# AlGaN UV LEDs for a low-carbon world

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## Introduction

### The Nobel prize in physics 2014

"for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources."

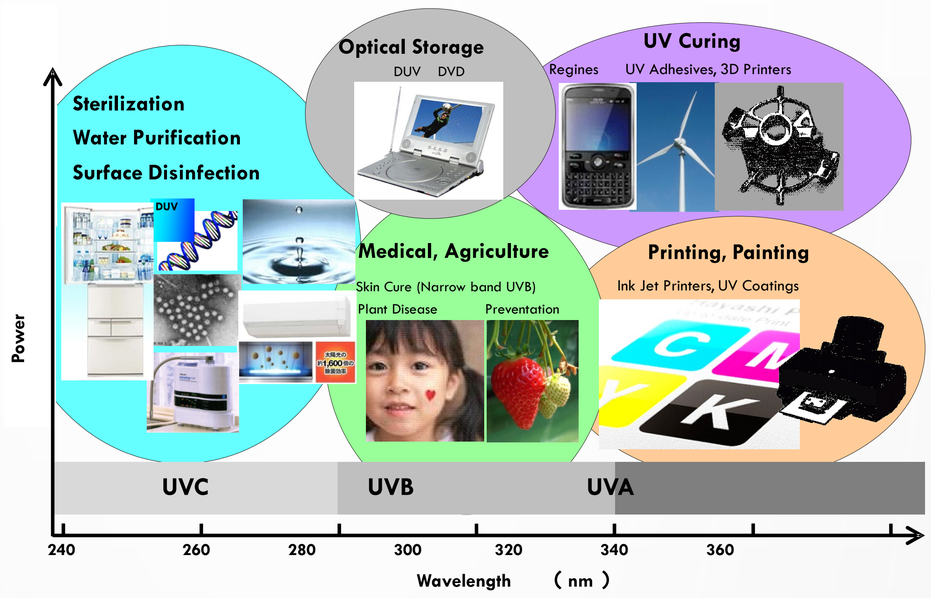
Prof. Akasaki

Prof. Amano

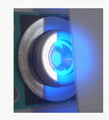
Prof. Nakamura

### LEDs in the world

### From visible to UV

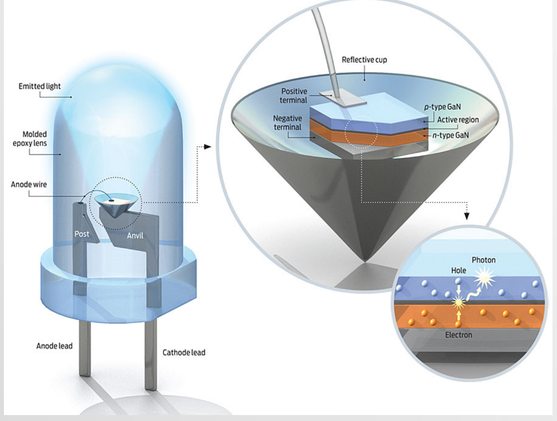



### Comparison to existing light sources



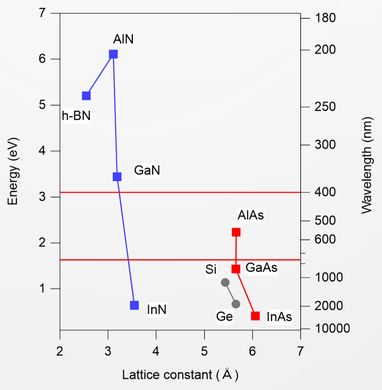
| | LED | Mercury lamp |
|---|---|---|
| Wavelength (nm) | 220-400 | 254 |
| Voltage (V) | DC 5-7 | AC 100-10,000 |
| Size (mm) | 2 | 50-5,000 |
| Output power | 50 mW | 10 W |
| Efficiency (%) | 2 | 20 |
| Ignition | Instant | 10-30 min |
| Lifetime (h) | 40,000 | 5,000 |
| Mercury | No | Yes |

