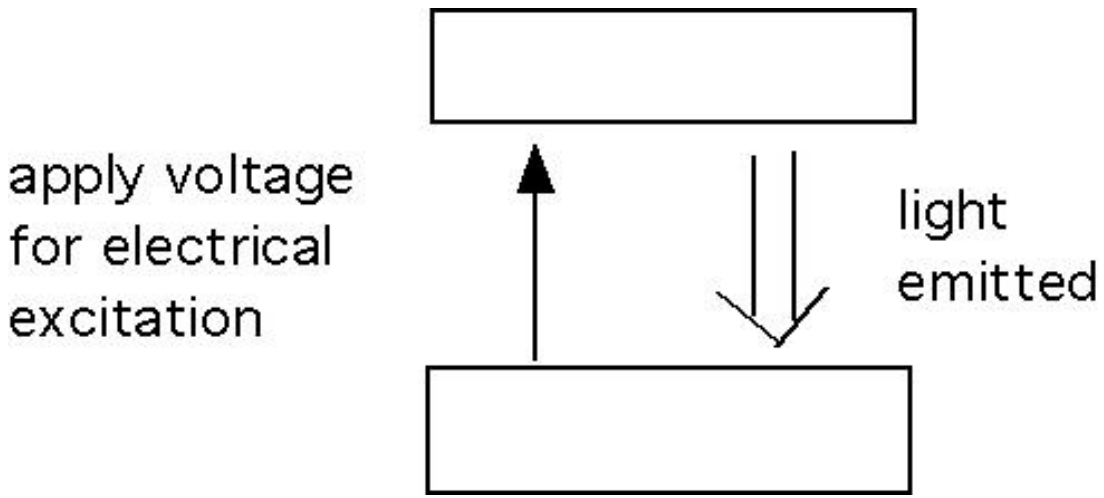
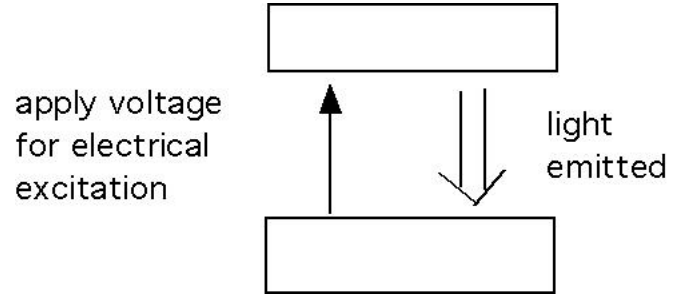
Light Emitting Diode "LED"



PERIODIC TRENDS IN BAND GAPS



	unit cell length (nm)	*band gap (eV)*	*wavelength (nm)*	*light*
C	0.357	6	230	UV
Si	**0.543**	**1.1**	**1100**	**IR**
Ge	0.566	0.7	1900	IR
Sn	0.649	< 0.1	>12,000	IR
Ge	0.566	0.7	1900	IR
GaAs	**0.565**	**1.4**	**890**	**IR**
ZnSe	0.567	2.7	460	blue
CuBr	0.569	2.9	430	blue

