ON THE ROAD TO RTS

(WHICH PATH TO FOLLOW?)

Overview, impressions, opinions, caveats, and provocations

The Road Not Taken
Robert Frost (1915)

Two roads diverged in a yellow wood,
And sorry I could not travel both
And be one traveler, long I stood
And looked down one as far as I could
To where it bent in the undergrowth.

Then took the other, as just as fair,
And having perhaps the better claim,
Because it was grassy and wanted wear;
Though as for that the passing there
Had worn them really about the same.

And both that morning equally lay
In leaves no step had trodden black.
Oh, I kept the first for another day!
Yet knowing how way leads on to way,
I doubted if I should ever come back.

I shall be telling this with a sigh
Somewhere ages and ages hence:
Two roads diverged in a wood, and I --
I took the one less traveled by,
And that has made all the difference.


B
C
M
C
M
B


$La_{2-x}Sr_xNiO_4$?

A liquid room-temperature superconductor?

Product Name	**Magnesium boride**
Product Number	553913
Product Brand	Aldrich
CAS Number	12007-25-9
Molecular Formula	MgB_2
Molecular Weight	45.93

TEST	**SPECIFICATION**
APPEARANCE	GREY POWDER
TITRATION	51.1%-54.8% MG (COMPLEXOMETRIC)
ICP ASSAY	CONFIRMS MAGNESIUM AND BORON COMPONENTS
X-RAY DIFFRACTION	CONFORMS TO STANDARD PATTERN.
	APPROVED MARCH 22, 2006 RJM
Packaging	**5, 25 g in glass btl**
Your Price	**USD 29.50**

Related Categories

Alternative Energy > **Materials for Hydrogen Storage**

Few other delightful recipes

H. Weinstock:

Pu under 350 GPa

E. V. Antipov:

Pu under 350 GPa, grown atomic-layer-by-layer

Ø. Fisher:

Pair a physicist and a chemist

Surprise: New superconductors discovered!

	T_c	
$SrTiO_3/LaAlO_3$ bilayer	200	mK
Li at room pressure	400	μK

(Surprise)^2: To learn of this at RTS workshop!
(A *very* cold room indeed!)

A fool-proof recipe to discover *many* new super-conductors: measure (almost) *anything* at lower T.

New (ideas) for RTS materials

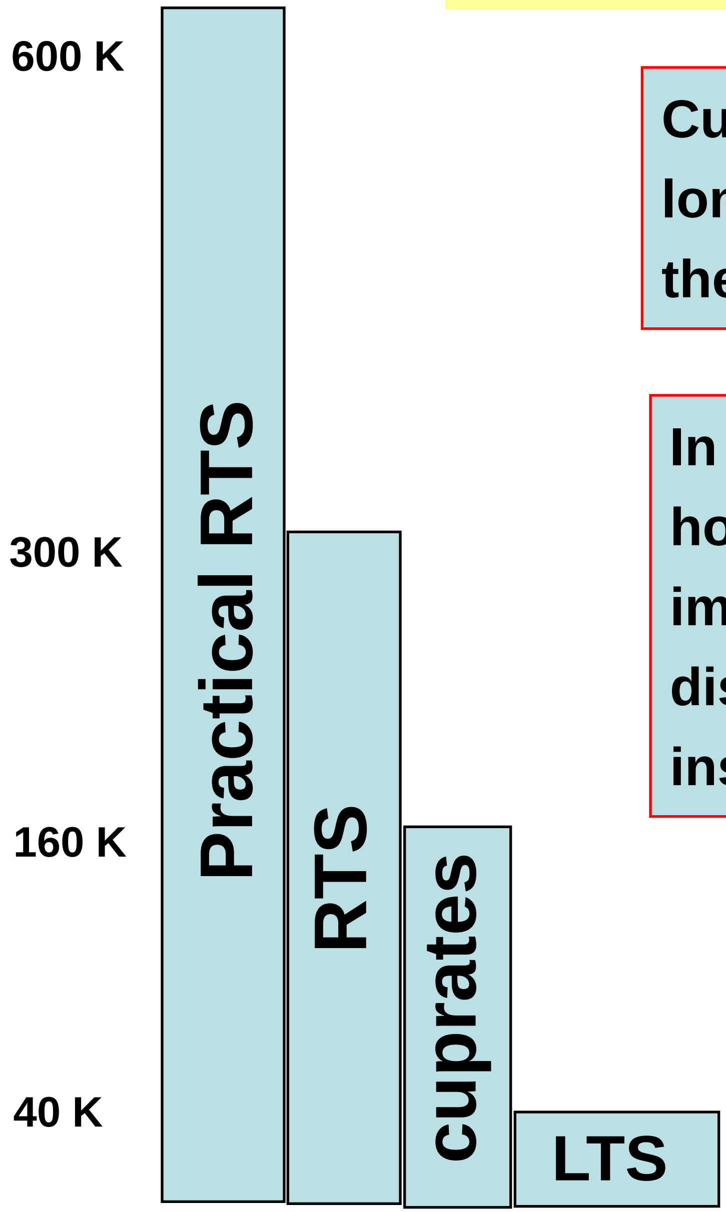
Surprisingly, very few.

