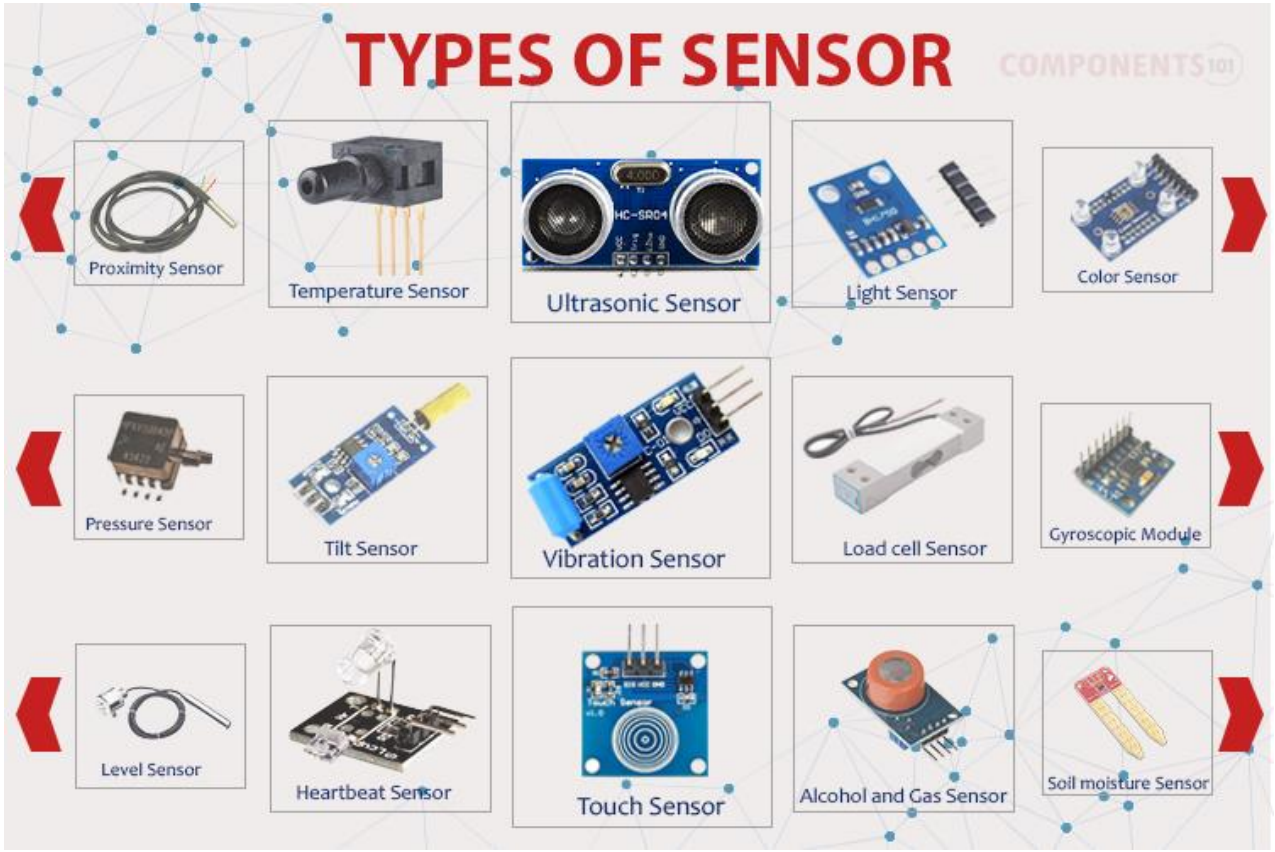
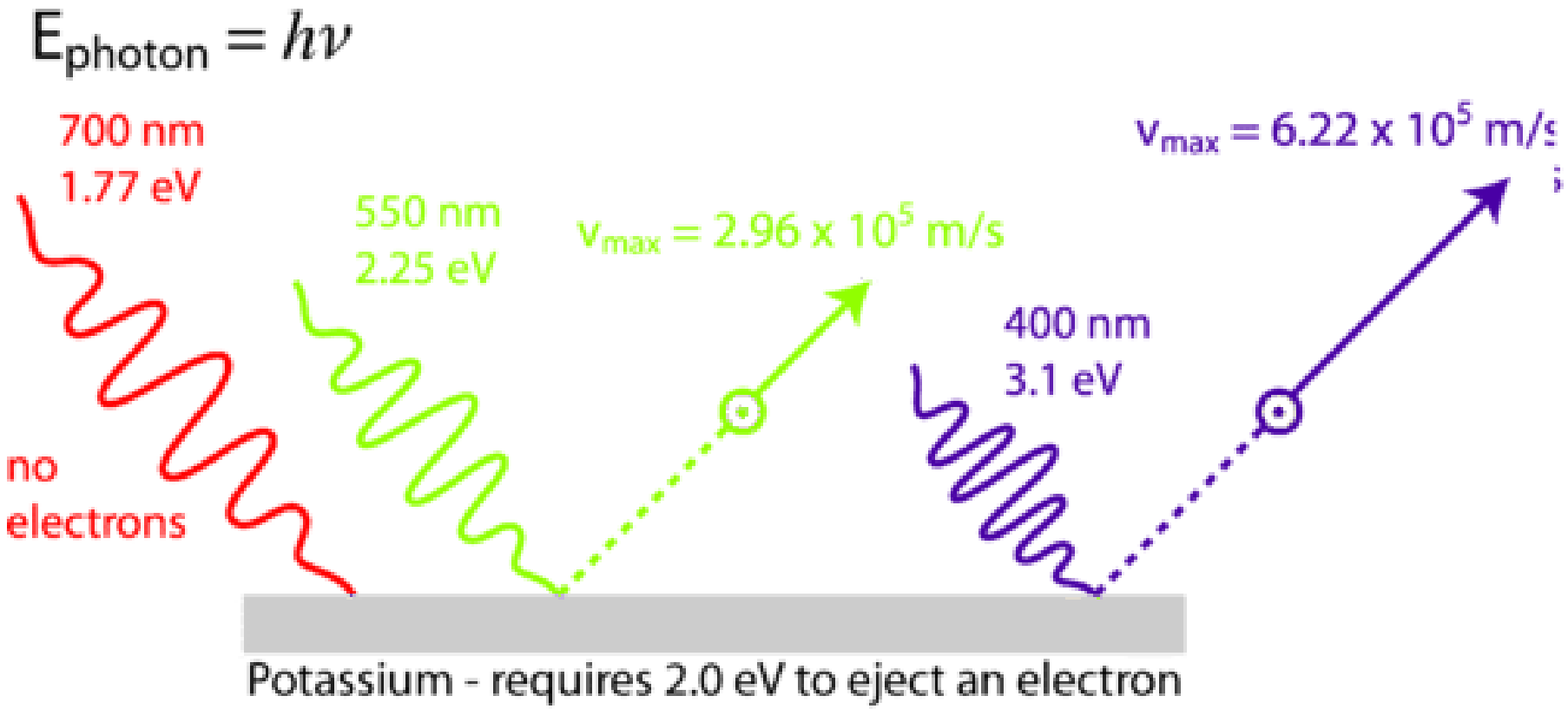
Image sensors

An image sensor or imager is a sensor that detects and conveys information used to form an image.