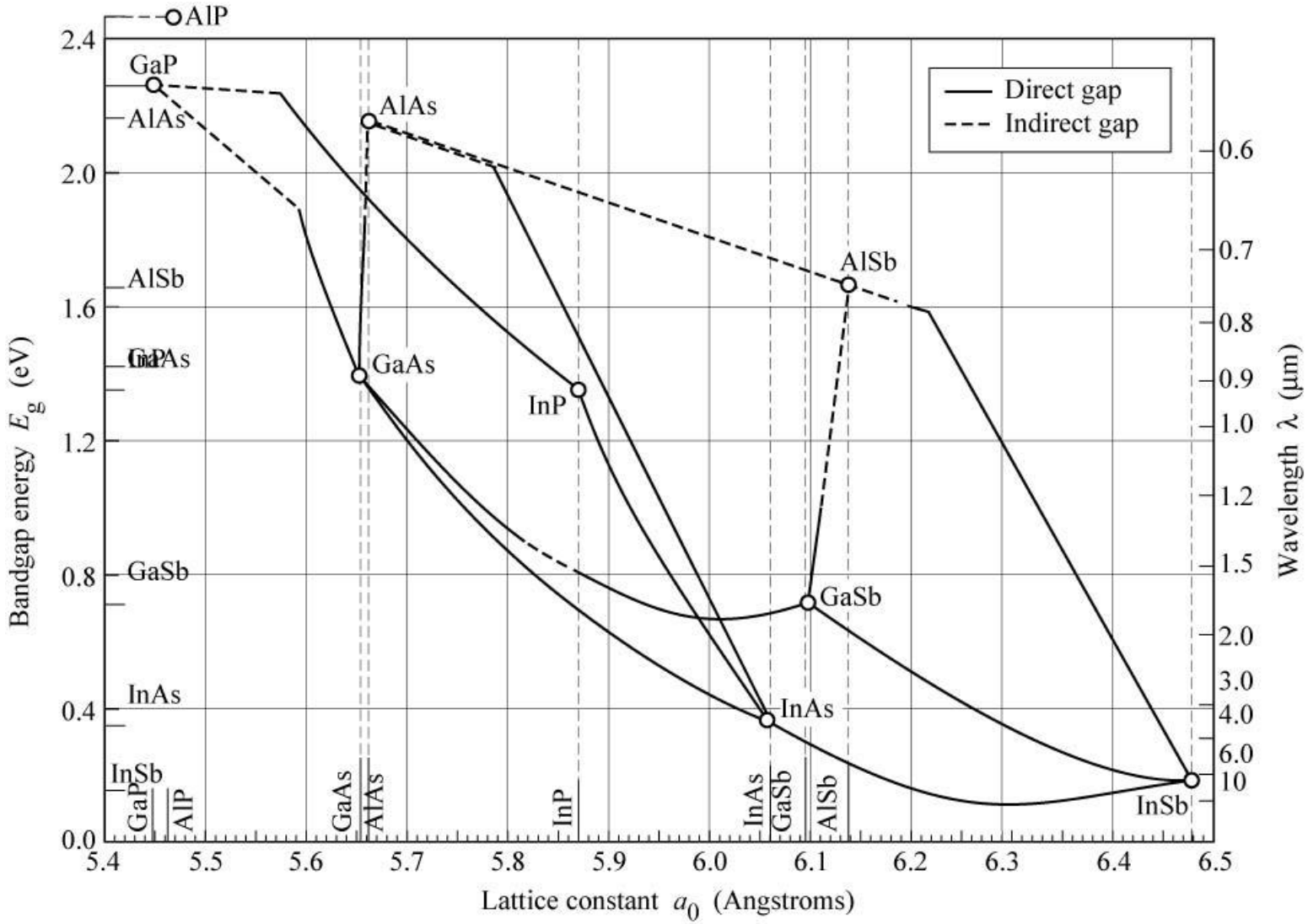
