

LED – Light Emitting Diodes

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Why LEDs?

- In 2011, lighting made up 12% of the total U.S. electricity consumption¹
- Incandescent lights last for ~1,000 hours and lose 95% of energy as heat².
- LEDs use ~25% as much energy as incandescent and last ~100,000 hours².



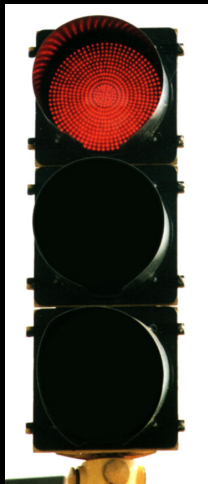
education.mrsec.wisc.edu



Bay Bridge Light Display, CBS
SF Bay Area

Why LEDs?

Incandescent bulbs light in 0.2 seconds – LEDs light instantly (10 nanoseconds, 10^{-8} seconds)³.



education.mrsec.wisc.edu

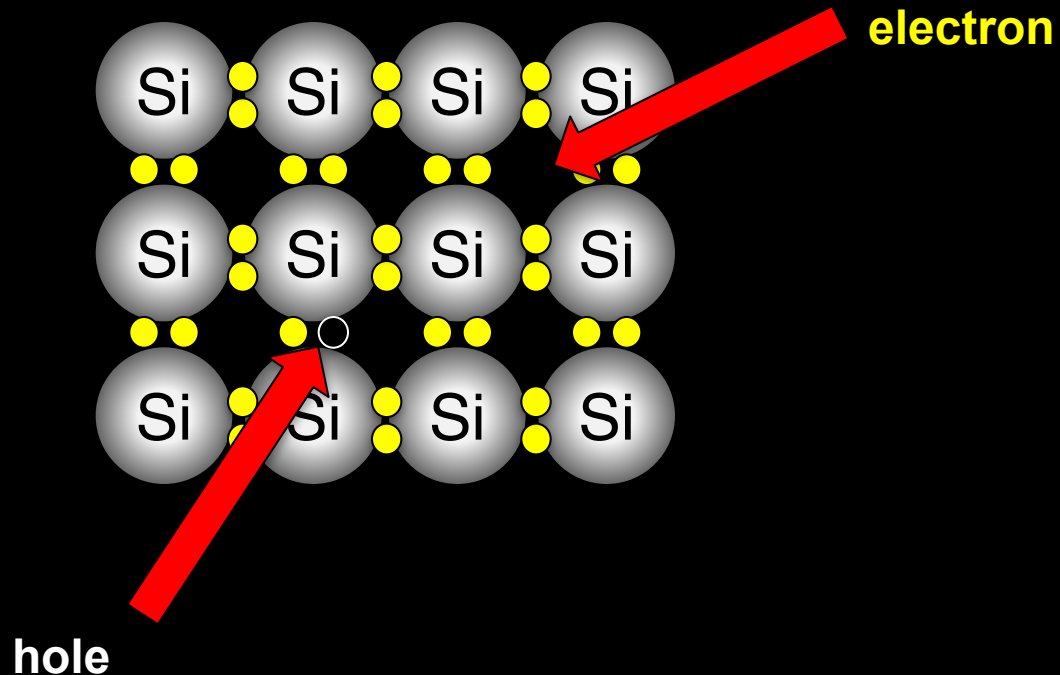


LED brake lights,
300cforums.com

3. LED color strip manual

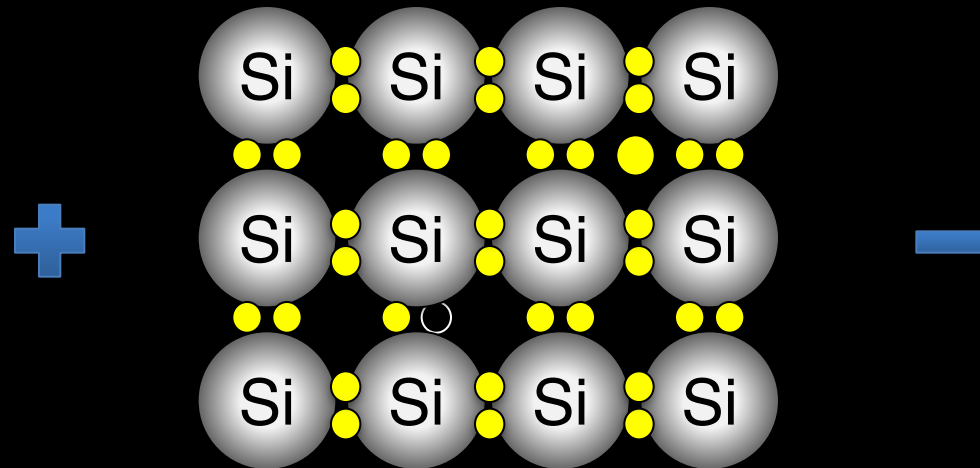
Semiconductors

In semiconductors, **electrons** absorb energy and are excited out of their bond. This creates a one-electron bond which is positively charged, referred to as a *hole*.



