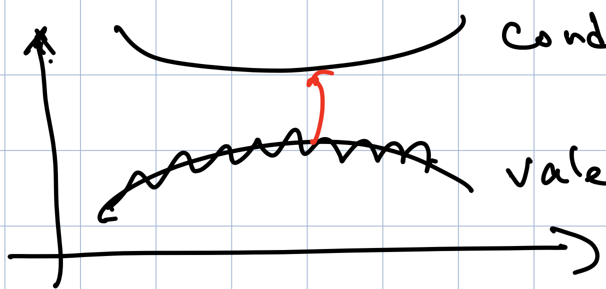
Optical properties of solids $\longrightarrow$ band theory

visible light: red 750nm, 1.7 eV; green 2.05eV; blue 400 nm, 3 eV; violet 3.1eV; (ultraviolet) 3.2 eV

invisible

Insulators



$E = \hbar\omega$

Insulator w/ $E_{gap} \geq 3.2$ eV

is transparent!

Semiconductor w/ small band gap

$\longrightarrow$ absorb energies above the band gap,

but transparent to energies below

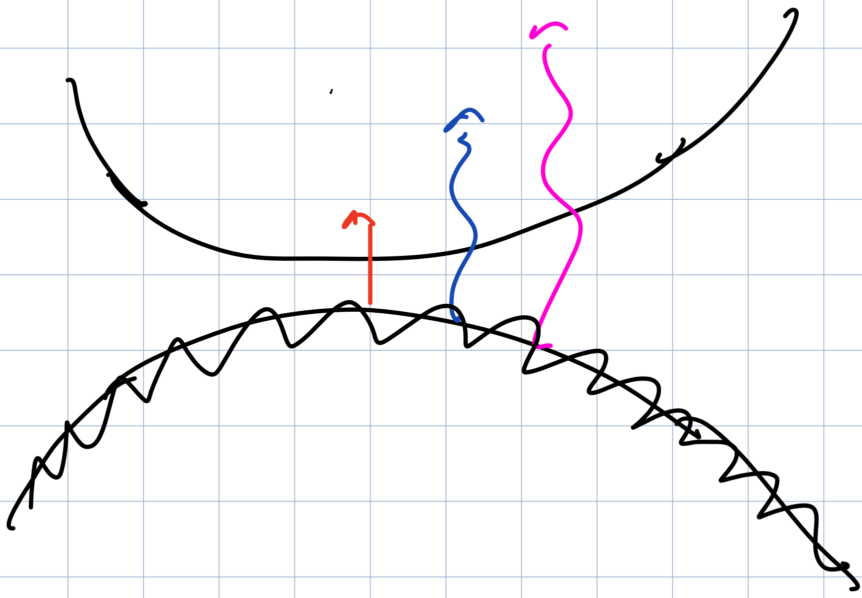
Ex: CdS (Cadmium Sulfide)

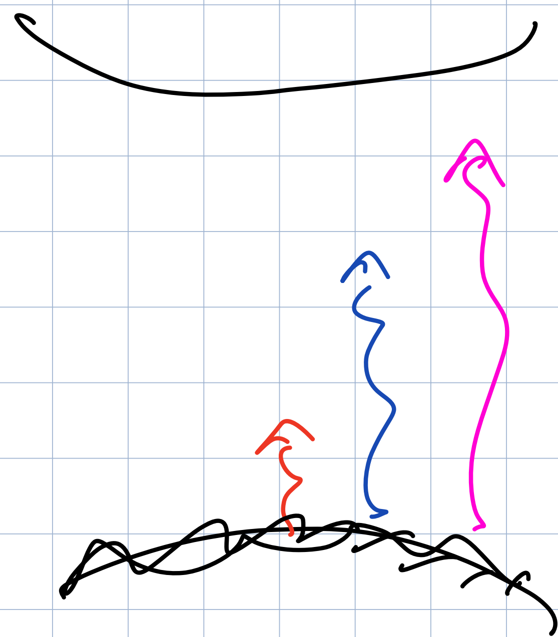
Band gap ~ 2.6 eV $\longrightarrow$ violet, blue absorbed

color $\sim$ redish

red, green not "