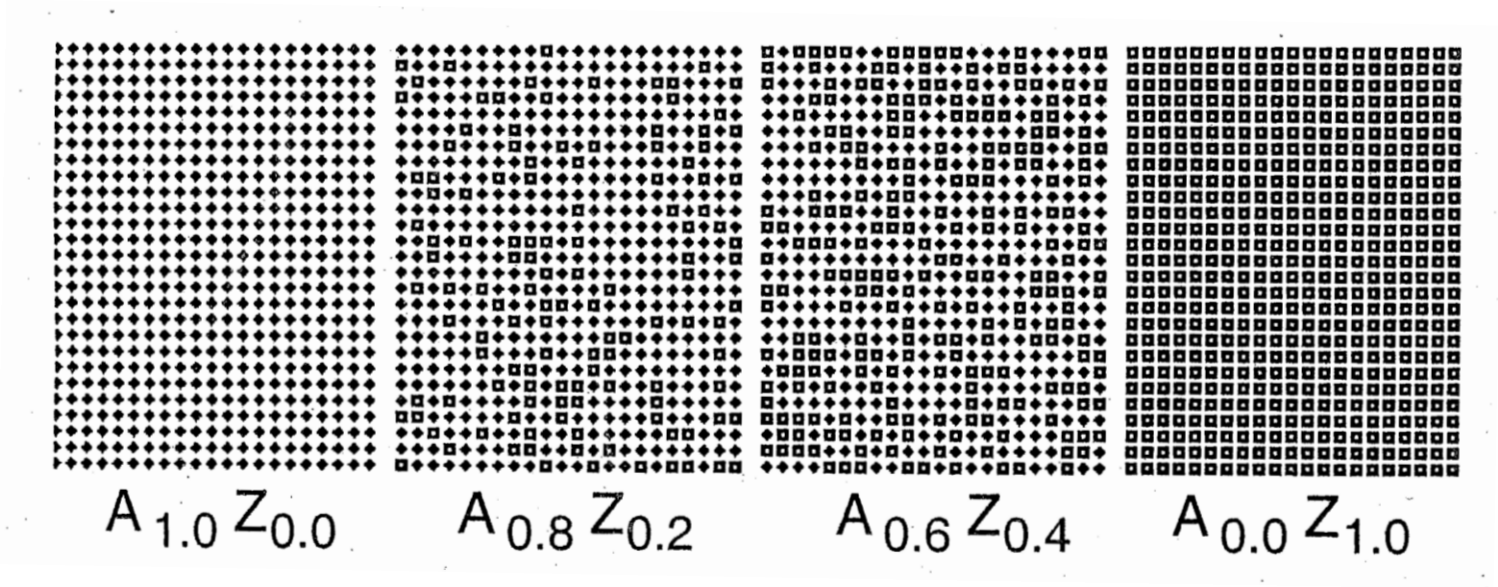