Semiconductors

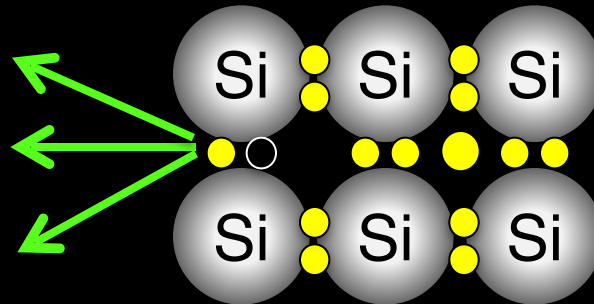
When a voltage is applied, **electrons** move towards the positive electrode. **Holes** move towards the negative electrode.



The energy required to mobilize an **electron** is determined by the type of atom and is called the **band gap energy**.

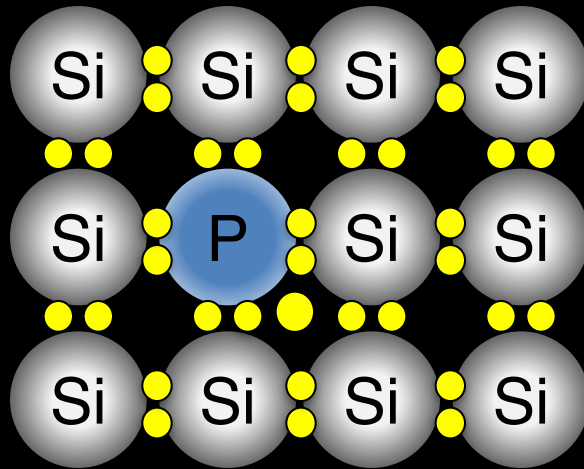
Band Gap Energy

- When a mobile **electron** combines with a **hole**, the **band gap energy** is released as light.
- The wavelength of the light corresponds to the magnitude of the **band gap energy** released.
- The magnitude of the **band gap energy** is determined by the chemical composition of the semiconductor.

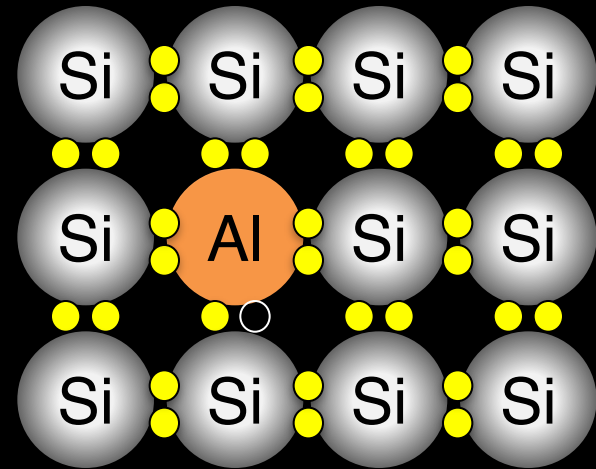


Semiconductors

To manipulate the number of mobile electrons and holes in a semiconductor, impurities called **dopants** are added.



N-type (negatively charged) – semiconductor **doped** with an atom containing one extra **electron**.