- ★ Nothing left?
- ★ Wrong bunch of people?
- ★ Hiding good ideas?

Nickelates:	**a hunch**
Hydrides:	**solid (conventional) theoretical base**
Tungsten bronze:	**still just a USO**

Links: talks by Rice, Ashcroft,...

Our best bet: cuprates



Cuprates are still the only known HTS -- the lone inhabitants of the top three-quarters of the conquered T_c range.

In cuprates, Δ can reach 50-80 meV, rising hopes that HTS could be reached by improvements -- stabilization, reducing disorder, suppression of competing instabilities, epitaxy, interface effects, etc.

USOs at 200-300 K in Bi-2278, ILC.

Normally rather under-doped. Doping at interfaces and percolation? (Small $\xi(T)$ signal, irreproducible, fragile – oxygen electromigration?)

The first step is to understand cuprates

This is our only signpost to the Tao.

We need to turn every knob we can that produces enhancement or depression of Tc – pressure, epitaxial strain, (dis)order (e.g., gentle irradiation, isovalent substitution), FEST and SuFET, interface doping and enhancement, anything else that works.

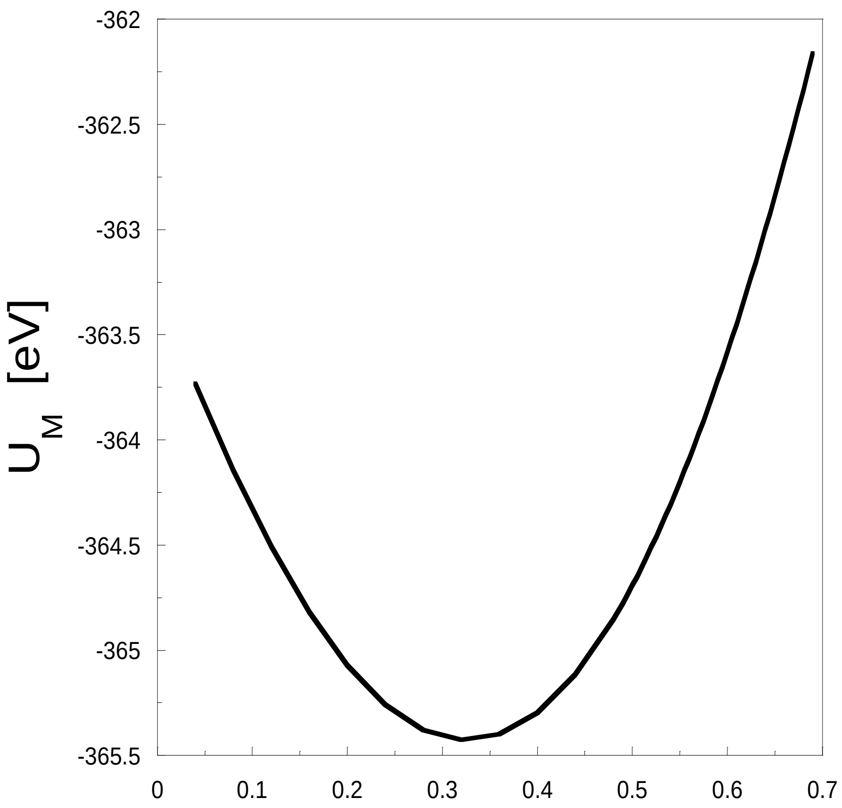
E.g.: Try Bi-2278/Swiss cheese (with a lot of holes).