Fig. 12.6. Bandgap energy and lattice constant of various III–V semiconductors at room temperature (adopted from Tien, 1988).

Varying compositions in solid solutions



$GaAs_xP_{1-x}$

x	1-x	color
1	0	near IR
0.6	0.4	red
0.35	0.65	orange
0.15	0.85	yellow
0	1	green

PRESS RELEASE

7 October 2014

The Nobel Prize in Physics 2014

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics for 2014 to

Isamu Akasaki

Meijo University, Nagoya, Japan
and Nagoya University, Japan

Hiroshi Amano

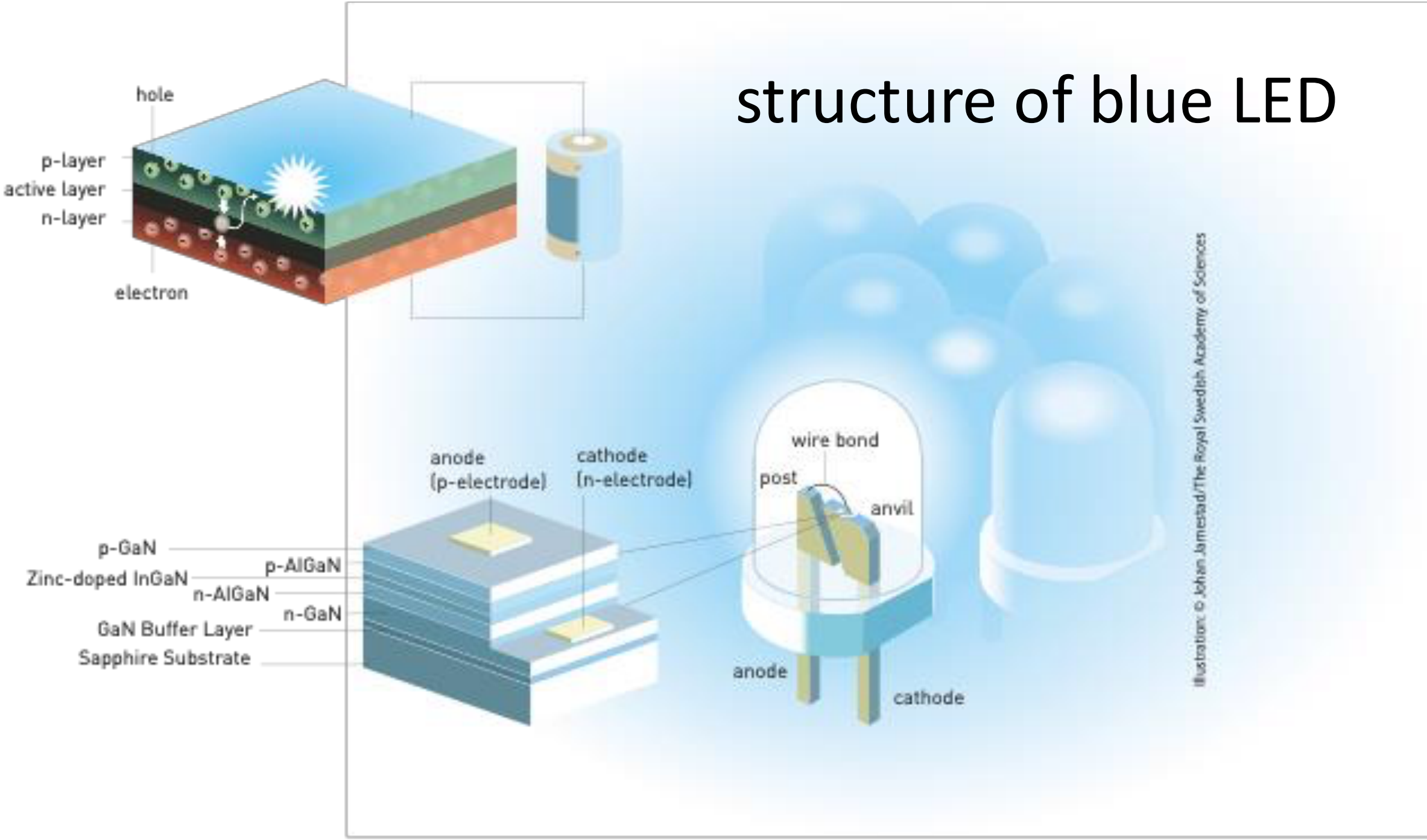
Nagoya University, Japan