Semiconductor w/ very small band gap



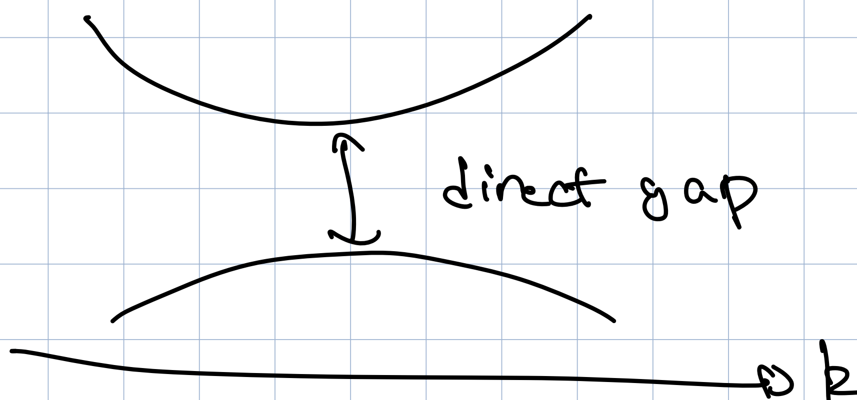


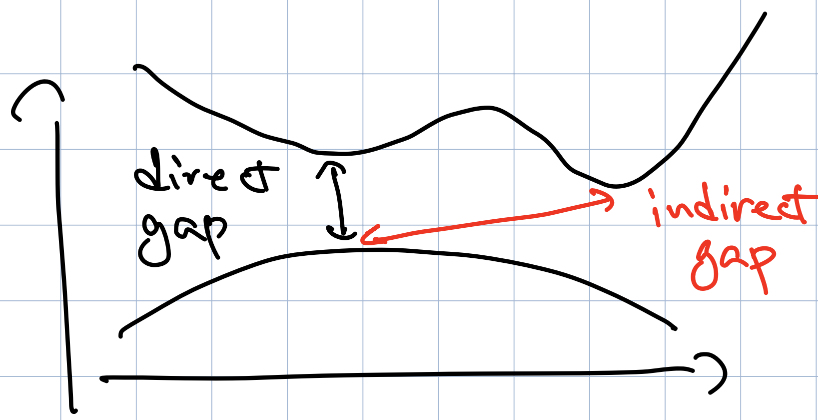
Black

Transparent

Example: diamond, quartz

E_{gap}





Very hard to excite electron in an indirect gap

$E = \hbar\omega = \hbar c k$

$\rightarrow \quad k = \dfrac{E}{\hbar c}$ $\rightarrow \sim eV$

$\longrightarrow$ extremely small

$\longrightarrow$ can't conserverve momentum

indirect gap transmission

1 photon in $\longrightarrow$ 1 e^- excited + 1 phonon excited

An example: Ge : optical absorption @ energies less than 0.8 eV: direct band gap

Metal : more complicated than insulators

photons → excite electrons → re-emit light
high conductivity

Re-emission → Metals look shiny

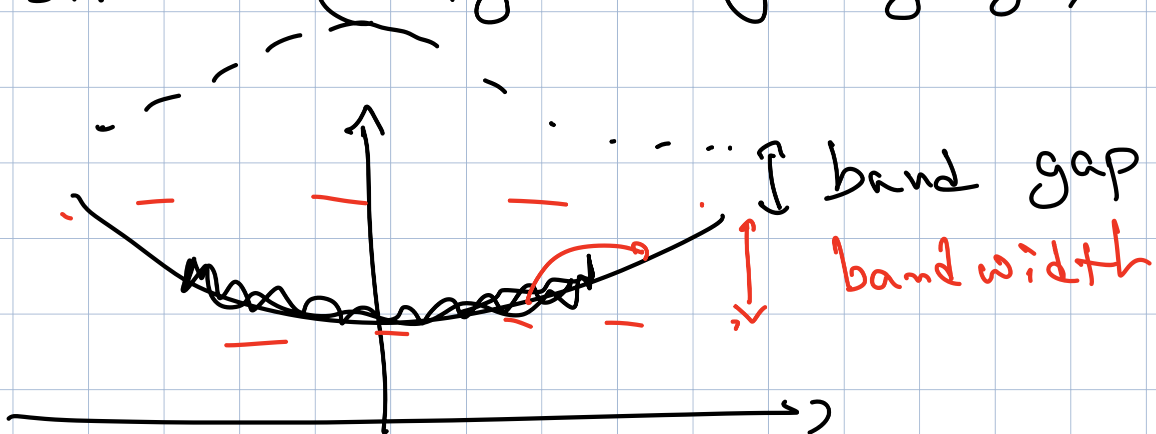
Noble metals (gold, silver, ...) look really shiny

Even among them

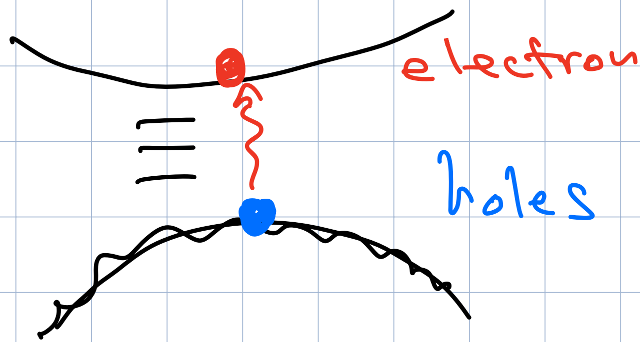
silver brighter than gold

Understood from band structure!

Bandwidth of conduction is larger for silver (in tight-binding language, t is large)



impurities



Si Si Si
Si ~~Si~~ P Si
Si Si Si

= Si Si Si
one free electron
Si Si Si
+ one proton
Si Si Si

1 nitrogen in 10^6 carbon atoms in diamond

⟶ yellow

Impurity

1) add charge carriers to an otherwise insulator
⟶ somewhat conducting

2) "free" electron can form a bound state w/ proton ⟶ "hydrogen atom"
↓
multiple states