We need to understand why T_c in CuO_2 plane varies from 10 K to 165 K – the importance of chemistry, crystal structure, order, etc.

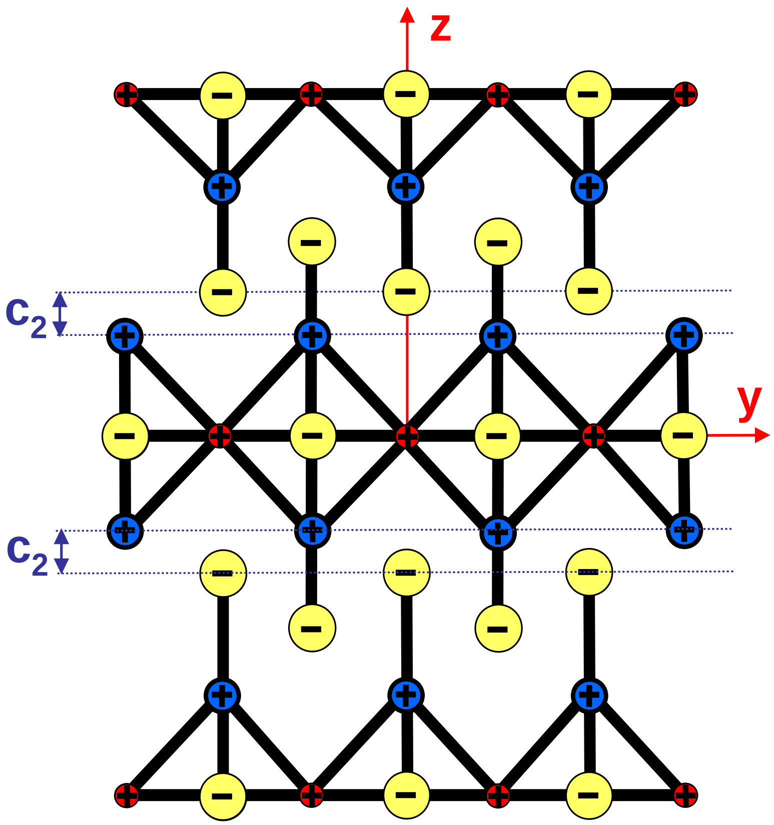
We need to understand *why is CuO_2 plane so unique.* ["The Ax."]

2D?   S=1/2?   E(Cu3d) = E(O2p)?