Shuji Nakamura

University of California,
Santa Barbara, CA, USA

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

structure of blue LED



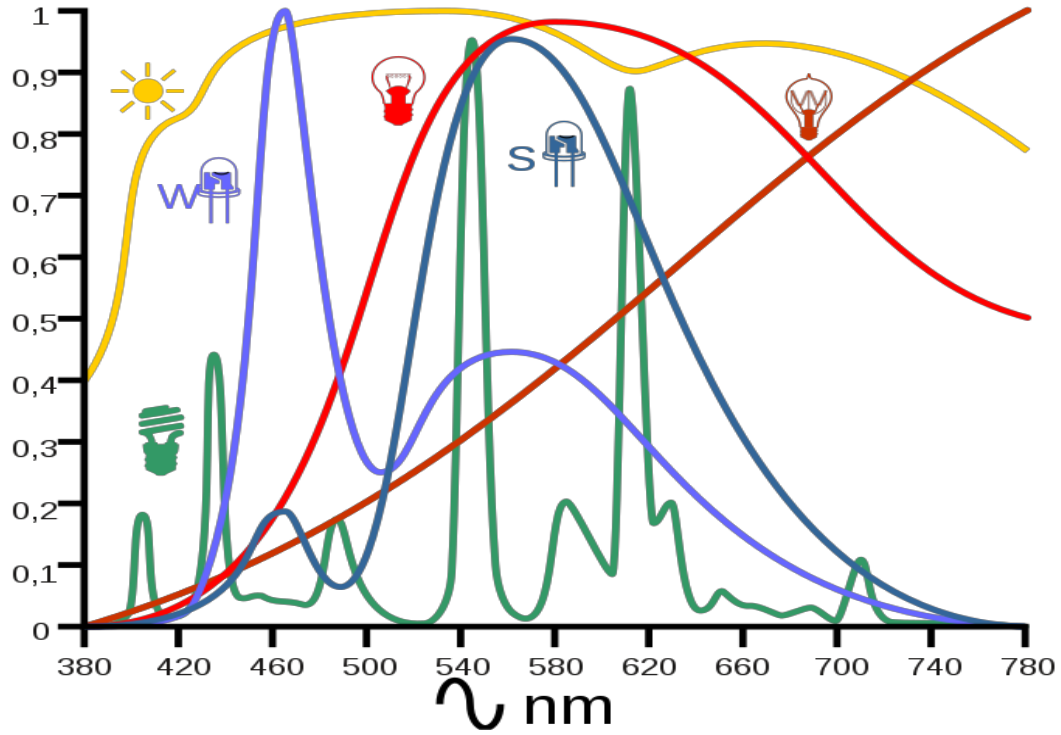


Figure 8.3 Wavelengths of light produced by different light sources

yellow = sun
green = fluorescent
blue = white LED
red = halogen
brown = incandescent

White LED lamps emit a bright white light, are **energy-efficient** and **long-lasting**.

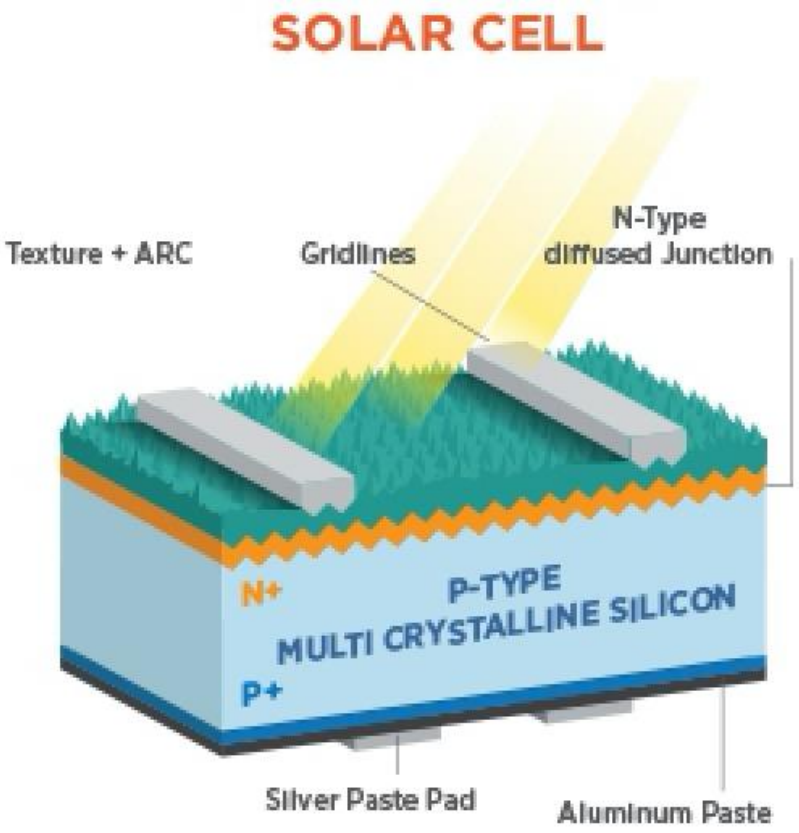
compare efficiency = luminous flux (lumen) per unit electrical input power (Watts).