## UV LEDs



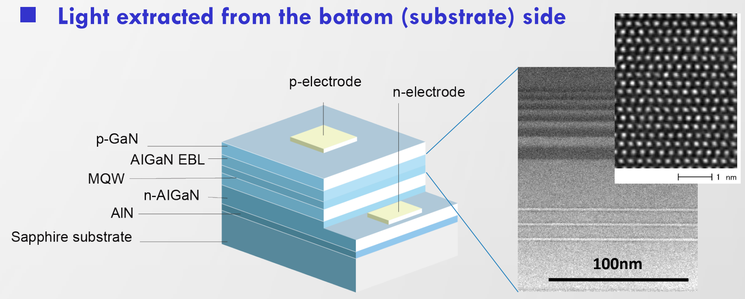

### Material: nitride semiconductors

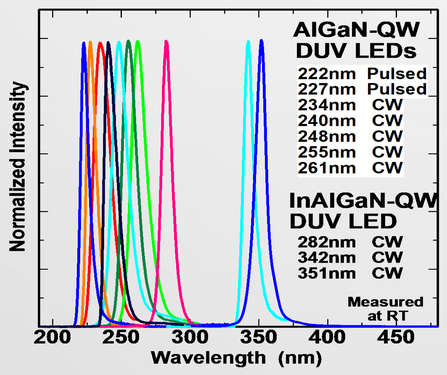
| 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|
| | B | C | N | O |
| | Al | Si | P | S |
| Zn | Ga | Ge | As | Se |
| Cd | In | Sn | Sb | Te |
| Hg | Tl | Pb | Bi | Po |



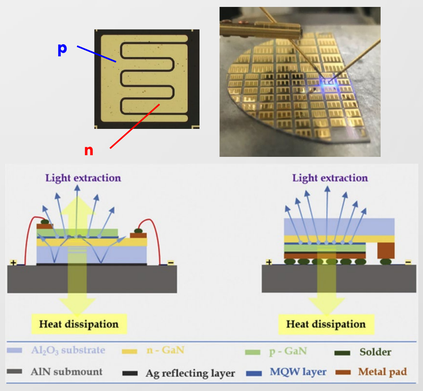

### Structure

- Thin film on sapphire substrate
- Light extracted from the bottom (substrate) side

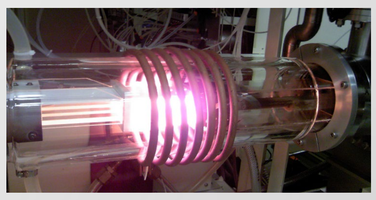



- p and n electrodes formed on the surface




### Growth machine

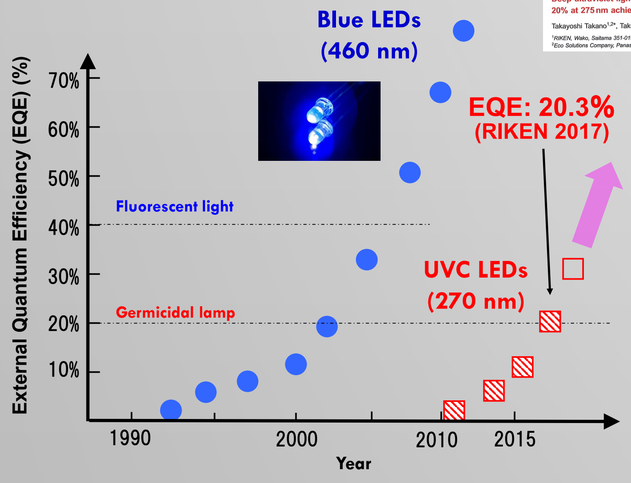


**Typical growth conditions:**

- 1000-1400 °C
- RF or resistance heating
- 10-30 kPa (AlN), 100 kPa (GaN)

## Current status & future

### Efficiency roadmap

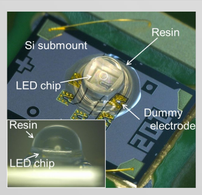



$\eta_{ext} = \eta_{int} \times \eta_{inj} \times \eta_{le}$

$\eta_{int}$ IQE (internal quantum efficiency) improved by using low-dislocation AlN
IQE : < 1% → 50%

$\eta_{inj}$ CIE (carrier-injection efficiency) improved by optimizing electron blocking layer
CIE: 20% → 80%

$\eta_{le}$ LEE (light-extraction efficiency)
LEE: 7%, further improvement required


### Hot topic: 230 nm LED

- UV light < 230 nm: strong disinfection of virus & human safe