- Charge – coupled sensor
- Active pixel sensor (CMOS)
- Ambient light sensor



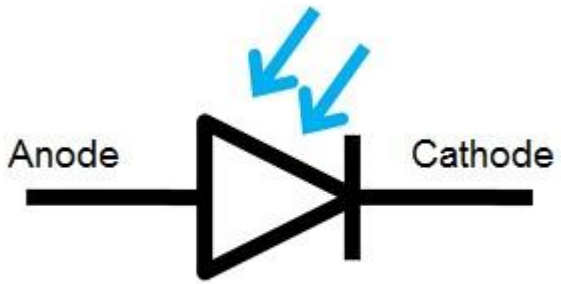
Photoelectric effect



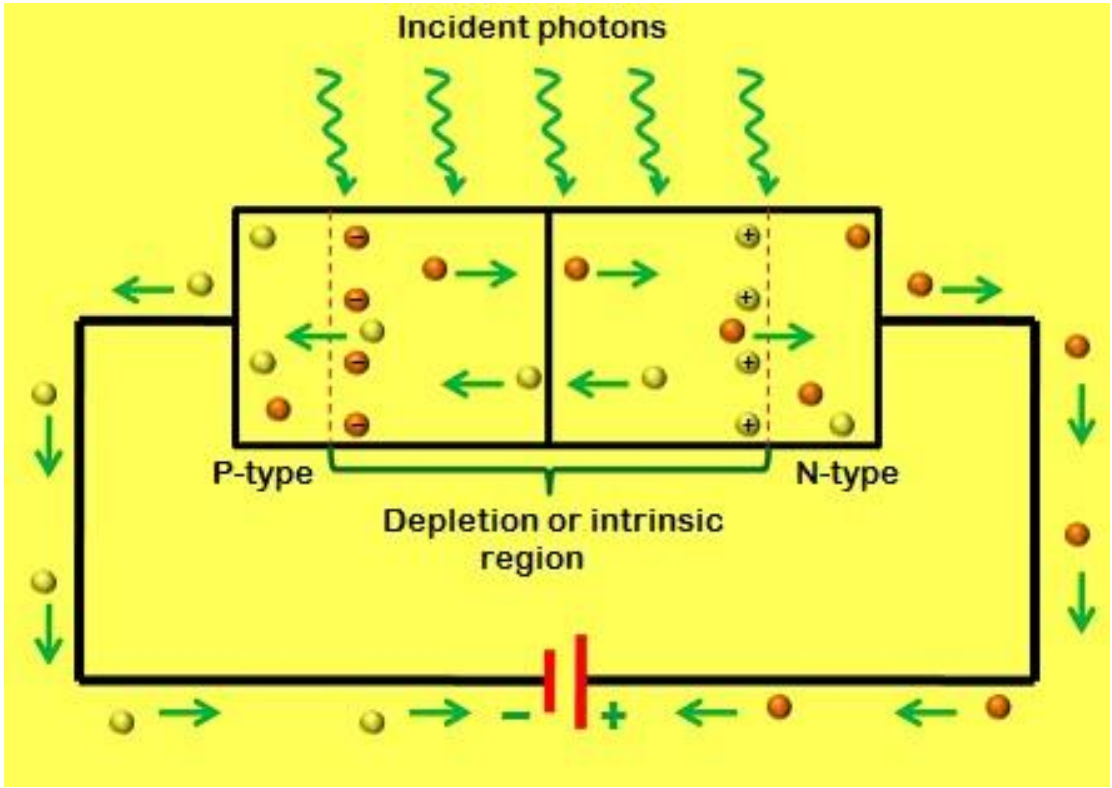
Light hitting a metallic surface with sufficient energy can transfer its energy to an electron, allowing it to escape. The velocity of the escaping electron can be computed using momentum conservation laws.

https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Introductory_Chemistry_%28CK-12%29/05%3A_Electrons_in_Atoms/5.04%3A_Photoelectric_Effect

When a light is made to illuminate the PN junction, covalent bonds are ionized. This generates hole and electron pairs. Photocurrents are produced due to generation of electron-hole pairs. Electron hole pairs are formed when photons of energy more than 1.1eV hits the diode. When the photon enters the depletion region of diode, it hits the atom with high energy. This results in release of electron from atom structure. After the electron release, free electrons and hole are produced.

