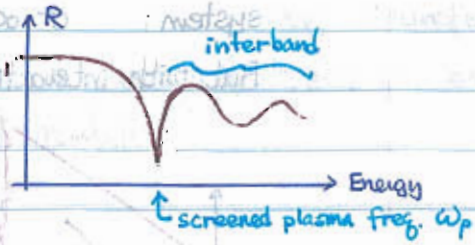
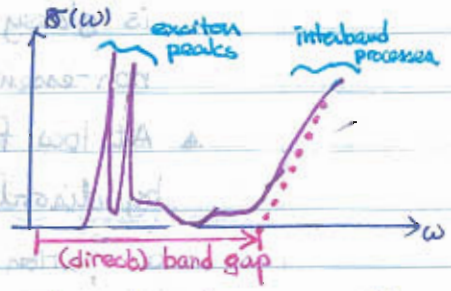
Optical Spectroscopy (II) [Armitage]

- Example: Simple Metals
  - In general, reflectivity looks like:

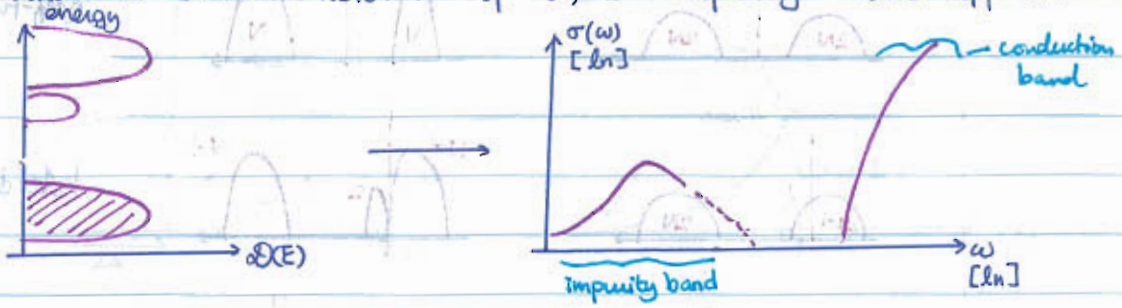


  - The screened plasma frequency is given by $\omega_p = \sqrt{\frac{4ne^2}{m\epsilon_\infty}}$
  - Ag & Au has similar mass/density, but ω_p differ by factor of 2, since Au has more interband processes $\Longrightarrow$ higher ϵ_∞
  - Width of peak ~ scattering rate near ω_p.

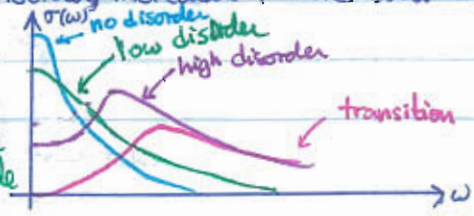
- Semiconductors & band insulators
  - dominated by interband transition at finite energy.
  - phonons can also appear as peak, but its energy will be different from that of excitons (excitons generally appear near the gap threshold).



  - While a semiconductor is doped, new "impurity" band appears



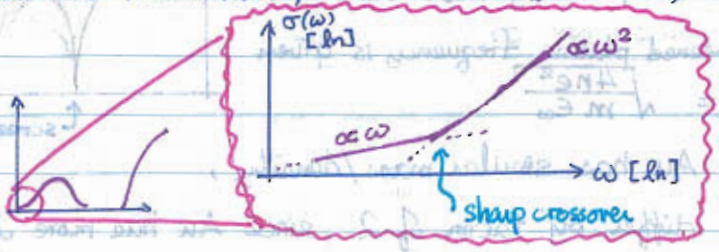
  - Hole donor & e^- donor will look similar, since optical spectroscopy creates electron-hole pairs; hence states related by particle-hole symmetry looks the same.
  - Dopping semiconductor, as dopping (disorder) increases, there will be a conductor —



NOTE: At high freq. high disordered systems & low disordered ones look similar, since we're probing at length scale shorter than disorder scale

For electronic glass (metal + disorder), in non-interacting

But with interactions, $\sigma \propto \omega\, U(r_\omega) + \omega^2$; $U(r) = \frac{e^2}{r_\omega \epsilon_\infty}$.



