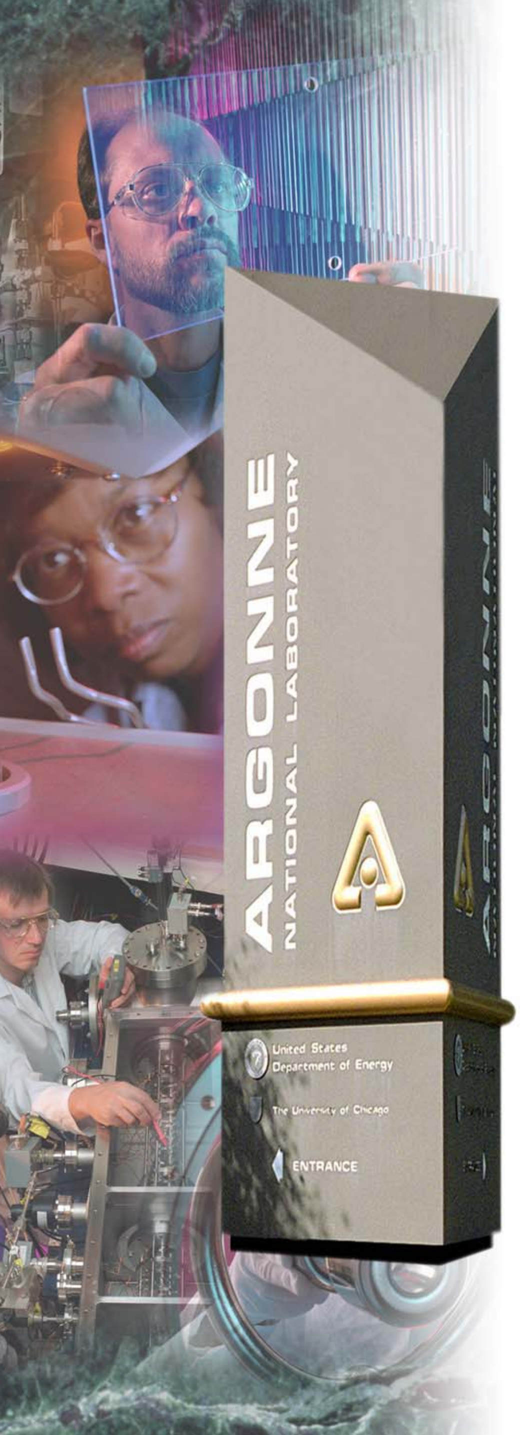

Future Materials Issues for Synchrotron Science

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Office of Science
U.S. Department of Energy

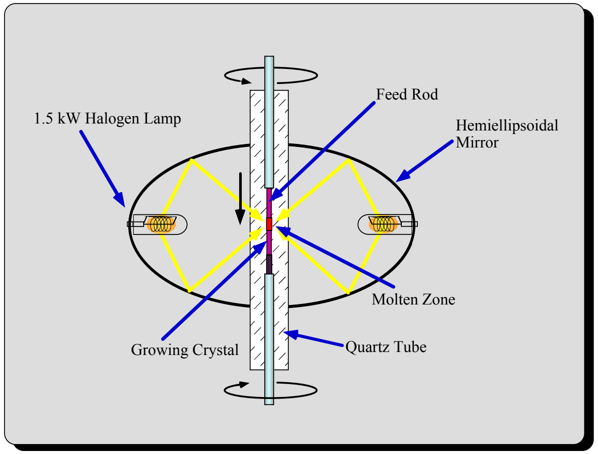
A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago

Goals

Highlight some ways that synchrotron x-rays might help the materials grower

Suggest some possible materials directions that will impact correlated electron studies