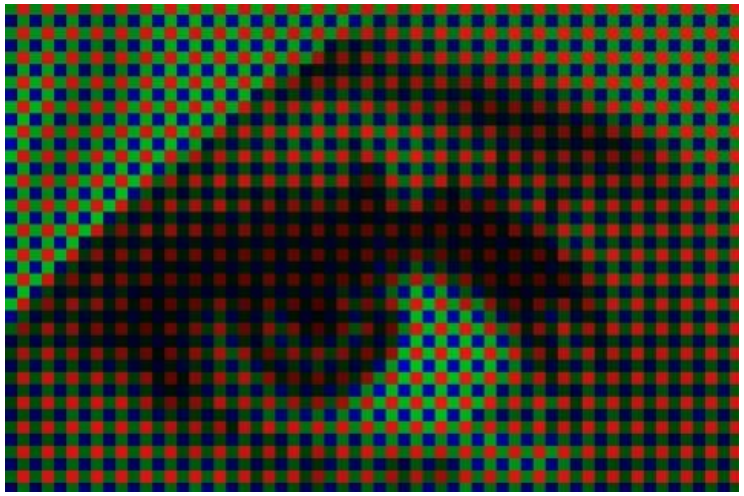


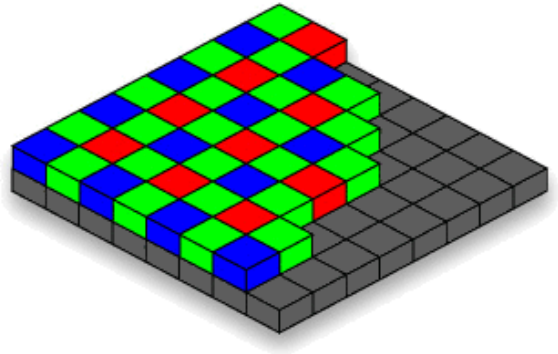
Photodiode symbol

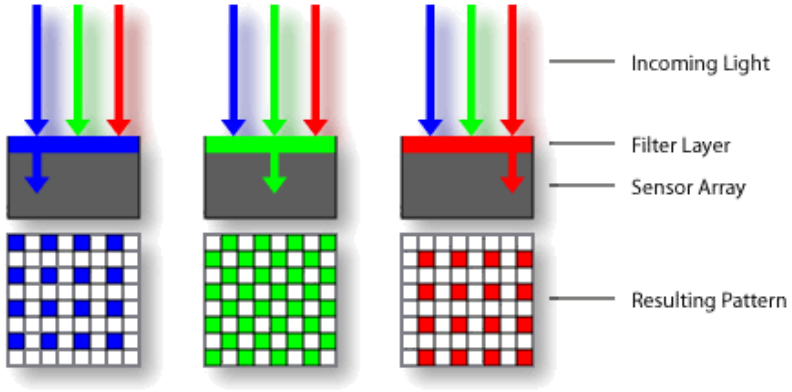


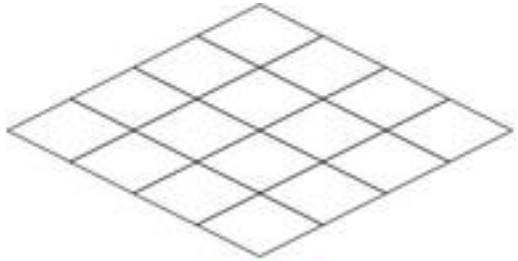
https://www.electronicshub.org/photodiode-working-characteristics-applications/

Bayer Filter

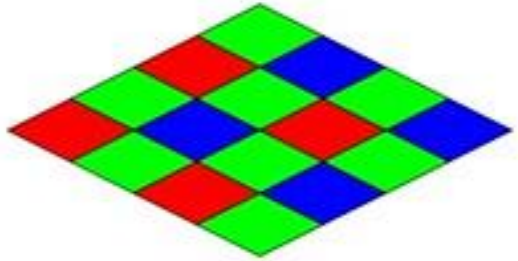






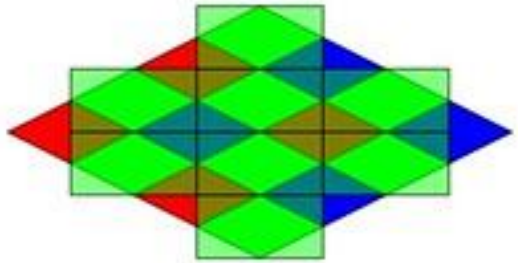


Photoreceptors

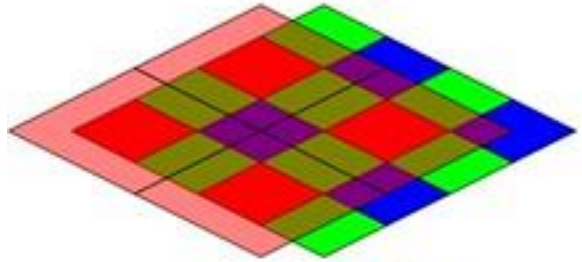


Bayer Filter – Each photoreceptor is sensitive to only red, green or blue light.

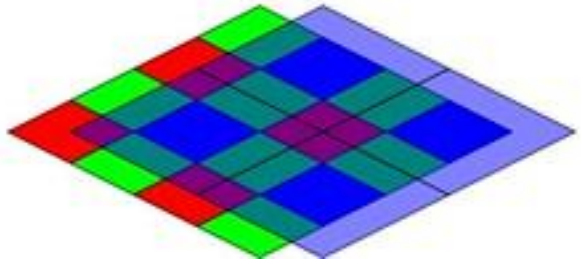
Note that there are twice as many photoreceptors for green light as for red light and blue light.



Green values for pixels corresponding to red and blue photoreceptors are interpolated from adjacent green photoreceptors.



Red values for pixels corresponding to green and blue photoreceptors are interpolated from adjacent red photoreceptors.



Blue values for pixels corresponding to green and red photoreceptors are interpolated from adjacent blue photoreceptors.

Note that red and blue have half the resolution of green.

Charge-coupled device (CCD)

- Uses photodiodes
- Converts light energy to electric signal
- Analog **voltage** signal converted to digital in the analog-digital converter (ADC)

