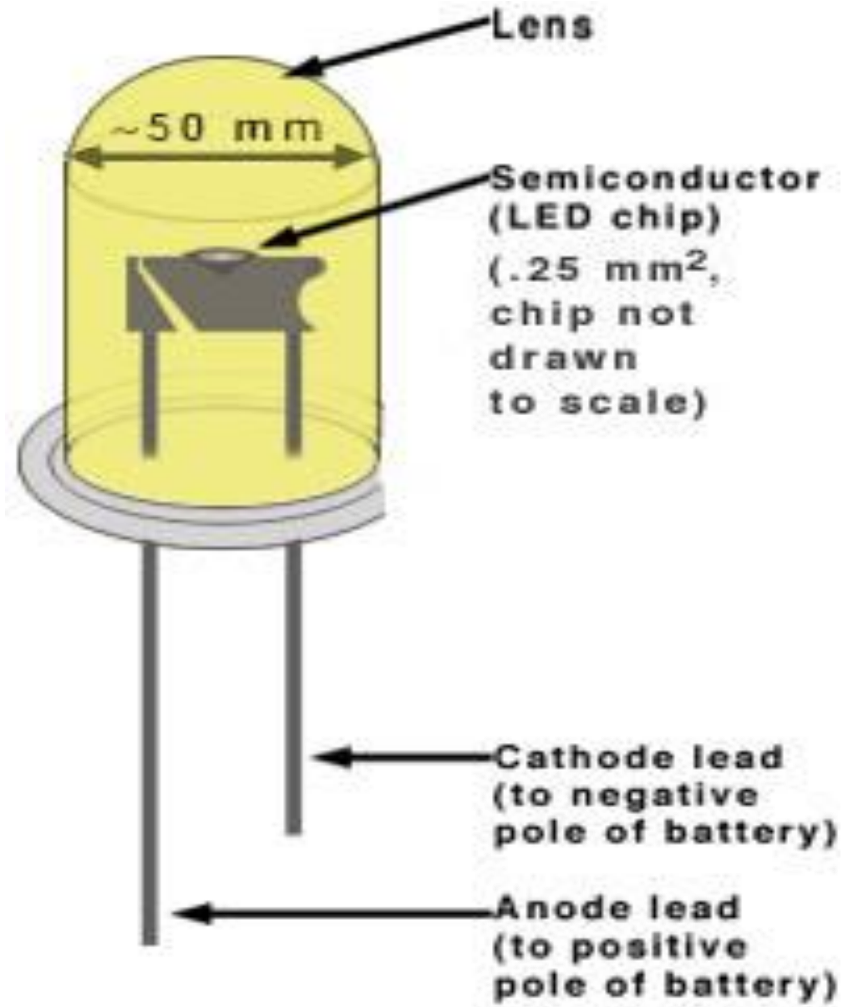
Sources

- **Light-emitting diodes (LEDs)**



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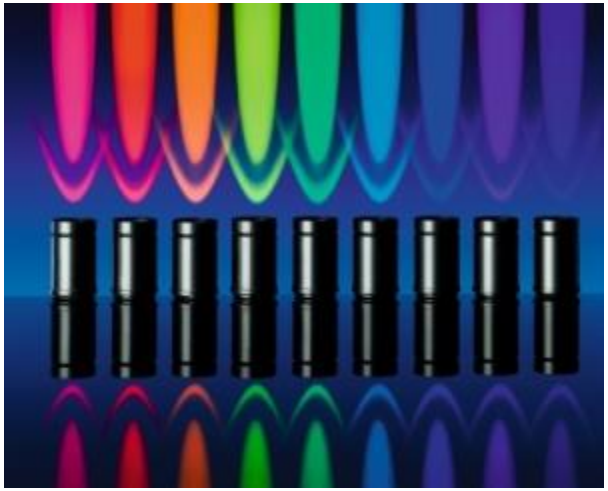
LED Light Sources: A Major Advance in Fluorescence Microscopy

Benefits of LEDs, include compact size, low power consumption, minimal heat output, high emission stability and extremely long life span.



Ten different LED modules which can be easily exchanged are currently available from UV to dark red.

Assignment