LEDs can produce over	300 lm/W	last up to 100,000 hours
fluorescent lamps	~ 70 lm/W	10,000 hours
incandescent bulbs	16 lm/W	1,000 hours

As about 1/4 of world electricity consumption is used for lighting purposes, LEDs contribute to saving the Earth's resources. Materials consumption is also diminished due to a longer lifetime.

DOE Solar Cell Materials: Silicon

- most common solar cells
- laboratory energy conversion efficiencies:
  over 25% for single-crystal cells
  over 20% for multicrystalline cells
- industrially produced solar modules 18%–22%



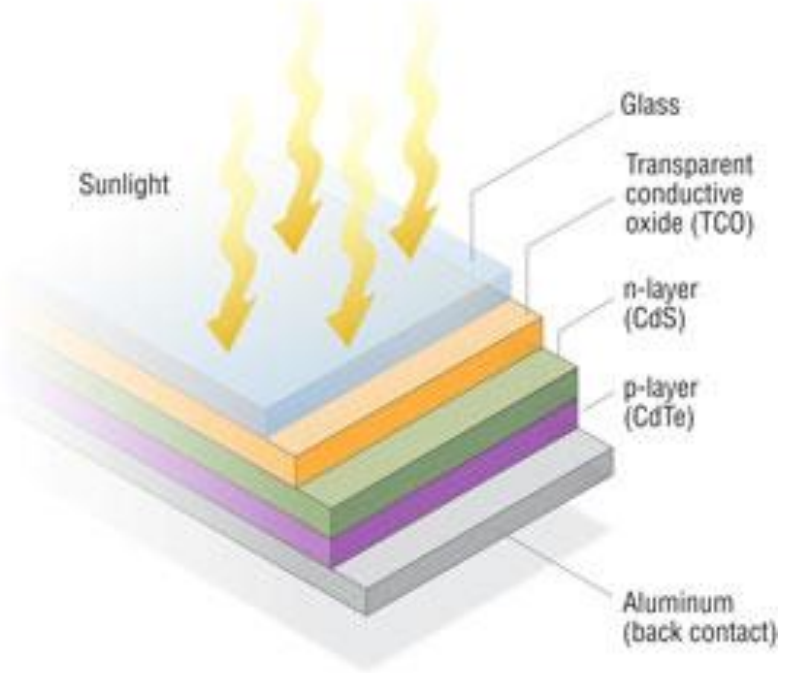
An antireflective coating (ARC), often titanium dioxide (TiC or silicon nitride (SiN), is deposited on the silicon surface.

To increase light trapping and absorption, the top of the solar cell can be textured with micrometer-sized pyramida structures, formed by a chemical etch process.

To create a p-n junction, typically a **phosphorus**-doped n^+ region is created on top of a **boron**-doped p-type silicon substrate. A metal electrode, such as **aluminum**, forms the back contact, whereas the front contact is most often formed using screen-printed **silver** paste applied on the top of the ARC layer.

DOE Solar Cell Materials: Cadmium Telluride

		13	14	15	16	17
		B	C	N	O	F
		Al	Si	P	S	Cl
11	12					
Cu	Zn	Ga	Ge	As	Se	Br
Ag	Cd	In	Sn	Sb	Te	I
Au	Hg	Tl	Pb	Bi	Po	At



CdTe solar cells are the second most common photovoltaic (PV) technology after crystalline silicon, currently representing 5% of the world market. CdTe thin-film solar cells can be manufactured quickly and inexpensively, providing a lower-cost alternative to conventional silicon-based technologies.

The record efficiency for a laboratory CdTe solar cell is 22.1% by First Solar.
2020: average commercial module efficiency ~ 18%.