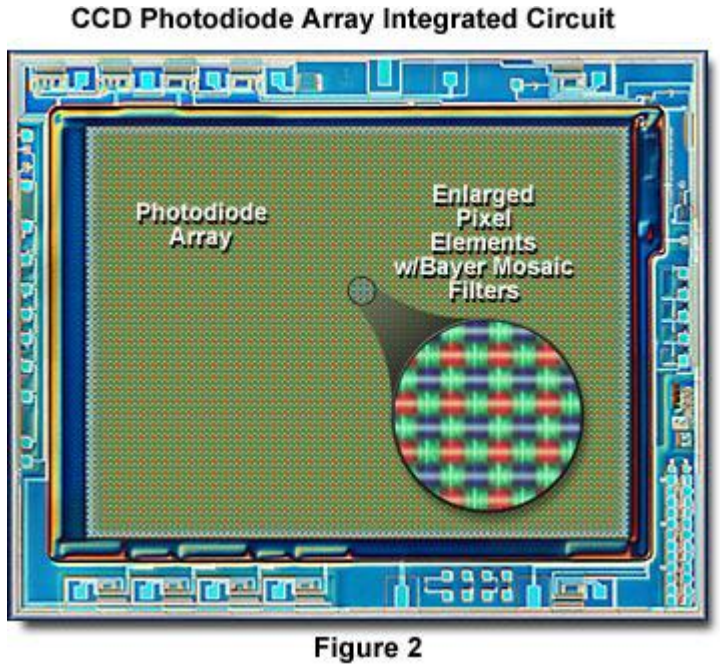


Figure 2

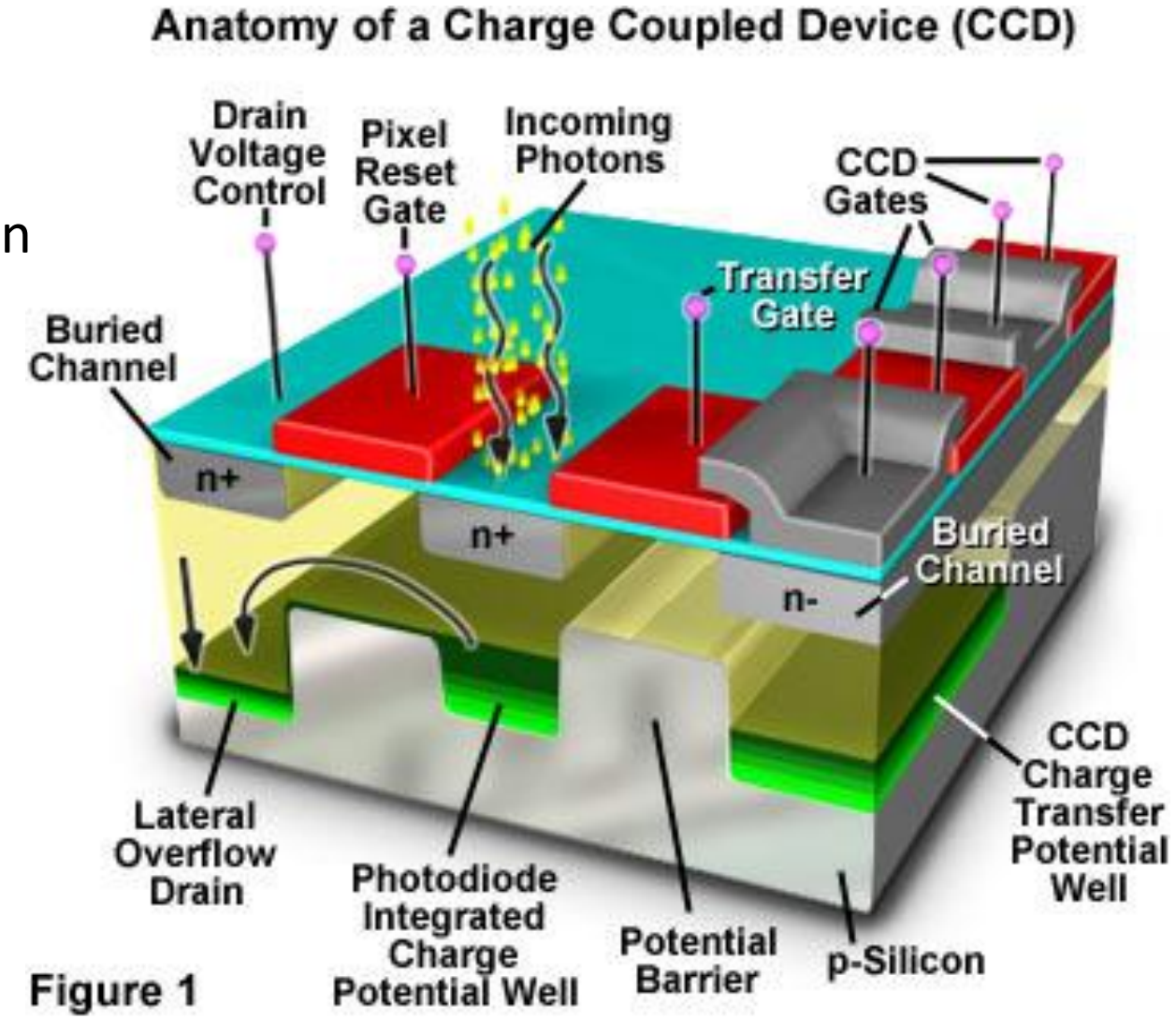
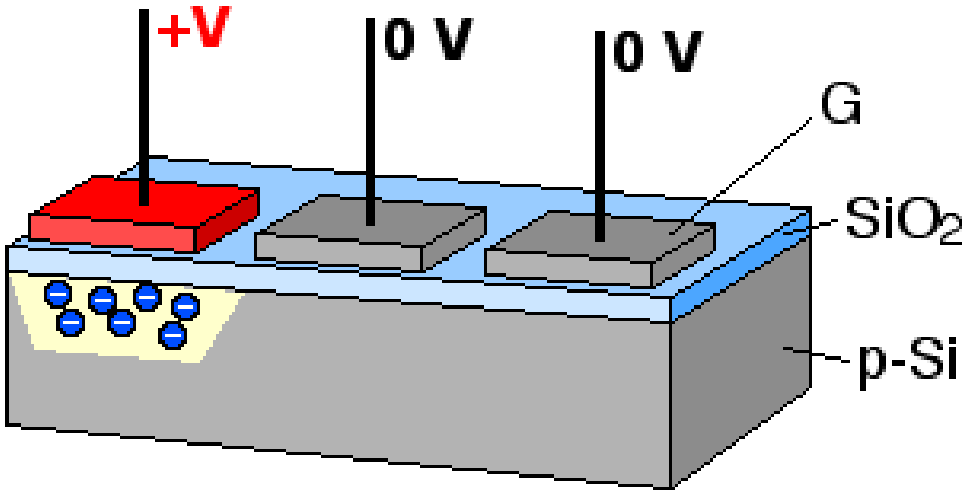


