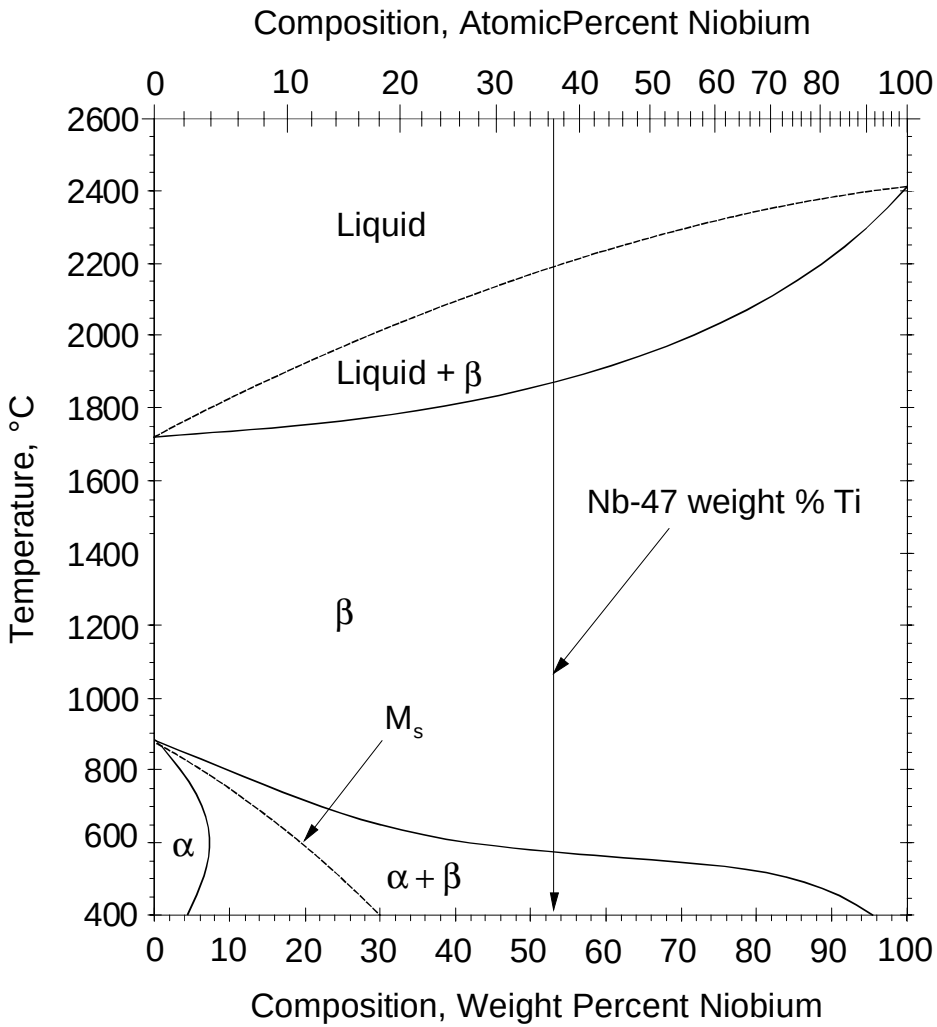
II. Basic Materials Issues

- Crystal Structures
  - Nb-Ti: body centered cubic *simple, ductile*
  - Nb_3Sn: cubic A15 Crystal structure with range of off-stoichiometric compositions
  - BSCCO: complex layered phase(s) not found at fixed stoichiometry of nominal phase
  - YBCO: layered phase of fixed cation stoichiometry but variable O content
- Only Nb-Ti is ductile
- Essential Phase Diagram Information
  - well known for LTS, poorly known for HTS

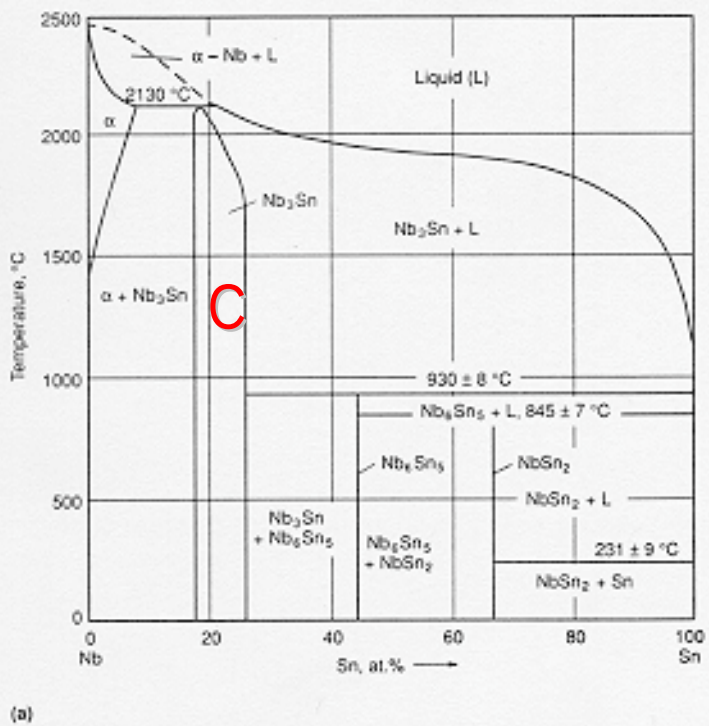
IIa. Nb-Ti Phase Diagram



Key features:

- Very high melting points
- Large separation liquidus and solidus leads to segregation on cooling
- Nb is bcc at all T, while Ti is bcc at high T and hcp at low T
- Nb-Ti alloys want to become 2 phase hcp and bcc at low T but cannot transform by diffusion
- The lattice acquires a soft phonon that has very important consequences:
  - E declines on cooling
  - p increases on cooling
- The martensitic phase transformation is only incipient for Nb47wt.%Ti but the resistivity is greatly increased and H_{c2} increased too

IIb. Nb-Sn Phase Relations



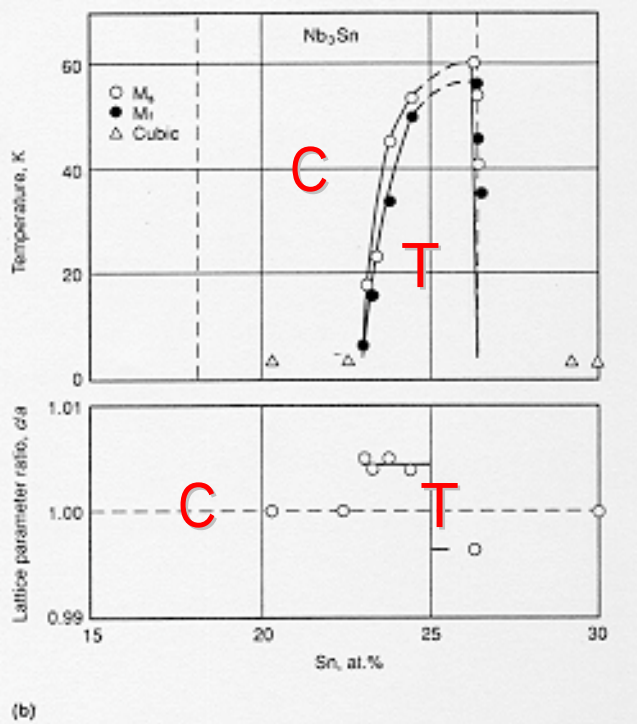


Fig. 12 Niobium-tin binary phase diagram. (a) Elevated temperatures. (b) Subzero temperatures. M_f, temperature at which martensite formation finishes during cooling; M_s, temperature at which martensite starts to form on cooling. Sources: Ref 11, 12

C: Cubic A15, higher H_{c2} phase, T: Tetragonal A15 phase

Broad composition range 18-25at.%Sn, LT shear transformation to a small tetragonality, lowering T_c and H_{c2}