Floating-Zone Crystal Growth



QuickTime™ and a YUV420 codec decompressor a

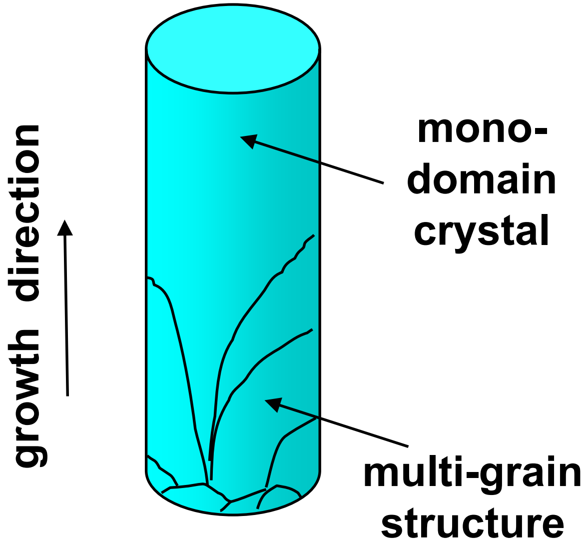
Advantages

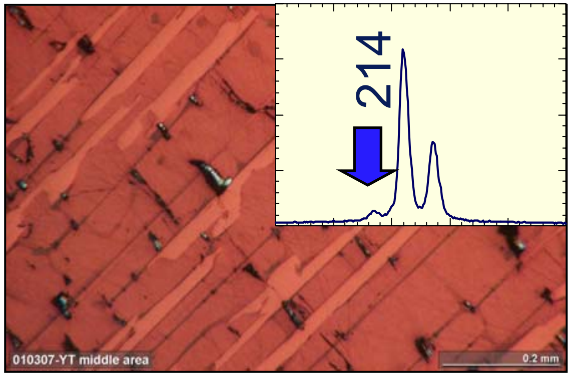
- Containerless growth = reduced contam-ination
- Large (cm^3) crystals can be obtained
- Excellent for high melting point materials (e.g., oxides)
- Huge success list: cuprates, manganites, titanates, vanadates, cobaltites, ruthenates, etc.

How SXR Might Help

- Real time monitoring of crystal growth
- "Phase spread" analysis
- Analysis of small crystallites

Real Time Monitoring of Crystal Growth





Can a FZ furnace be put on a beamline? If so, should it be?

- Image or monitor grain development and growth
- Know immediately if second phases are precipitating
- Real time composition analysis with high spatial resolution

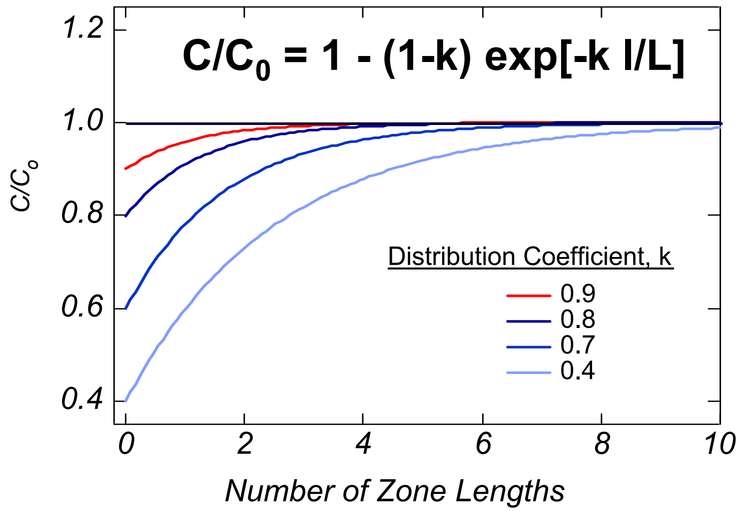
Examples:

-ESRF ID-19 $KAl(SO_4)_2$ xtal topographic monitoring

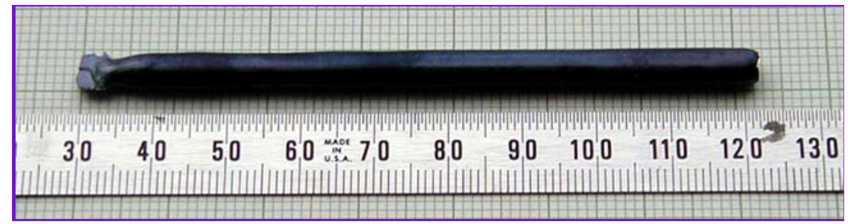
-Lysozyme growth [Acta Cryst. 95, 650 (1999)]

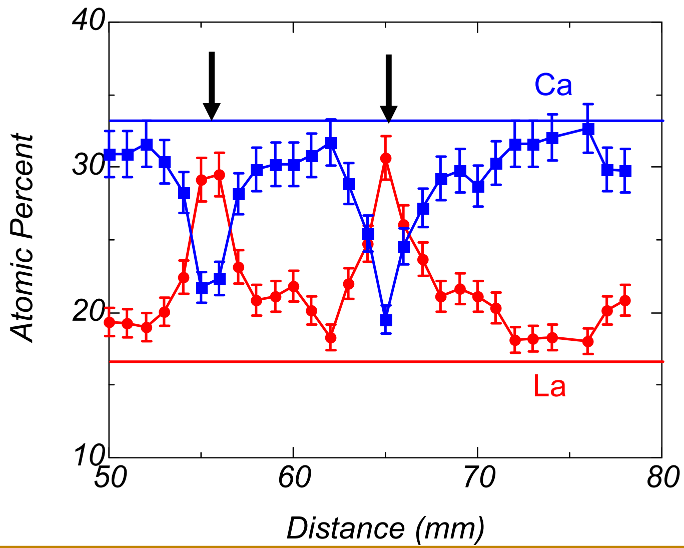
-APS MOCVD ferroelectric films

Exploiting the Zone Distribution



We like to study doped crystals

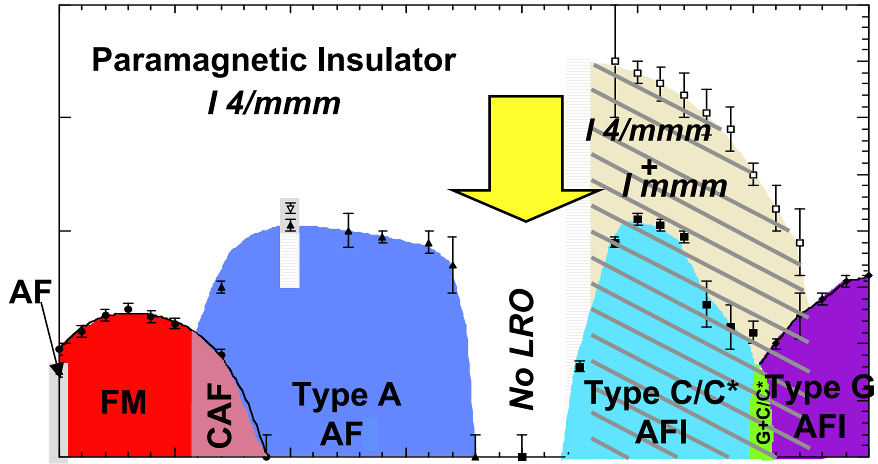




- For homogeneous crystals, we want to $C/C_0 \sim 1$
- Opportunity to study "phase spread" in a single growth
- Need high spatial resolution, means to validate chemistry

Why?