$r_\omega = \xi \ln\left(\frac{I_0}{\hbar a}\right)$

localization length

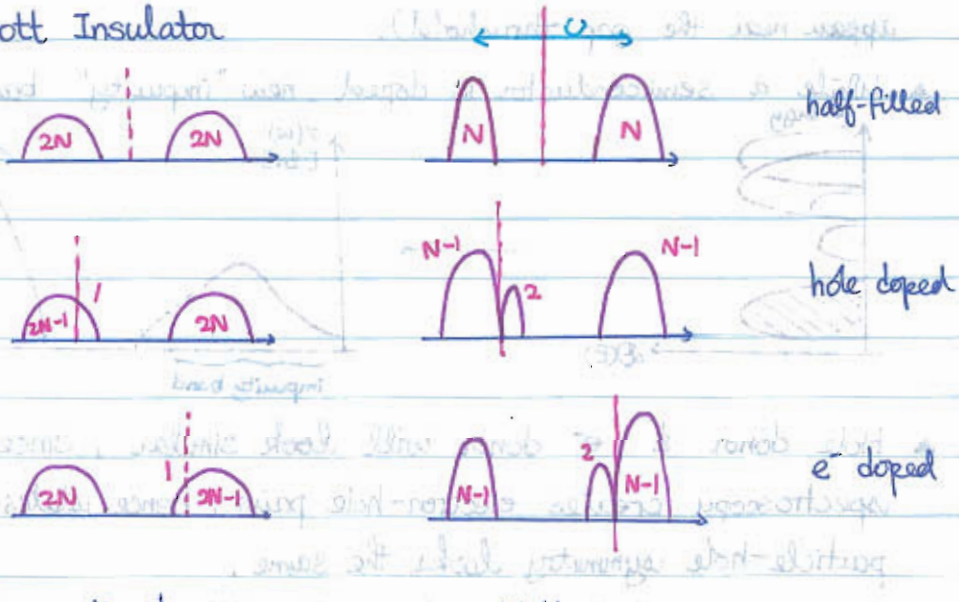
ionization energy

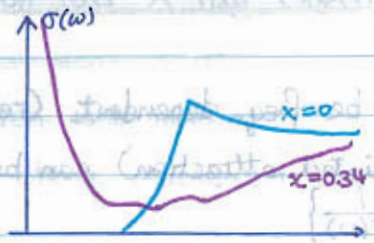
But even with the functional form $\sigma \propto \omega \cdot U(r_\omega) + \omega^2$, the sharp transition from $\propto\omega$ to $\propto\omega^2$ are still not captured.

▲ These e^--glasses may be understood as Fermi glass: the state is glassy because of the Fermi statistics, and interaction is non-essential (as oppose to Coulomb glass.)

▲ At low freq. & low temperature, the electrons are localized by disorder. So conductivity is better understood as dissipation

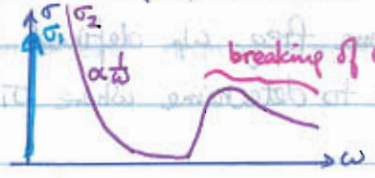
• Mott Insulator





In Mott insulator, spectro-weight transfer is faster as function of dopping as compared to band insulator.

- Example: Superconductor
  - ▲ In perfect superconductor $\begin{cases} \sigma_1(\omega) = \frac{\pi}{2}\frac{Ne^2}{m}\delta(\omega) \\ \sigma_2(\omega) = \frac{Ne^2}{m\omega} \end{cases}$
  - ▲ At low energy,

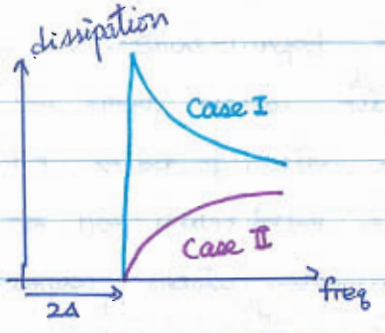


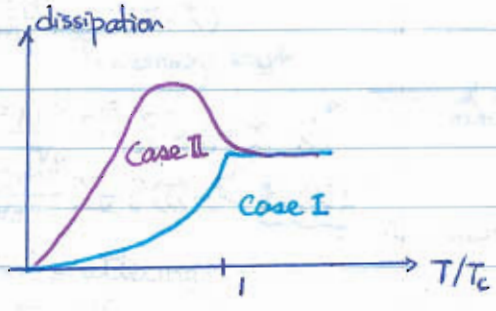
  - ▲ At finite temperature/with disorder, one expects:

$$\sigma_{sc}(T) = \underbrace{\sigma_{1s}(T)}_{\delta\text{-fcn piece}} + \frac{iN(T)e^2}{m\omega} + \underbrace{\sigma_N(T)}_{\text{"normal" piece}}$$

The more precise form given by Mattis–Bardeen formalism.

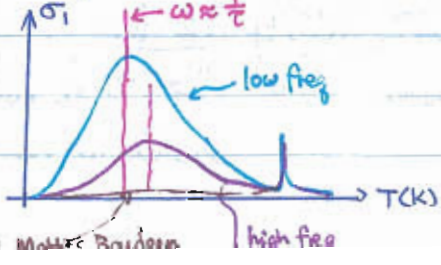
▲





Case I & Case II differ by the coherence factors that enter into calculations. For case II, coherence factors cancel out the density of state singularity at 2Δ. Case II occurs in s-save sc.

For YBCO (d-wave)



- Extended Drude Model
  - Allow $m^*(\omega)$ & $\tau(\omega)$ to be freq. dependent (reasonable since interaction (e.g. phonon mediated attraction) can be time delayed)
  - $\frac{m^*(\omega)}{m_b} = -\frac{\omega_p^2}{4\pi\omega} \mathrm{Im}\left\{\frac{1}{\sigma(\omega)}\right\}$

    $\frac{1}{\tau(\omega)} = \frac{\omega_p^2}{4\pi} \mathrm{Re}\left\{\frac{1}{\sigma(\omega)}\right\}$
  - Interaction increases optical mass over band mass at $\omega \to 0$ limit.
  - Can use Matthiesen rule to estimate $\frac{1}{\tau(\omega)}$, where the rates for different processes
  - To invert Drude formula to get $m^*(\omega)$ & $\tau(\omega)$, we need the plasma freq. ω_p defined by $\int_0^\infty \sigma_1^{intra}(\omega) = \frac{\omega_p^2}{8}$. But it's hard to determine where σ_1^{intra} stop, so need to estimate.