IIc. Nb_3Sn Structure

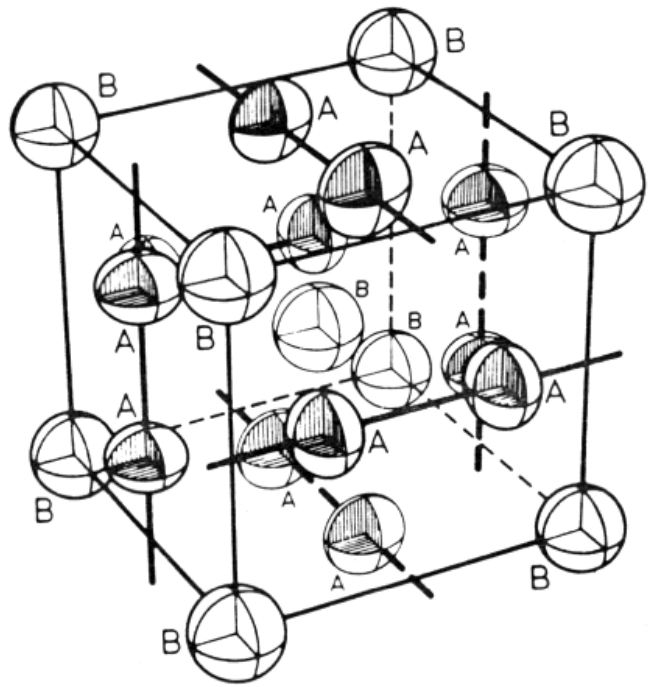


Figure 1
The A15 type structure A_3B, space group $Pm3n$

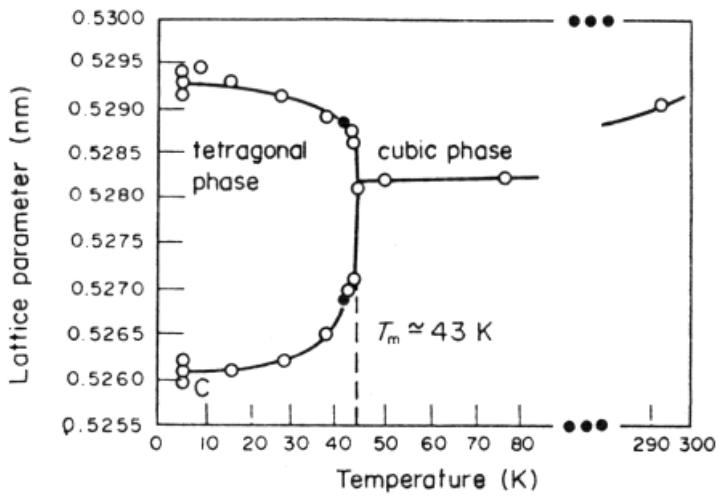
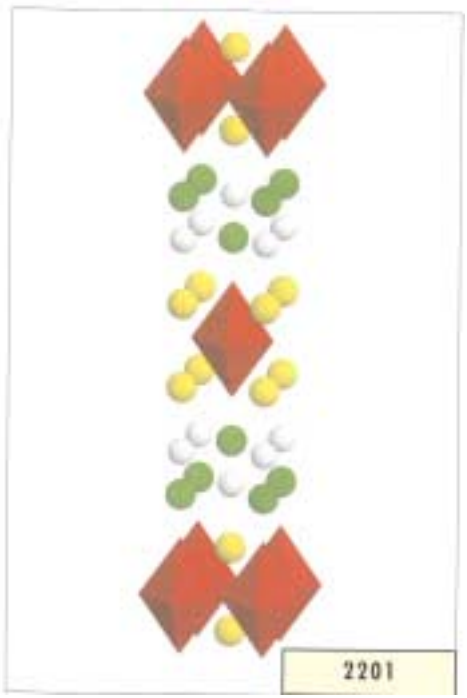


Figure 2
Structural instability in Nb_3Sn

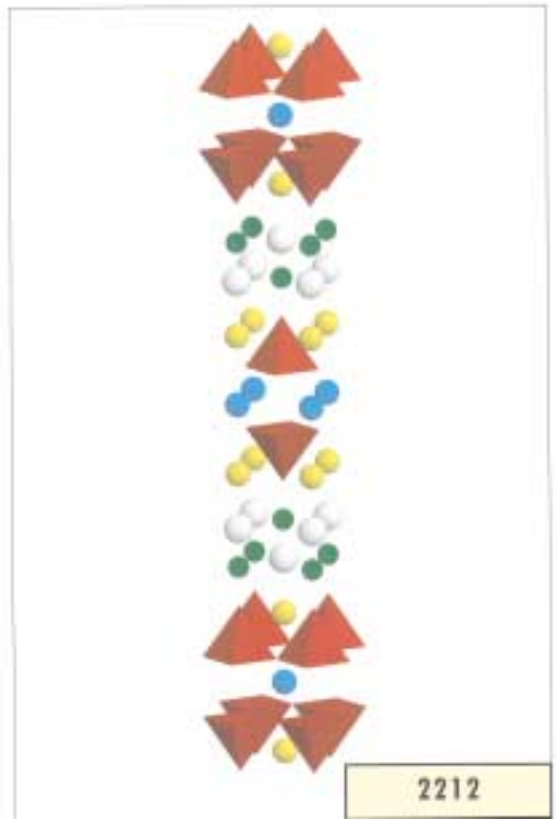
Cubic structure with 3 orthogonal chains in which the Nb atoms are more closely spaced than in pure Nb: high N(0).

Departures from stoichiometry must be accommodated by vacancies or anti-site disorder