Figure 1

https://hamamatsu.magnet.fsu.edu/articles/ccdanatomy.html



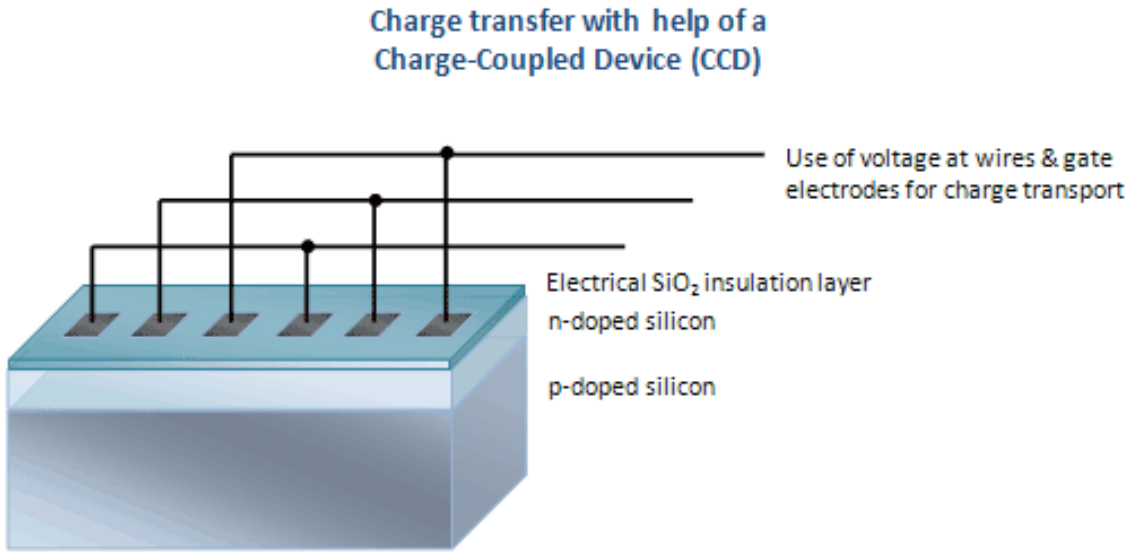
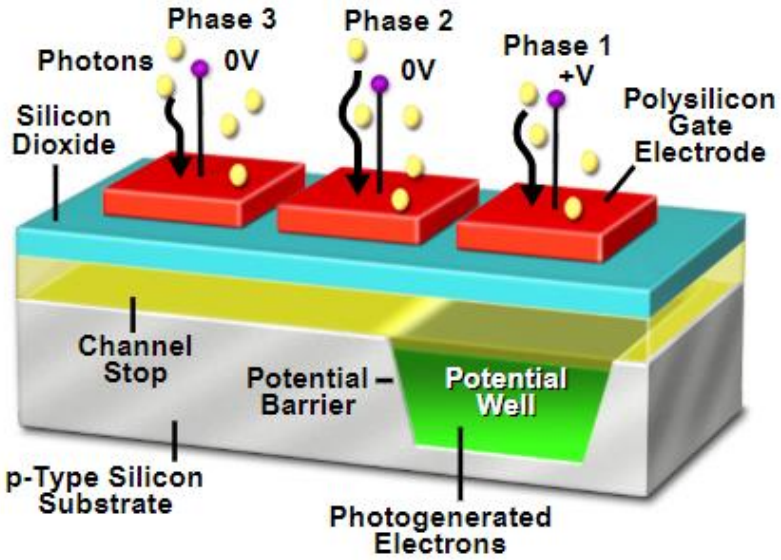
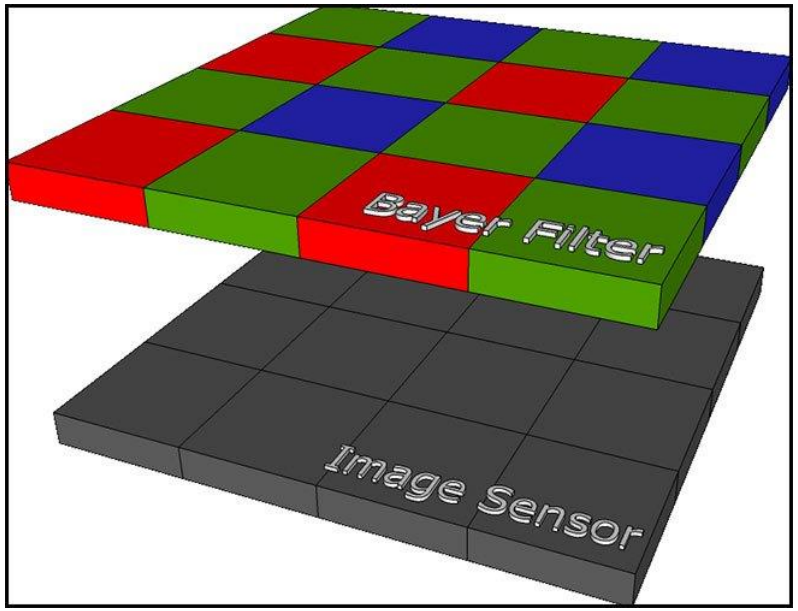
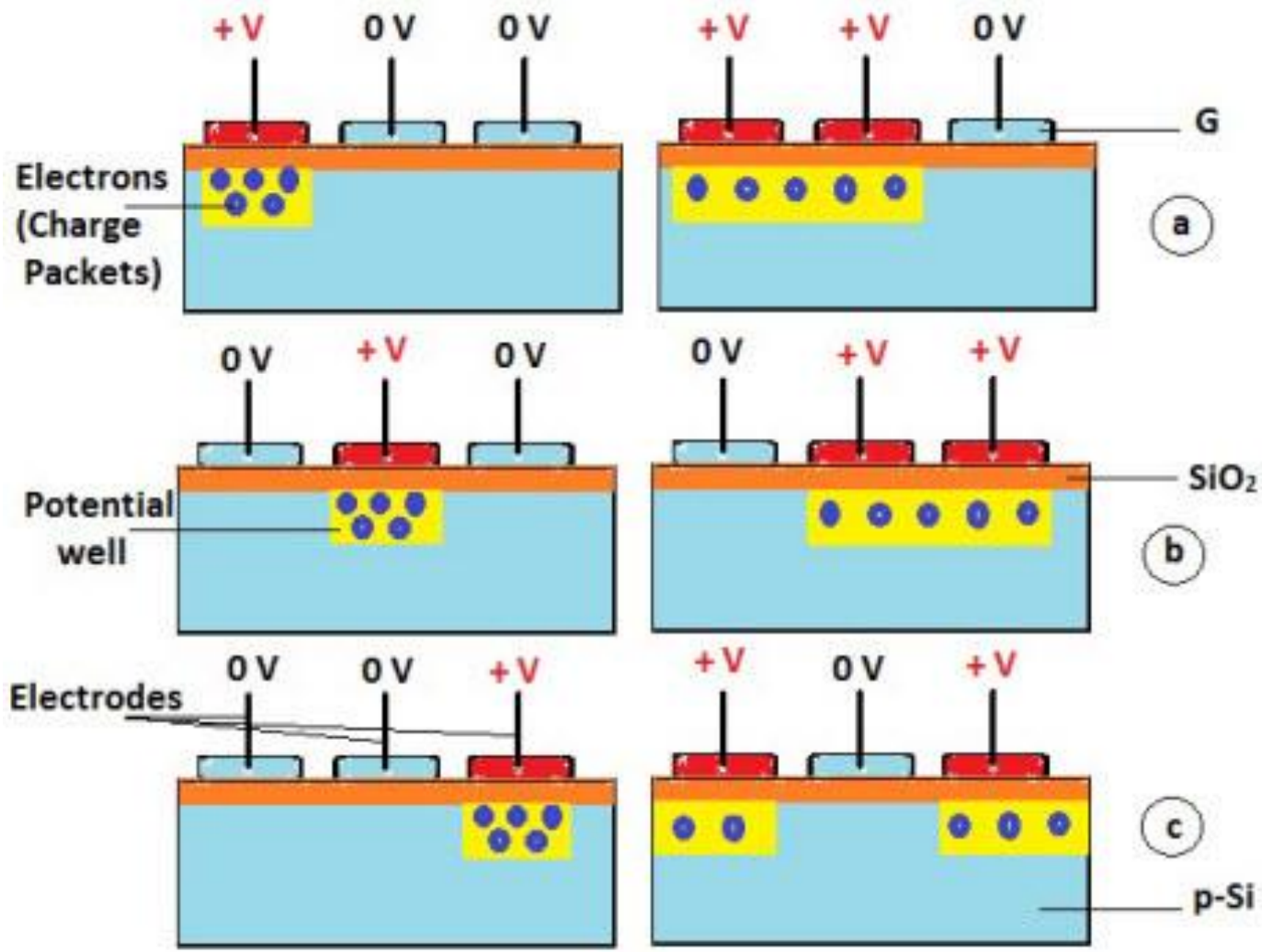


Image generation with a CCD camera can be divided into four primary stages or functions: charge generation through photon interaction with the device's photosensitive region, collection and storage of the liberated charge, charge transfer, and charge measurement. During the first stage, electrons and holes are generated in response to incident photons in the depletion region of the MOS capacitor structure, and liberated electrons migrate into a potential well formed beneath an adjacent positively-biased gate electrode.

Electrons generated in the depletion region are initially collected into electrically positive potential wells associated with each pixel. During readout, the collected charge is subsequently shifted along the transfer channels under the influence of voltages applied to the gate structure.



