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 emits 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

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

Ultraviolet light:
- Wavelength: $\lambda < 400$ 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
AlGaN-LED

UV – LED

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## Comparison to low pressure Hg-Lamp

<table>
<thead>
<tr>
<th>AlGaN UV-LED:</th>
<th>Hg low pressure Lamp*:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency: 5-15%</td>
<td>Efficiency: 40%</td>
</tr>
<tr>
<td>Lifetime: &gt; 15,000 h</td>
<td>Lifetime: 16,000 h</td>
</tr>
<tr>
<td>Output Power: 30 mW (100 mA)</td>
<td>Output Power: 4 W (100 mA)</td>
</tr>
</tbody>
</table>

- 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)

- UV LEDs ramp up the quiet side of the LED market
  [http://ledsmagazine.com/features/9/2/5](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

- HG low pressure lamps data