Semiconductor rescue

First Solar reclaims and reuses 90% of the panels' semiconductor material

First Solar separates the cadmium telluride semiconductor from old panels' glass and polymer sheets, then reclaims and purifies the material for use in new panels.

Shredder

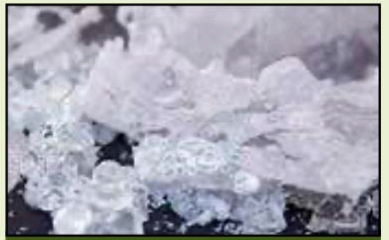
Hammer mill

Crushed/milled scrap holding bin

Film removal and solid/liquid separation

Film/glass separation

Clean glass cullet



Laminate material

Metals precipitation

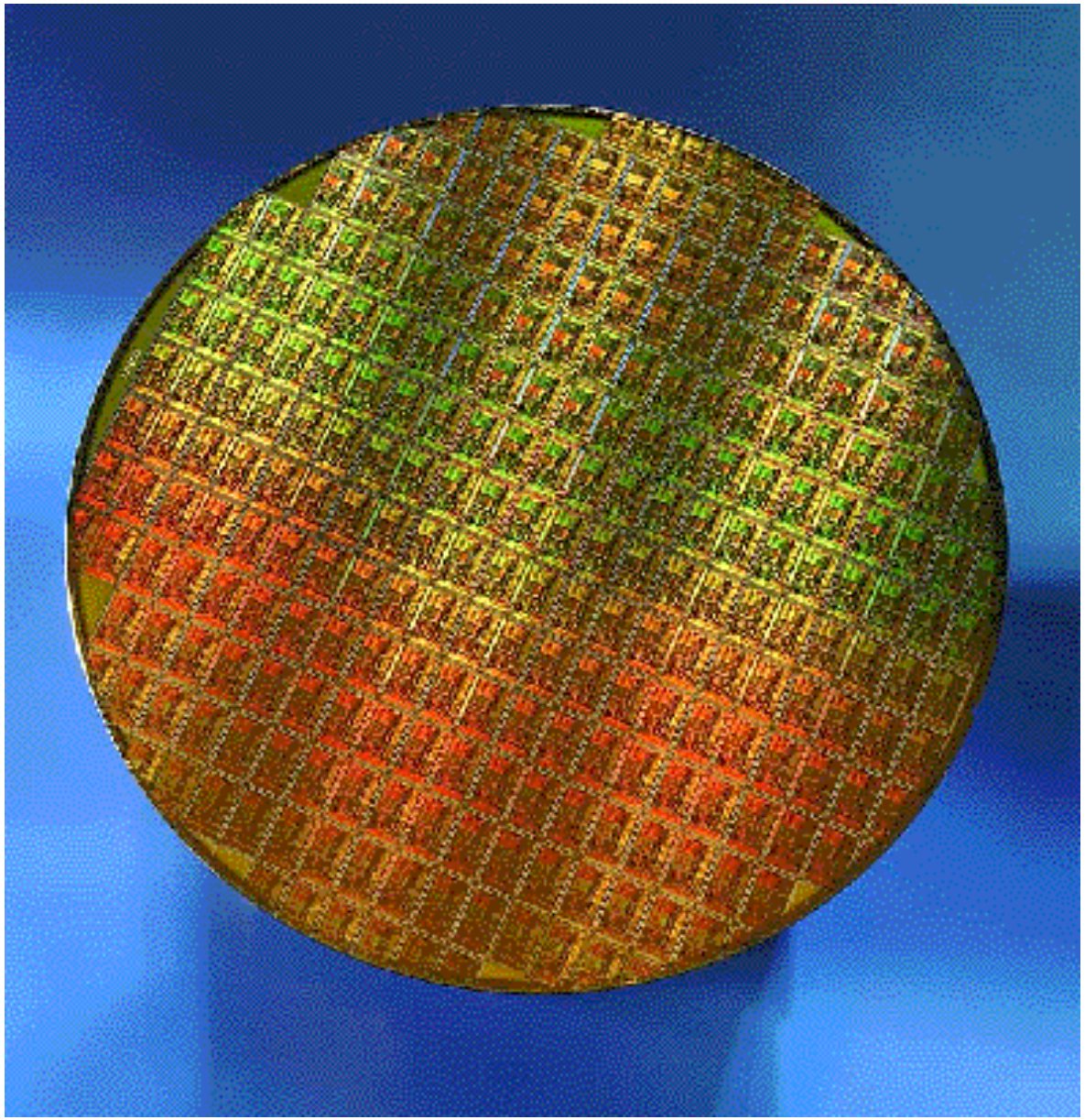
Unrefined semiconductor material

Third party Cd/Te separation and refining

CdTe

Source: First Solar

Semiconductor Processing

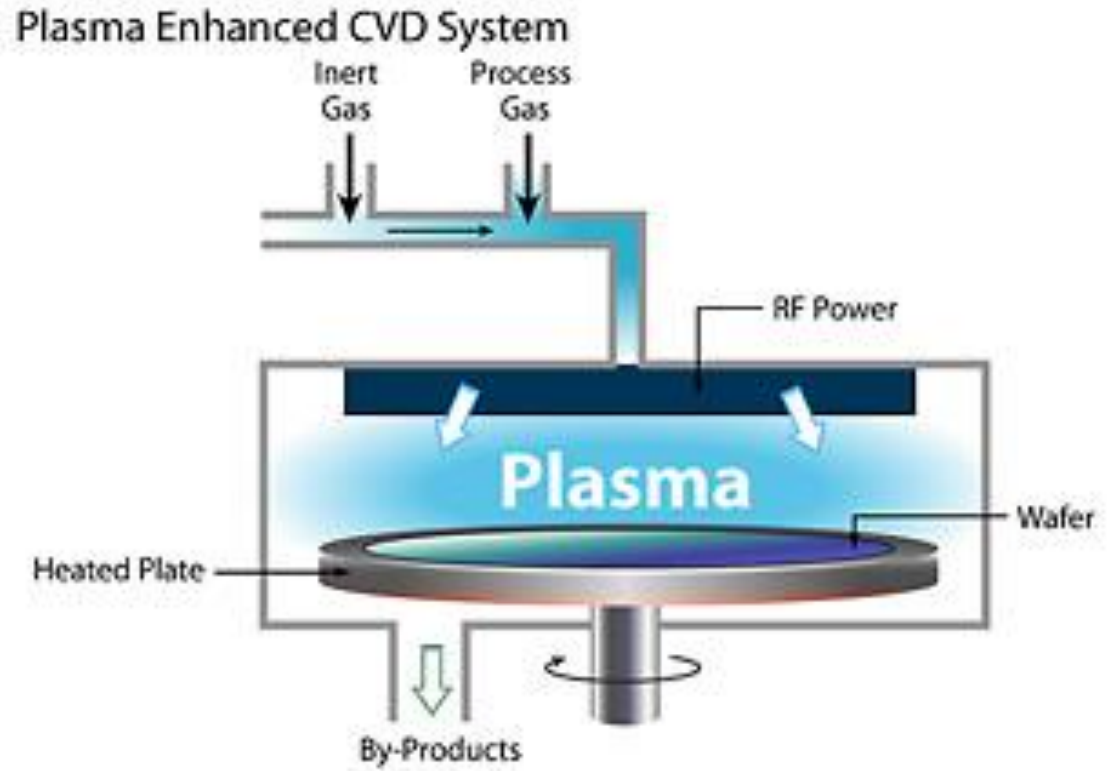


patterned Silicon Wafer

Intel: The Making of a Chip

options for silicon base

silicon ingot



Chemical Vapor Deposition

Molecular Beam Epitaxy