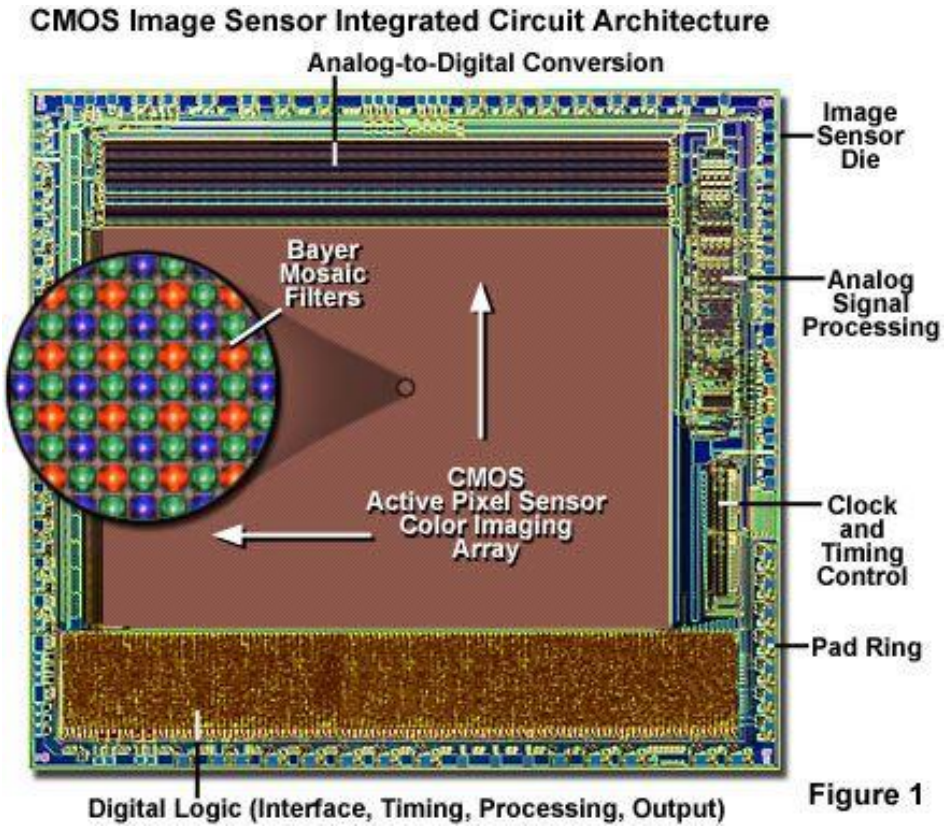


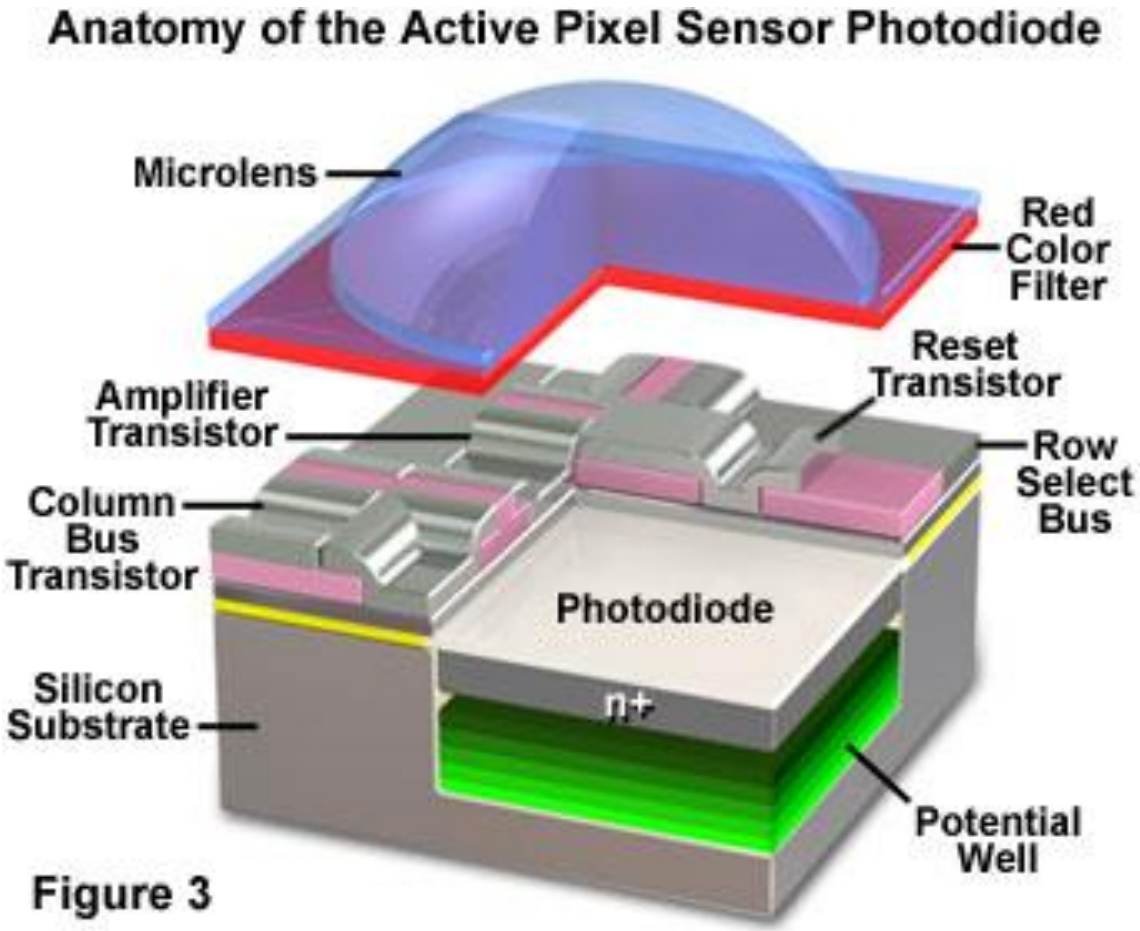


https://www.findlight.net/blog/charge-coupled-devices-cmos-silicon/

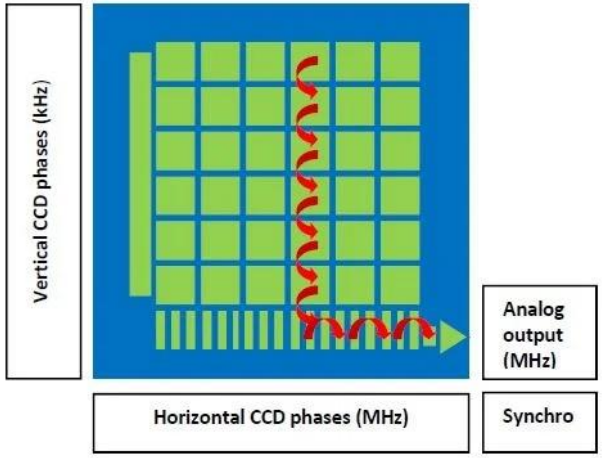
CMOS Sensors

- Uses photodiodes
- Converts light energy to electric signal
- Analog **voltage** signal converted to digital in pixel itself