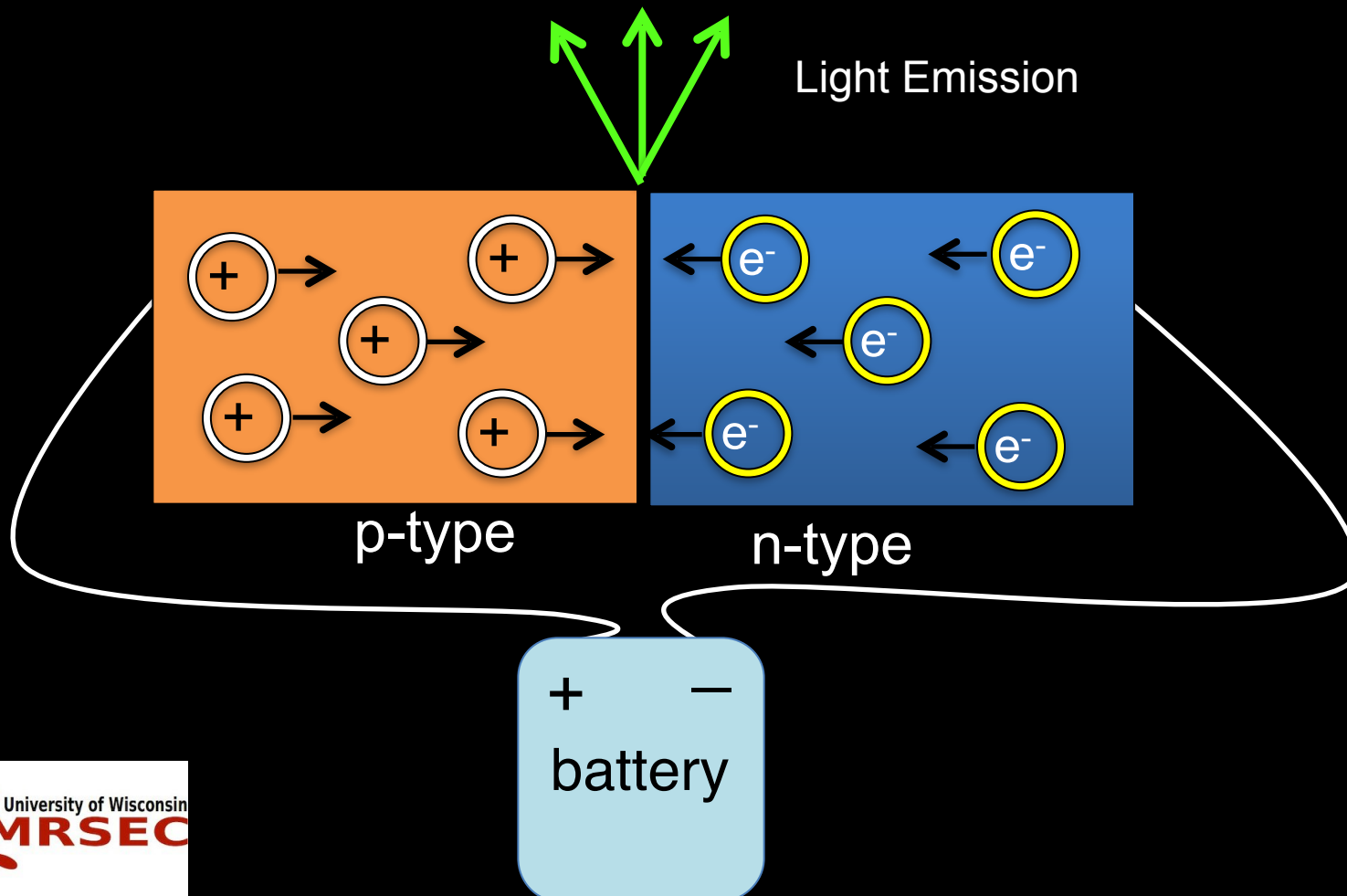


P-type (positively charged) – semiconductor **doped** with an atom containing one less **electron**.

Semiconductors and LEDs

LEDs are made with nanotechnology.

Semiconductors are deposited one atomic layer at a time to create an abrupt n- and p-type junction.