A hidden soft coordinate: La-O layer corrugation

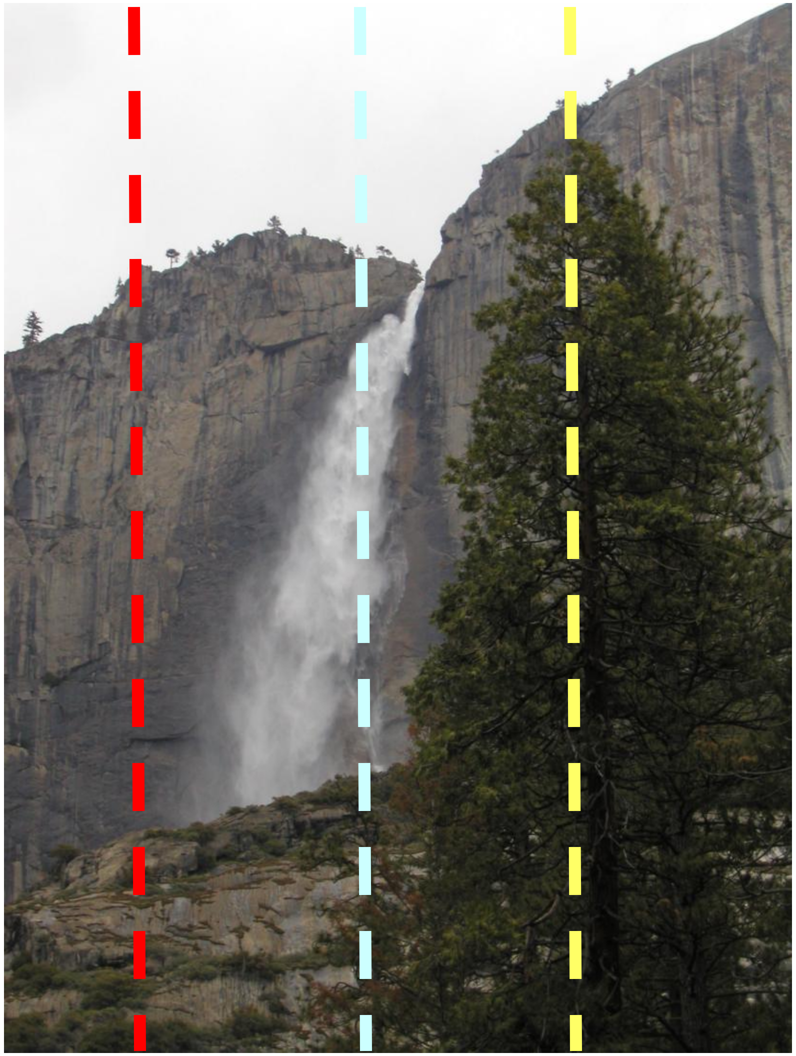


The calculated Madelung energy as a function of the La-O corrugation length c_2.



LCO structure viewed along the x-axis.
The thick black lines indicate ‘hard contacts’.
The rigid layers do not touch but ‘levitate’ on electrostatic forces.

Caveat 1: $T_c = f(n, x, \delta, \Theta, \text{(dis)order},\ldots)$



To be sure of statements that relate T_c with one variable, one should ensure that the others are kept constant.

A prime example: isotope effect experiments.

Surface has additional variables: oxygen volatility, atomic reconstruction, surface states, etc. These are difficult to measure and control.

Caveat 2: Trace RTS would have little use

Clarity and consistency would help

Real or inverse space?

Shubnikov-de Haas oscillations; Microwave measurements (l = 10 μm);

ARPES: E(k) dispersion; Fermi Surface; k is a good quantum number; Bloch-wave quasi-particles; metallic conductivity. Compatible with Fermi Liquid.

STS: Inhomogeneity on 1-2 nm scale; static for months hence not electronic; no translation symmetry; k is not a good quantum number; localized states; very small amplitude of charge variations. Compatible with (bi)polarons, local pairs, JTE.

Caveat 3:
How to falsify experiment-theory hybrids?

Ø. Fischer: STS + BCS; ~30 meV Einstein oscillator (=phonon?)

Perfect fit: a great challenge to competing theories.

Optics: Drude $\epsilon_1 = \epsilon_\infty - \frac{\omega_p^2}{\omega^2 + \Gamma^2}, \quad \epsilon_2 = \frac{\omega_p^2 \Gamma}{\omega(\omega^2 + \Gamma^2)}$ **+ mid-IR**

where $\omega_p^2 = 4\pi n e^2/m^*$

Generalized Drude: $\Gamma(\omega)$, $m^*(\omega)$

ARPES $\delta E > 0.2$ eV, $\delta k > \pi/4a$

$\delta(dE/dk) = \infty$

$\delta(d^2E/dk^2) = \infty^\infty$

In lieu of conclusions: my bets

- **In 10 years, we will reach T_c = 200 K.**

  This will happen in cuprates.

  Likely, by some sort of nano-scale engineering.

- **In any case, Interface science (of complex oxides but possibly other electronic materials) will advance greatly in the next few years.**

- **The above will NOT be achieved by means of Quantum Computing.**

[Rationale: we already have 50% of RTS, but only 1 ppb of a Quantum Computer.]