Experimentalist Guide to Superconductivity [Canfield]

- Focus mostly on phonon-mediated SC.

- Experimentally, BCS T_c eqn has 3 parameters:
  $k_B T_c = 1.13 \hbar\omega_D e^{-1/V D(\epsilon_F)}$
  - ▲ ω_D: prejudice towards lighter mass elements.
  - ▲ V: prejudice towards the edge of structural phase transition (e.g. CDW)
  - ▲ $D(\epsilon_F)$: prejudice towards transition metal elements (for their d-levels).
  - ▲ Caveat: Need to suppress Coulomb repulsion too....

- In 1950's – 60's there is large scale search for higher T_c.
  - ▲ Focus mainly on binary compounds.
  - ▲ These can be made (by arc melting) and test (mostly by $\rho(T)$ & often by $\chi(T)$) quickly.
  - ▲ The samples are poly-crystal/powders form.

- For decades T_c stuck at ~20K
  - ▲ Some theoreists predict $T_c \lesssim 30$K

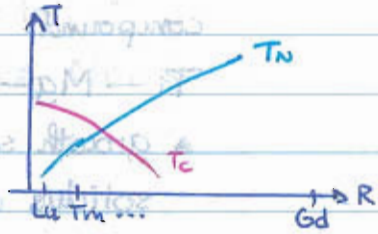
- Then comes the Cuprates.... old BCS-type SC seach become dormant....

- But then in { 1994: RNi_2B_2C & YPd_2B_2C ; 2001: MgB_2
  - ▲ YPd_2B_2C is metastable (~diamond) and prefers another structural form.

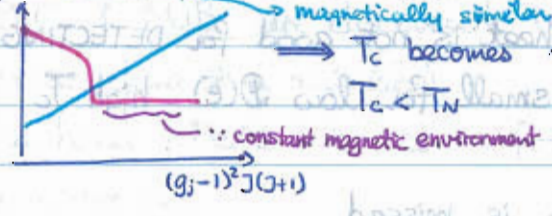
- Both $LuNi_2B_2C$ & YPd_2B_2C satisfy the 3 prejudices.

- RNi_2B_2C & YPd_2B_2C, being quadratary compounds, are very tricky to grow.
  - ▲ First in poly-crystal form. Single crystal catch up within weeks.

- Interplay between SC & magnetism:



  - ▲ For BCS-type SC, magnetism is bad for pairing.
  - ▲ Some outliner in the trend comes from elements with strong magnetic anisotropy, which reduces the effect of pair breaking by magnetism.
  - ▲ H_{c2} anisotropy & size can be understood by the anisotropy & strength of internal $\vec{B}$-field anisotropy.
  - ▲ H_{c2} also shows sharp feature when passing through T_N.
  - ▲ Consider $(Ho_{1-x}Dy_x)Ni_2B_2C$, where T_c & T_N crosses.



  - ▲ Instead consider $(Lu_{1-x}Dy_x)Ni_2B_2C$ —— found T_c drops at the same time when T_N drops. SC appears only when AF order presents.
    - ▶ possible reasons: AF ordering is anisotropic, thus compare to paramagnet (local moment) it distubs BCS pairing less.
  - ▲ $YbNi_2B_2C$ in the series also contains heavy fermion physics

- In $LuNi_2B_2C$, phonons are soften up at low T
  $\Longrightarrow$ close to structural transition
  $\Longrightarrow$ strong e^- – phonon coupling.

- Then, experimentalists try to consider more teritary / quadritary compound. But in 2000 Japanese group (while searching Ti – Mg – B) found MgB_2
  - ▲ growth seems difficult since there is no exposed liquid – solidus line.
  - ▲ However, considering vaper pressure curve, by sealing Mg & B in container, B absorb Mg in vapor.

- Isotope effect ($T_c \propto 1/\sqrt{m}$) is observed & confirm phonon mediating mechanism (found $T_c \sim M^{0.26}$, since we're only changing B & full phonon freq depends on all masses)

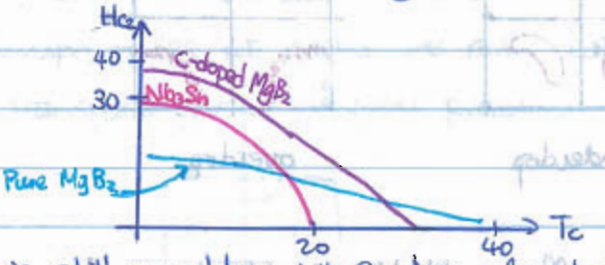
- From specific heat, $\Theta_D \sim 750\,K$
  - ▲ Specific heat is not good for DETECTING T_c, since the kink is small for low $D(\epsilon)$ high T_c BCS SC.

- Why MgB_2 is missed
  - ▲ It is hard to grow from "classical" mechanism
  - ▲ It has low $D(\epsilon_F)$ —— conflict with prejudice.

- Anisotropy in H_{c2} is difficult to get, since there's no single crystal. But can still be detect by two kinks in χ:

- The anisotropy can be understood by bonding
  - MgB_2 has both σ-bond & π-bond.
  - Anisotropy comes from σ-bond (π-bond ~ 3D)
  - Both σ-band & π-bond $\Longrightarrow$ 2-gap (observed)
    (both gaps turn on at same T_c)

- By doping MgB_2 with C, T_c ↘ while H_{c_2} ↗
  - The material thus beat industry standard Nb_3Sn



  - But J_c is still a problem. Nb_3Sn has almost field independent J_c.
  - Doping with C $\Longrightarrow$ making SC dirty (w/ defects)
    $\Longrightarrow$ changing mean-free path
    $\Longrightarrow$ higher H_{c_2}.

- Both RNi_2B_2C & MgB_2 are discovered (somewhat) by accident (in part when searching other materials)
  On the other hand, FeAs-SC comes from systematic study of planer Fe compounds.