Phase diagram of bilayer manganites, $La_{2-2x}Sr_{1+2x}Mn_2O_7$



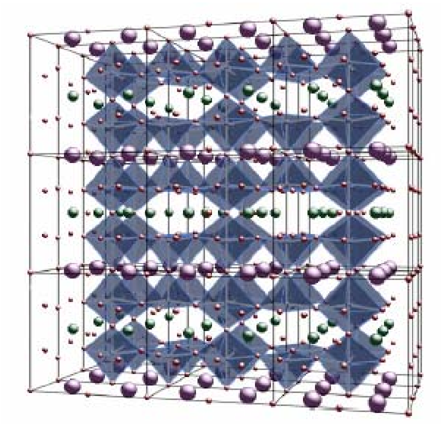
x in SrO•$(La_{1-x}Sr_xMnO_3)_2$

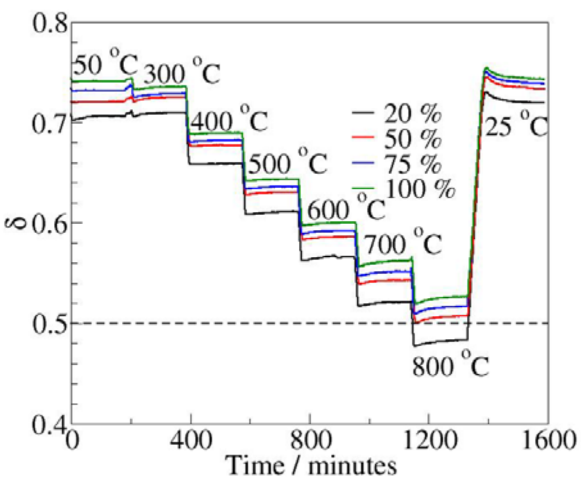
- Large crystals for x < 0.6
- "junky" crystals for x > 0.6
- But this is a really interesting area!

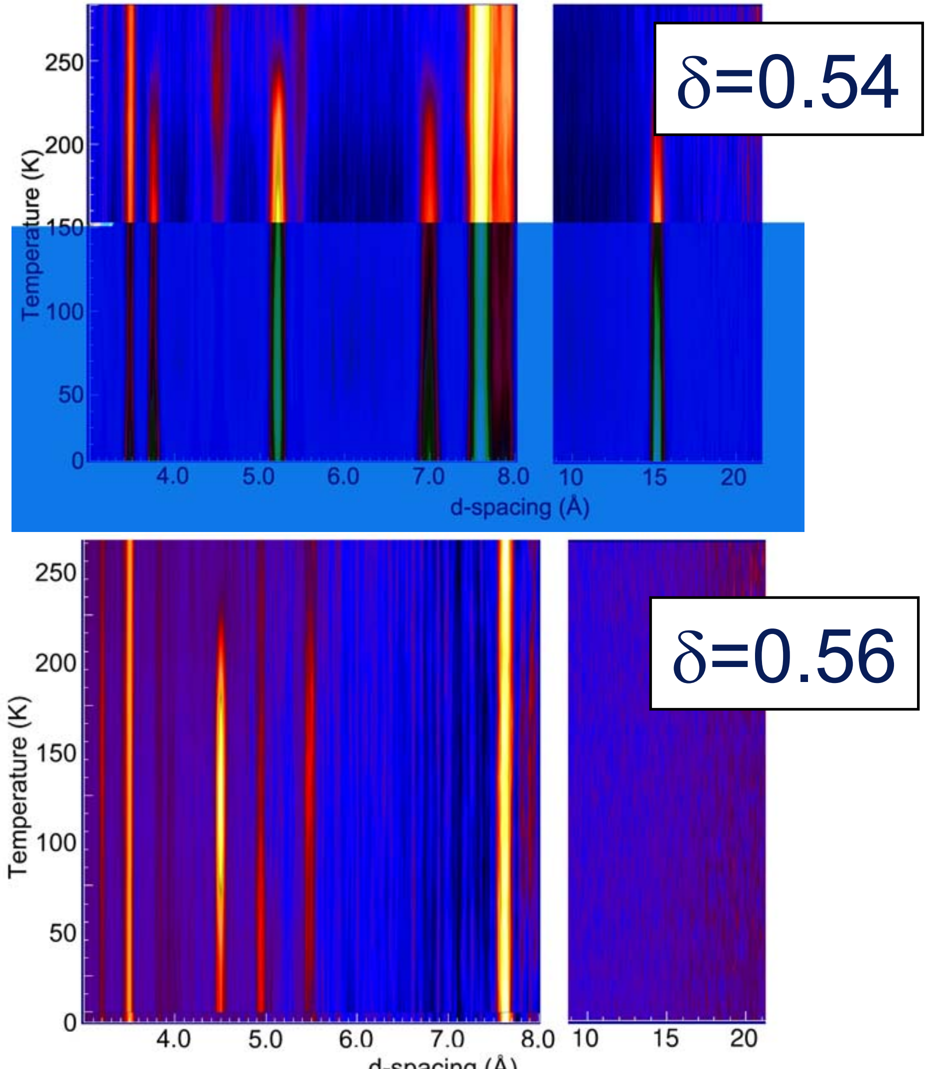
- Magnetic structures
- Diffuse magnetic scattering (element specific)
- Competition with SNS?

