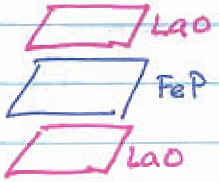
Fe As Based Superconductor [Canfield]

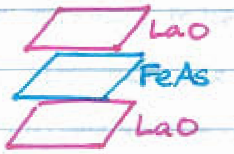
- Some materials are not discovered because people look into places (materials) that are easy to look (make, probe, etc), not the place where the "key" is. (Gp I, II, V, VI are hard to work with....)

Part I : End of tyranny of Cooper

- Example: $RFeAs(O_{1-x}F_x)$ $T_c \lesssim 55K$
  $RFeAsO_{1-x}$ $T_c \lesssim 50K$

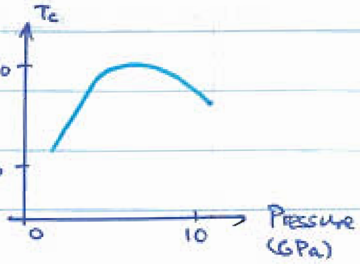


- From Hosono's group. Stale with LaOFeP
  - ▲ Dope F ⟹ SC with T_c at 3K



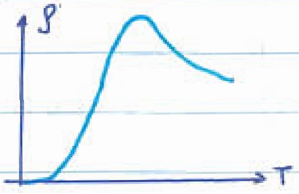
- Next we get $La(O_{1-x}F_x)FeAs$
  - ▲ SC with $T_c \sim 26K$
  - ▲ $x=0$ ~ creppy metal

- As is very hard to work with (toxic, volatile, reactive)



- T_c can be tuned with pressure

- Pressure ⟹ Volume $\searrow$
  Alternatively can change elements.
  e.g. La ⟶ Sm.



- Example: NdFeAs
  - ▲ high pressure synthesis (2~3 GPa)
    (in original LaFeAs, sample made at atmospheric pressure)
  - ▲ Not single phases (domains with enough F to SC coexist with domains with not enough F and hence normal).

- Possible to polish to get small grain to get ARPES done.
- Band structure & ARPES get qualitatively similar, but quantitatively ARPES shows variation in z-direction (⇒ no nesting)
- Gap data fit well to anisotropic s-wave.
- Shows H_{c2} anisotropy.
- From penetration study (which gives superfluid density), anisotropic s-wave seems to fit best with experiment.

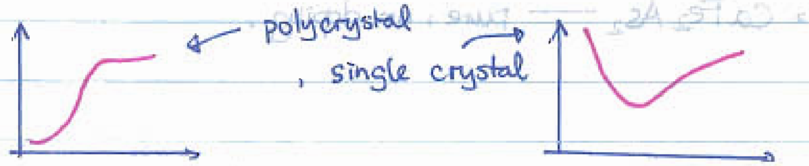
- Summary for RFeAsO
  - Hard to check how much F are substituted.
  - Mixed phase is a problem
  - Grow is complicated & difficult.
  - Largest single crystal : 200-400 μm in basal plane (very thin).

Part II: End of tyranny of oxygen

- $(AE_{1-x}A_x)Fe_2As_2$ $\begin{cases} A = K, Na, Li \\ AE = Ba, Sr, Ca \end{cases}$
  - Easier to grow
  - $(Ba_{1-x}K_x)Fe_2As_2$: T_c ↗ 40 K.
  - As in the oxide case, the FeAs plane is the same, only that interlayer changes.

- Valance:

La	Fe	As	O		Ba	Fe_2	As_2
+3	?	−3	−2		+2	?	$(-3)\cdot 2$
	+2					$(+2)\cdot 2$	

- 

- Reason: ~1% Sn substitute Ba.

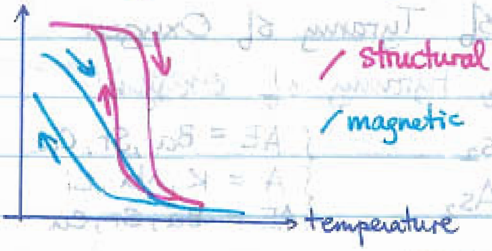
- ▲ tet-ortho transition as expected.
- ▲ With K substitute Ba, $T_c \sim 30K$ for 40% K
- ▲ Again see anisotropic H_{c2}

- In general, FeAs material has tet-ortho transition, & related to magnetic transition. These transition are sensitive to (chemical) tuning.

- Can also make $SrFe_2As_2$ & $CaFe_2As_2$
  - ▲ $CaFe_2As_2$ has strongest 1st order structural phase transition, compare with Sr- & Ba-

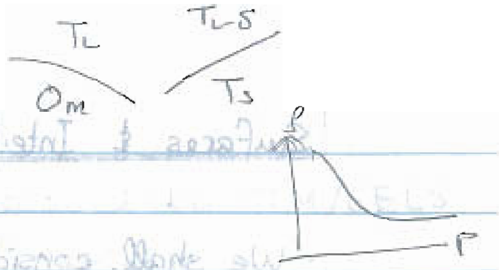
- All the materials are very soft (so ω_{Debye} is small...?),

- Neutron scattering on $CaFe_2As_2$ shows magnetic transition



- $CaFe_2As_2$ vs. $SrFe_2As_2$ & $BaFe_2As_2$
  - ▲ much softer
  - ▲ smaller lattice parameter
  - ▲ easier to pressure induce T_c

- $CaFe_2As_2$ — pure, no doping.



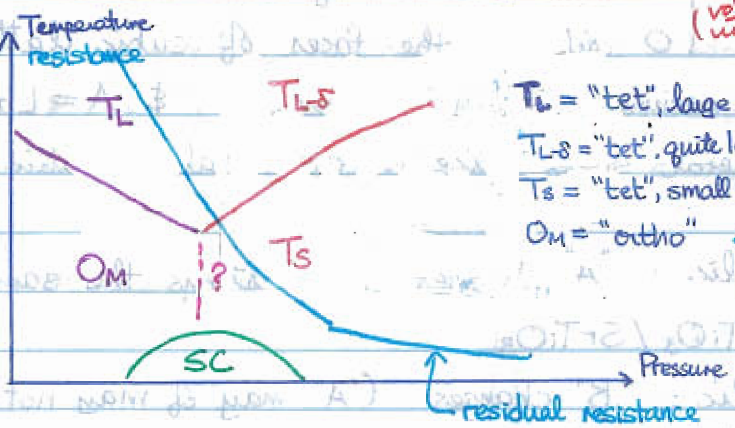
- With pressure on $CaFe_2As_2$:

$$\xRightarrow{\text{Pressure}}$$

no SC $\longrightarrow$ SC $\longrightarrow$ no SC

residue resistivity ↘ $\longrightarrow$

volume = (volume of unit cell)



T_L = "tet", large unit cell
$T_{L-\delta}$ = "tet", quite large unit cell
T_s = "tet", small unit cell
} non-magnetic

O_M = "ortho" ⟵ magnetic

- For $BaFe_2As_2$, pressure dependence is less.