IId. The BSCCO Family

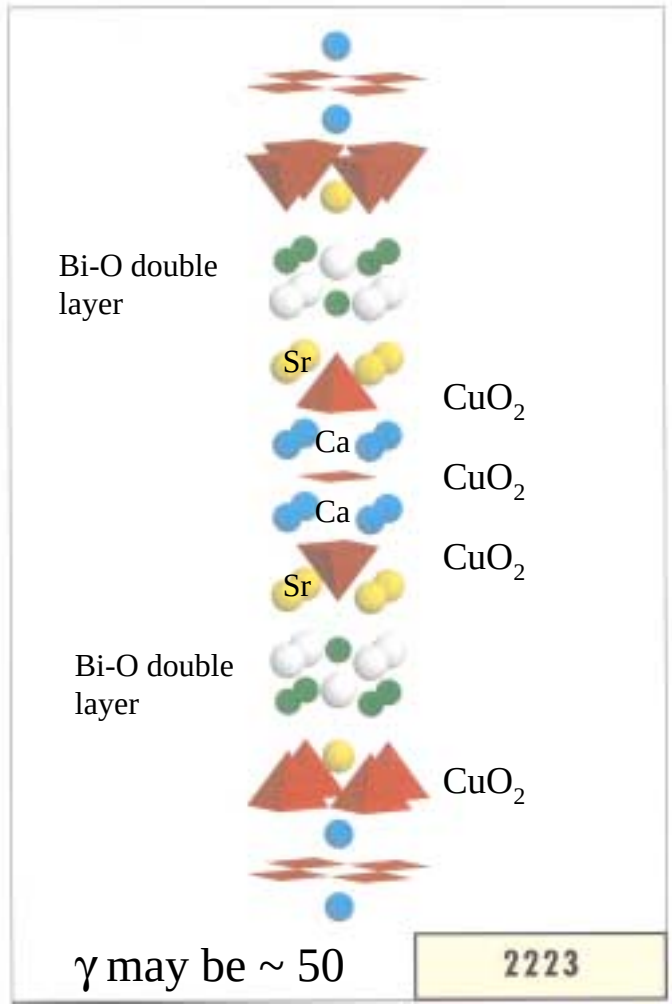


Tc ~30K



γ ~ 200-300

~70-95K

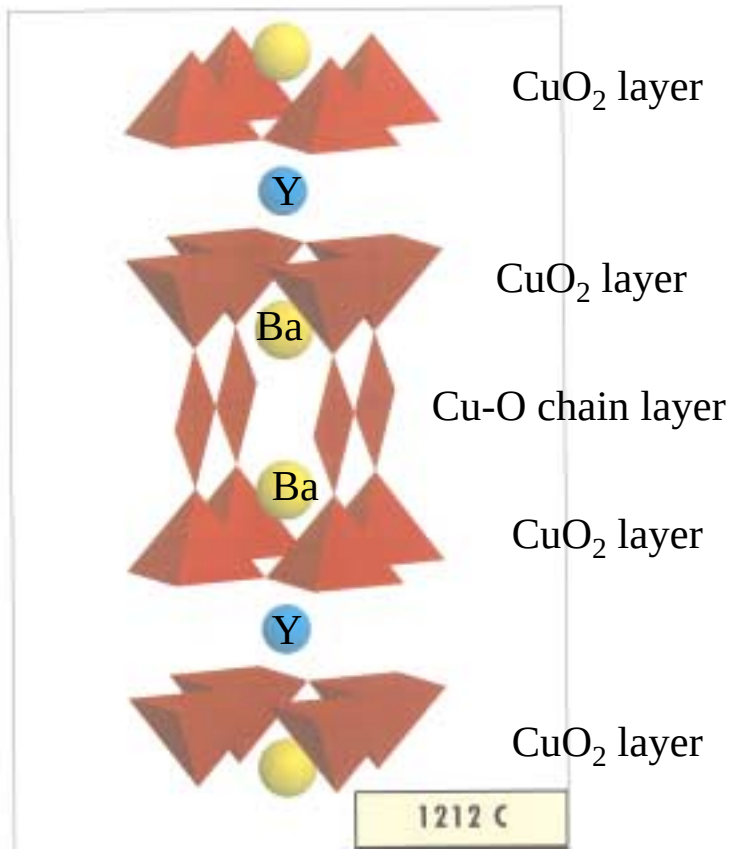


γ may be ~ 50

~105-110K

IIe. YBCO

- YBCO ($YBa_2Cu_3O_{7-x}$) possesses the first crystal structure with $T_c > 77K$
- It has defined cation stoichiometry 1:2:3, but O content is variable from 6-7
  - $T_c > 90K$ demands $x<0.05$
- YBCO is often thought of as being archetypal but in fact the Cu-O chain layers are very unusual
  - Make charge reservoir layer metallic
  - Most HTS are 2D, but YBCO is anisotropic 3D with electron mass anisotropy $\gamma = (m_c/m_a)^{0.5}$ of ~7



IIf Summary Materials Issues

- Higher T_c means greater crystal complexity
  - body centered cubic Nb-Ti with random site occupation, ductile
    - phonon anomalies
  - Nb_3Sn ordered A15 phase, brittle
    - other intermetallics often distort phase field
  - YBCO is anisotropic 3D, low carrier density, cation stoichiometric, brittle
    - metallic charge reservoir layer
  - BSCCO has 3 layered phases none of which exist at cation stoichiometry, micaceous with self-aligning tendencies
    - strongly anisotropic, 2D (but depends on doping state)
    - poorly understood phase relations
- Materials quality at scale of ξ is always an issue!