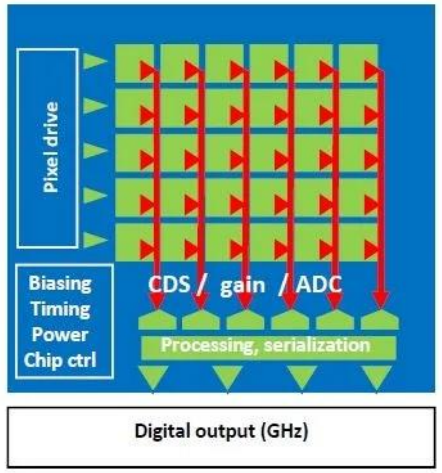




Difference between charge-coupled and CMOS



CCD = Photon-to-electron conversion (analog)



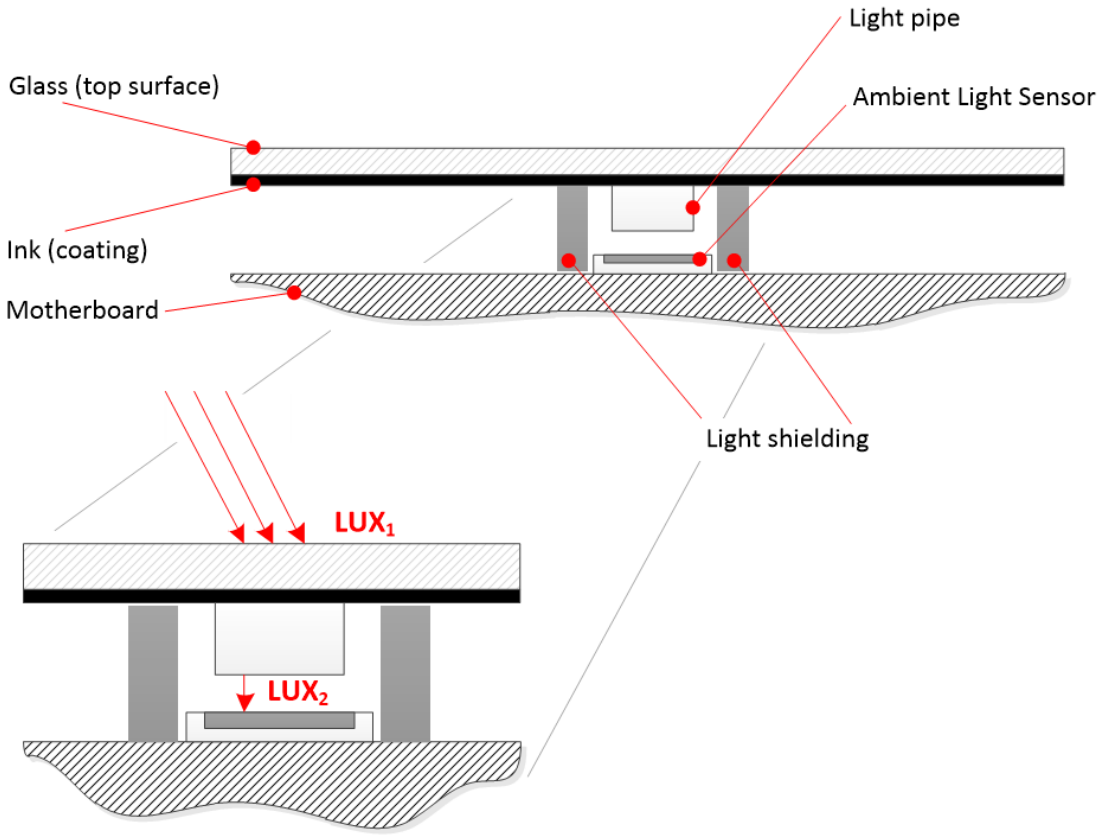
CIS = Photon-to-Voltage conversion (digital)

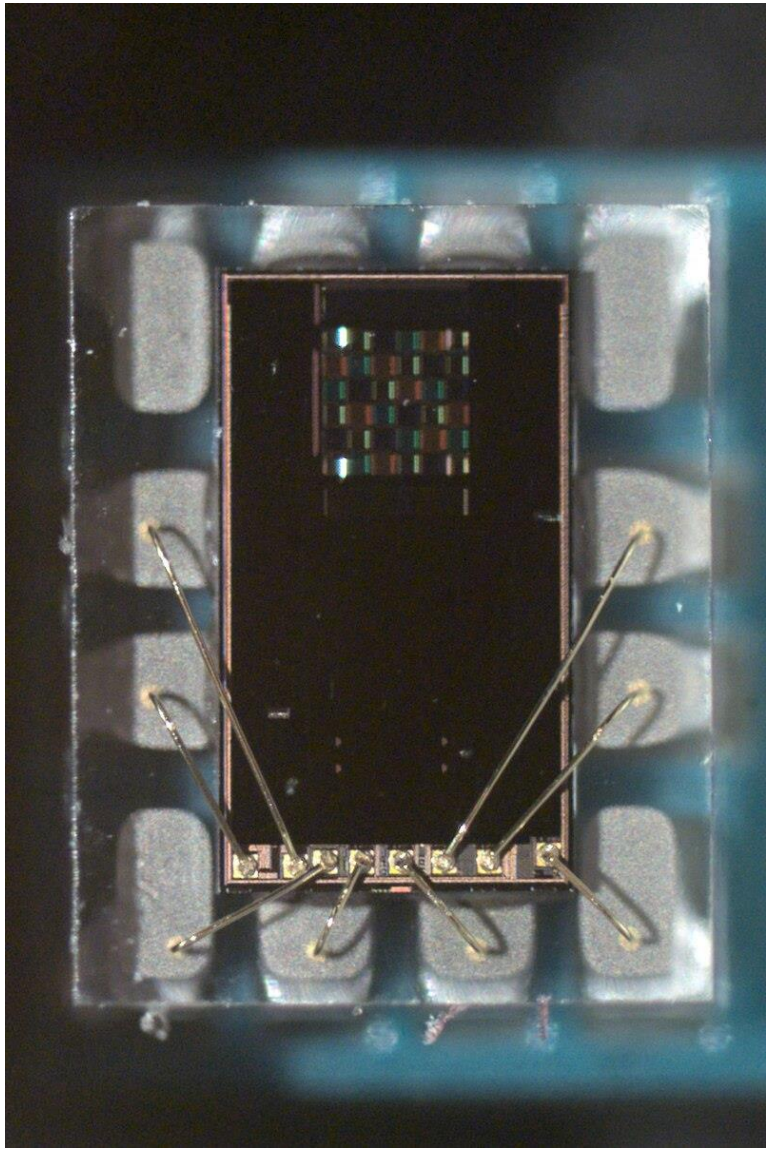
Characteristic	CCD	CMOS
Signal from pixel	Electron packet	Voltage
Signal from chip	Analog Voltage	Bits (digital)
Readout noise	low	Lower at equivalent frame rate
Fill factor	High	Moderate or low
Photo-Response	Moderate to high	Moderate to high
Sensitivity	High	Higher
Dynamic Range	High	Moderate to high
Uniformity	High	Slightly Lower
Power consumption	Moderate to high	Low to moderate
Shuttering	Fast, efficient	Fast, efficient
Speed	Moderate to High	Higher
Windowing	Limited	Multiple
Anti-blooming	High to none	High, always
Image Artefact	Smearing, charge transfer inefficiency	FPN, Motion (ERS), PLS
Biasing and Clocking	Multiple, higher voltage	Single, low-voltage
System Complexity	High	Low
Sensor Complexity	Low	High
Relative R&D cost	Lower	Lower or Higher depending on series