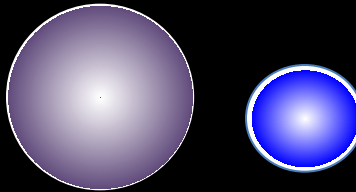


Atom size determines bond length

- Larger atoms → longer bonds → less energy → **longer wavelength emitted**

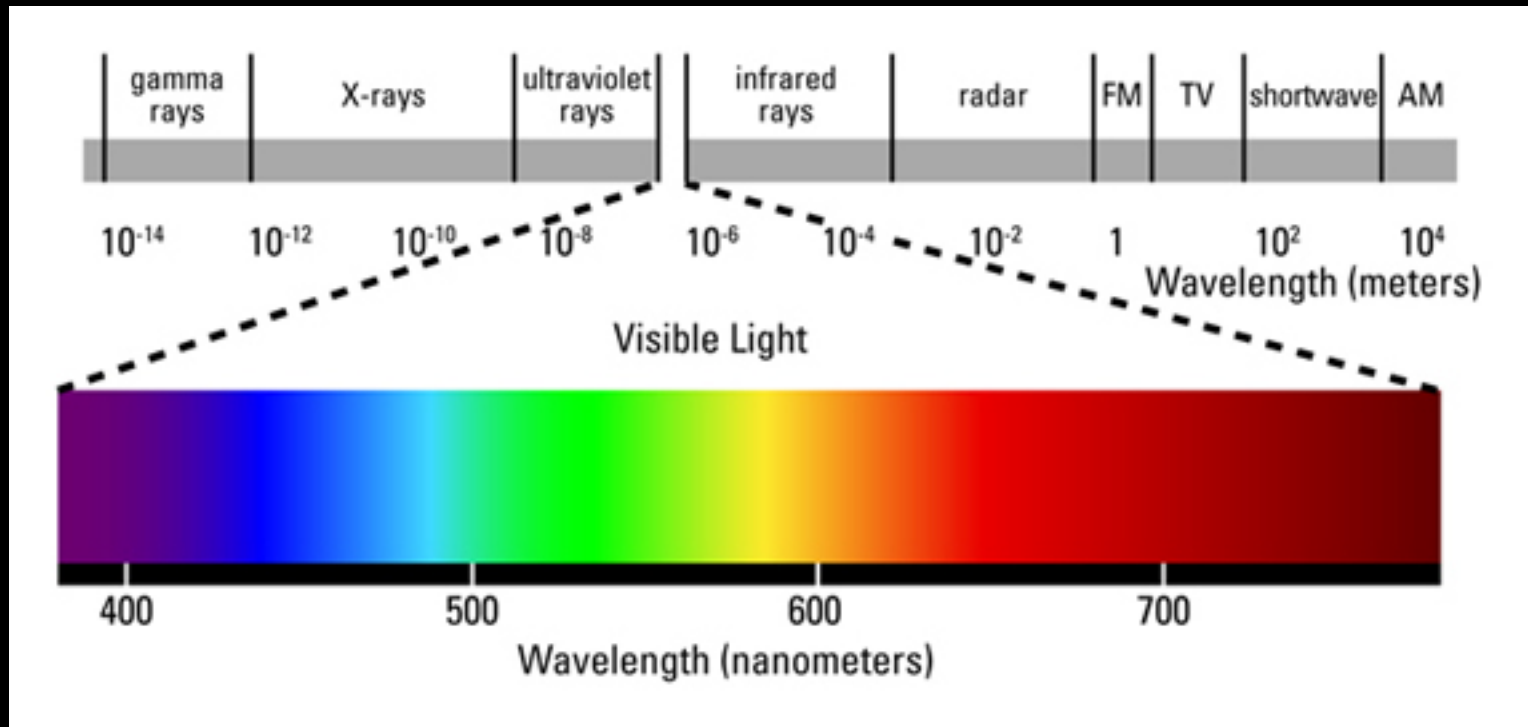


- Smaller atoms → shorter bonds → more energy → **shorter wavelength emitted**



Light and color

Shorter wavelengths = greater energy



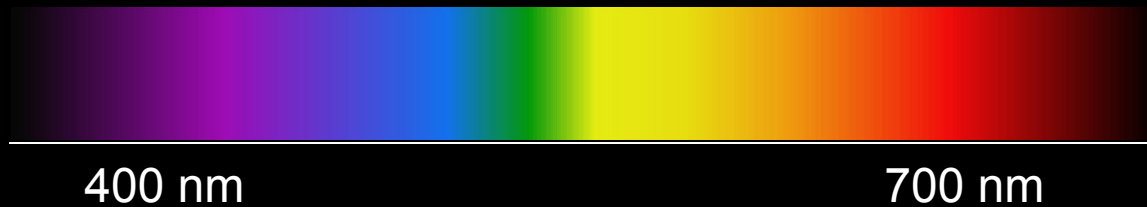
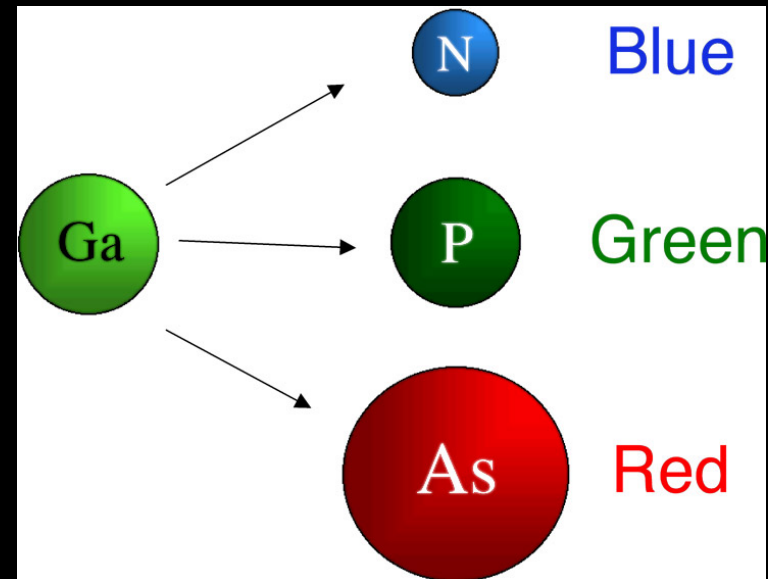
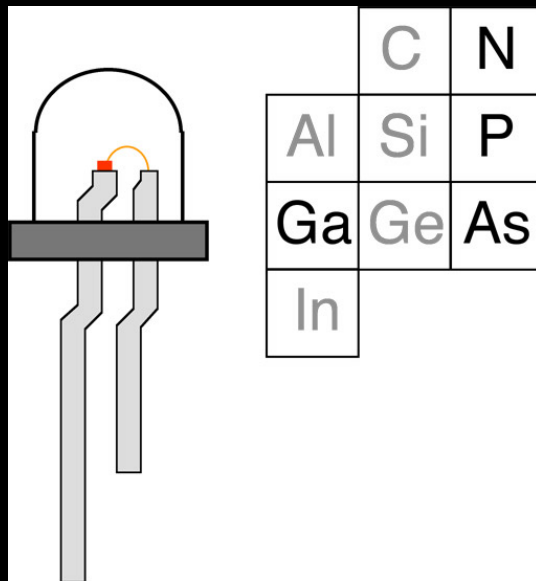
Periodic Table of the Elements

