**Conduction with Impurities**

**Weak localization effects at non-zero temperatures**

For sufficiently high disorder, it is possible to have localization at T = 0. It is also theoretically possible to have localization effects at non-zero temperatures. The requirement is that the electron can complete many scatterings before its phase gets ‘broken’, i.e., randomized to around π or so. Impurity scattering doesn’t randomize the phase as its purely elastic. But does randomize position. Such diffusion takes place according to:



where ℓ is the ±change in position associated with each e-impurity collision, roughly. Phonon scattering does change the energy/phase however. The energy-diffusion rate would be, in the low-T regime:



where T, analogous to ℓ, is the energy change associated with each phonon-electron collision. Now the phase change a particle acrues in time t, when the energy is a function of time E(t), is Δφ = ∫0tE(t´)dt´. So likewise, the change in phase associated with this is:



Question: how long until Δφphonon ~ π ~ 1. This is when,



So naturally the phase breaking time → ∞ when T → 0. Then it seems we could observe localization as long as the electron can traverse the sample within this time. This distance traversed within this time would be:



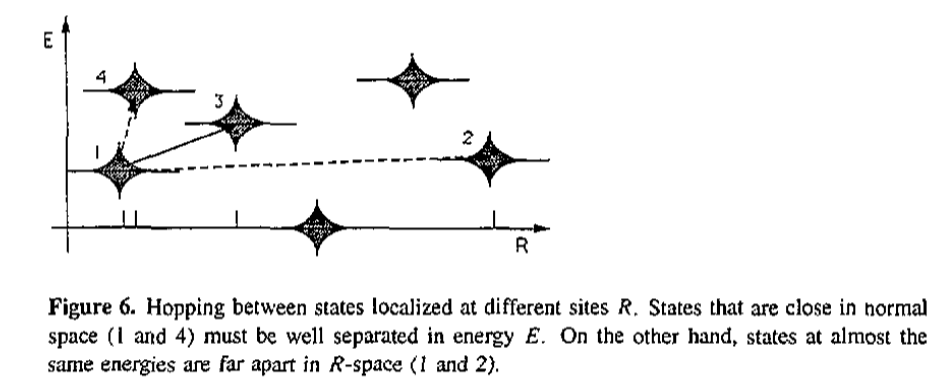
So we would need:



it would seem.

**Strong localization at non-zero T (Mott Hopping)**

The above discussion basically says we can take account of weak localization by simply replacing the zero-phonon phase breaking length L, with Lφ. But for sufficiently high disorder, the electron states at the Fermi surface are localized and ρimp = ∞ basically. But this would be tempered by the fact that at non-zero T, the phonons, rather than impeding conductance, will actually abbet it, by giving electrons the energy to hop from localized state to localized state.



We can qualitatively work out the T-dependence of the conductivity with this model. Probability of hoping to another state a distance R away, and with a difference ΔE in energy is product of P(jumping to that energy)×P(jumping to that position). Both of these probabilities are approximately exponential, when states are localized.



For a ball Rd around our given position, the average energy difference between states within that ball is, assuming states are isotropically distributed:



Filling this into P, choosing the R which maximizes P, and asserting that Pmax ~ σ, we have:



And so we’d expect an ρ(T) curve like this, I guess…’cause I’m not sure what the high T resistance would look like. It might be that it resembles a semi-conductors T-dependence as eventually the electrons might be lifted to a higher, de-localized, band.