https://www.azom.com/article.aspx?ArticleID=16321

Ambient light Sensors

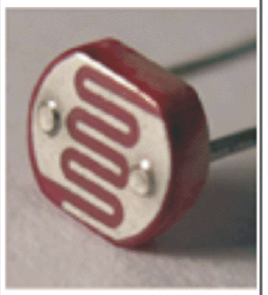
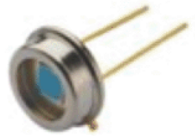
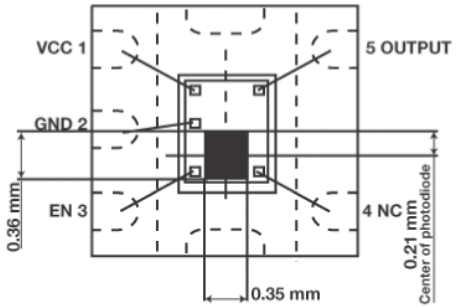
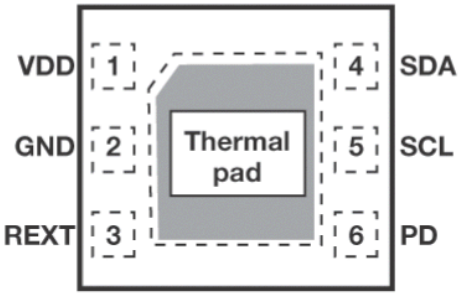
- Uses various type of sensors to detect ambient light
- Used to control the brightness of screens



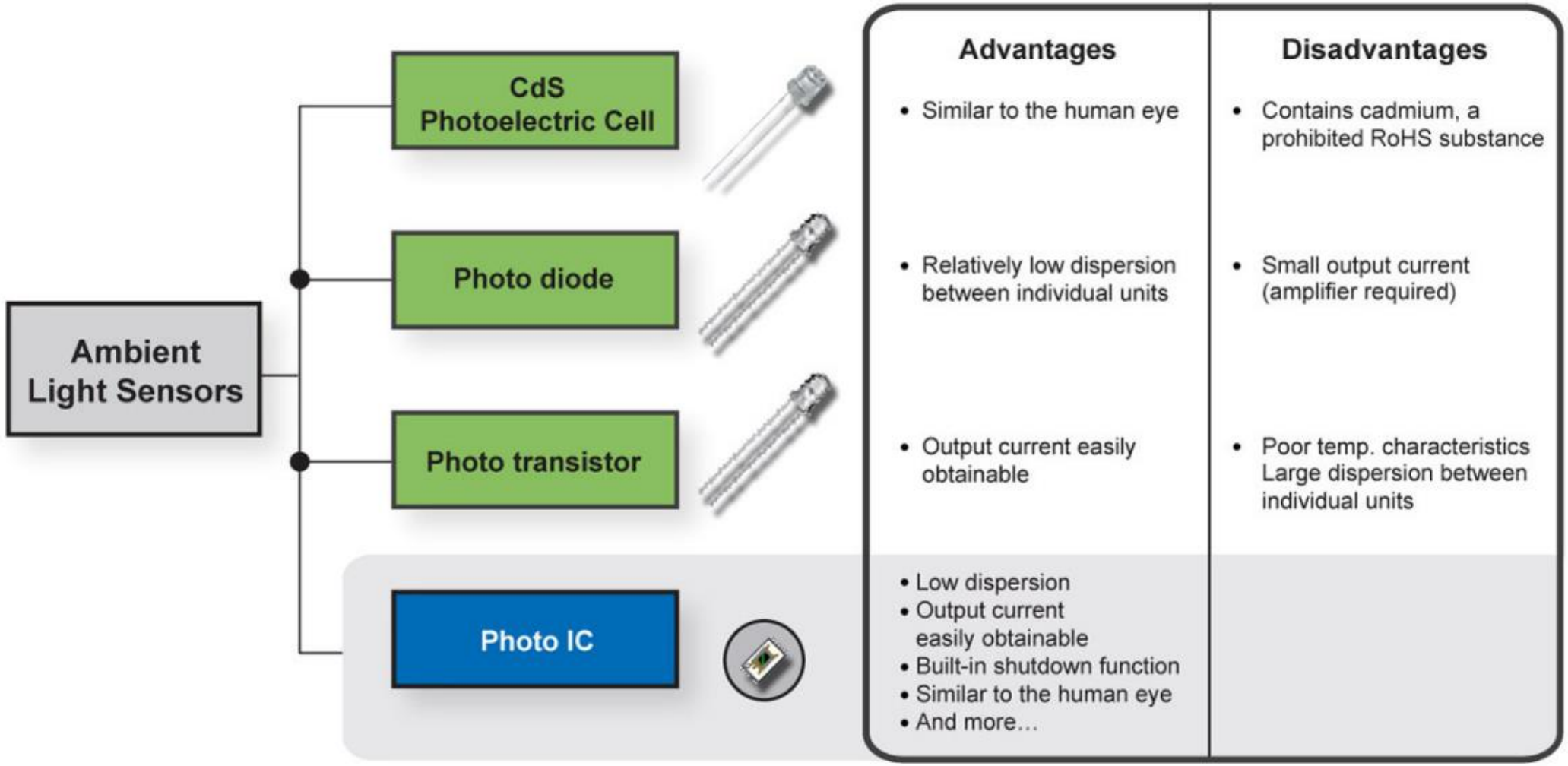


https://en.wikipedia.org/wiki/Ambient_light_sensor

https://learn.microsoft.com/en-us/windows-hardware/design/component-guidelines/ambient-light-sensors

Device	Photo resistor	Photo diode	Photo transistor	Photo diode and current amplifier	Photo diode, current amp, ADC and filter
Referenced part #	PDV-P500X	Everlight DTD-15	Everlight DPT-092	EL7900	ISL29001
					
Accuracy	Not guaranteed	Not guaranteed	± 75%	± 33%	15-bit resolution
Current (1000 lux)	Varies	3 μA	2.6 mA (70 klux)	0.9 mA	0.3 mA
Range	1 to 100 lux	7 to 50 klux	1 k to 100 klux	1 to 100 klux	0.3 to 10 klux
Response time	55 ms	6 ns	15 μs	0.5 ms	100 ms
Enable function	No	No	No	Yes	Yes

https://www.edn.com/making-sense-of-light-sensors/



https://www.rohm.com/documents/11303/41217/CNA09016_wp.pdf