Periodic Table of the Elements																		18	
1 1A 11A											13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	2 VIII 8A			
1 H Hydrogen 1.0079	2 He Helium 4.00260											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.998403	10 Ne Neon 20.1797		
3 Li Lithium 6.941	4 Be Beryllium 9.01218											11 Na Sodium 22.989768	12 Mg Magnesium 24.305	13 Al Aluminum 26.981539	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.95591	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.9332	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92159	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80		
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium 98.9072	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.90447	54 Xe Xenon 131.29		
55 Cs Cesium 132.90543	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98037	84 Po Polonium [208.9824]	85 At Astatine 209.9871	86 Rn Radon 222.0176		
87 Fr Francium 223.0197	88 Ra Radium 226.0254	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown		
Lanthanide Series		57 La Lanthanum 138.9055	58 Ce Cerium 140.115	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium 144.9127	62 Sm Samarium 150.36	63 Eu Europium 151.9655	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967			
Actinide Series		89 Ac Actinium 227.0278	90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.0289	93 Np Neptunium 237.0482	94 Pu Plutonium 244.0642	95 Am Americium 243.0614	96 Cm Curium 247.0703	97 Bk Berkelium 247.0703	98 Cf Californium 251.0796	99 Es Einsteinium [254]	100 Fm Fermium 257.0951	101 Md Mendelevium 258.1	102 No Nobelium 259.1009	103 Lr Lawrencium [262]			
Alkali Metals		Alkaline Earths		Transition Metals		Basic Metals		Semi-Metals		Nonmetals		Halogens		Noble Gases		Lanthanides		Actinides	

chemistry.about.com/od/periodictables/ig/Printable-Periodic-Tables/Periodic-Table-Wallpaper.htm

Atom size determines LED color

Scientists and engineers use the periodic table to make a range of semiconductors to produce a variety of colored LEDs.



LED Color Strip Data

Composition	Color Emitted	Energy (voltage)	Wavelength (λ)
$\text{In}_{0.06}\text{Ga}_{0.94}\text{N}$	BLUE		450 nm (shortest)
$\text{GaP}_{1.00}\text{As}_{0.00}$	GREEN	1.95	550 nm
$\text{GaP}_{0.85}\text{As}_{0.15}$ or $\text{In}_{0.50}\text{Ga}_{0.35}\text{Al}_{0.15}$	YELLOW	1.85	600 nm
$\text{GaP}_{0.65}\text{As}_{0.35}$ or $\text{In}_{0.50}\text{Ga}_{0.43}\text{Al}_{0.07}$	ORANGE	1.81	630 nm
$\text{GaP}_{0.40}\text{As}_{0.60}$ or $\text{Al}_{0.25}\text{Ga}_{0.75}\text{As}$	RED	1.70	670 nm
$\text{GaP}_{0.00}\text{As}_{1.00}$	Infrared	1.12	850 nm (longest)

Acknowledgments

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Thank You

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