Extreme Sensitivity to Oxygen Content, Order

Spin states in Co^{3+} compounds

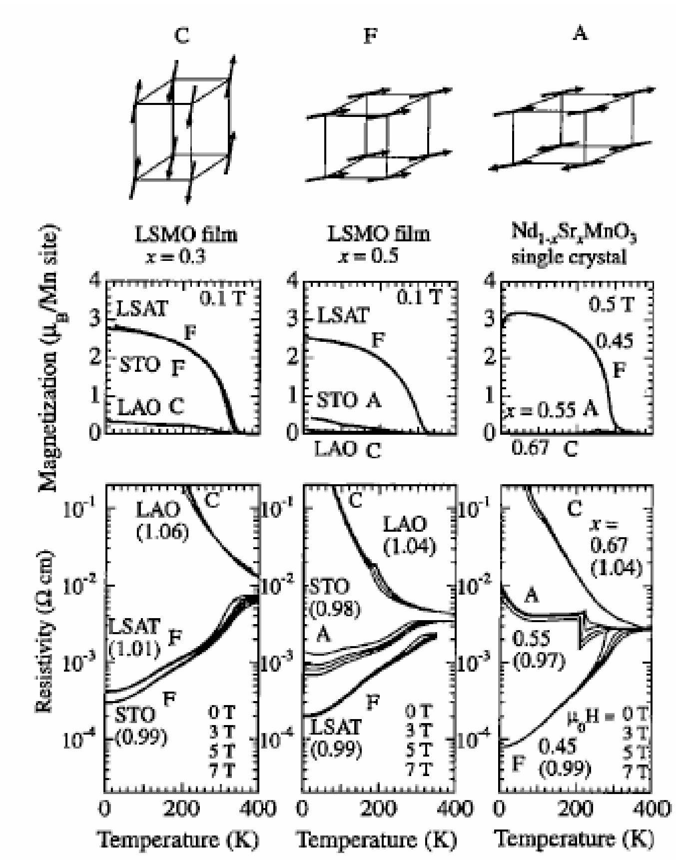


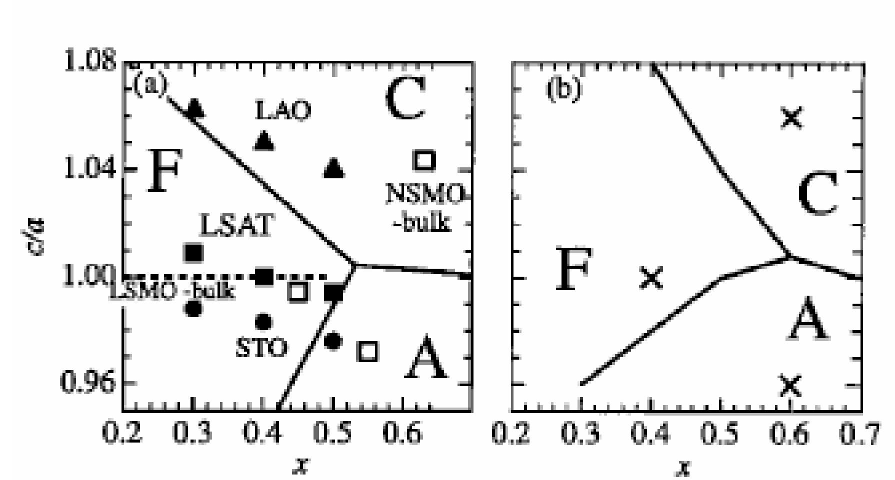




Hybrid Materials: Control of Interface Orbital Polarization

Y. Konishi et al. JPSJ 68, 3790 (1999)



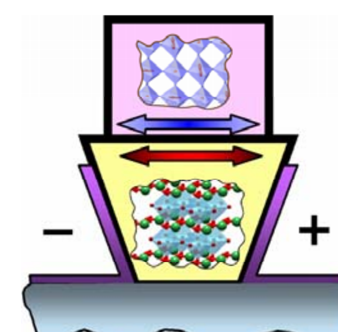


SXR Opportunities:

- Interface magnetism
- Resonant scattering - OO at interfaces?

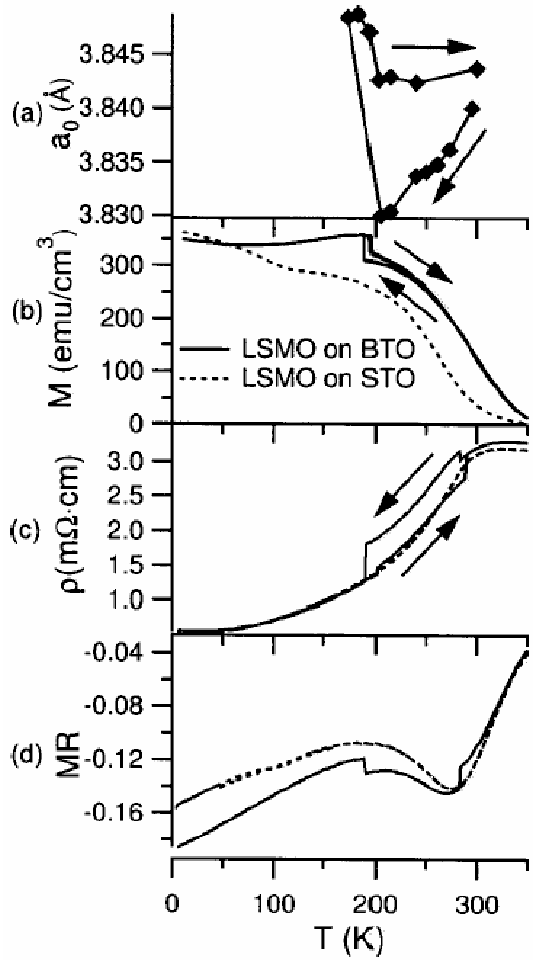
Put complex materials on same footing as metallic multilayers

Active Control:



Prototype CMR-Piezoelectric Hybrid

D. Dale et al. APL 82, 3725 (2003)



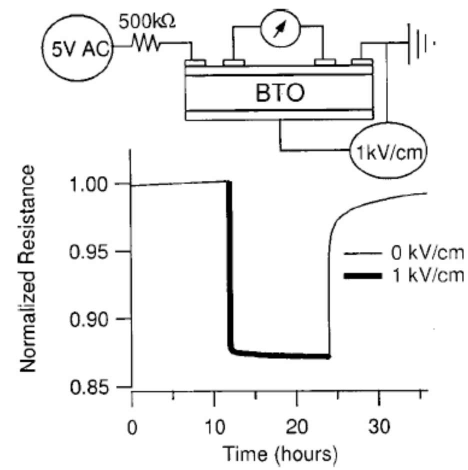


FIG. 2. R vs time, measured along the in-plane ⟨100⟩ of LSMO on BTO. The 1 kV/cm poling field was turned on and off at 12 and 24 h, respectively.

Poling of $BaTiO_3$ (BTO) piezoelectric results in decreased resistivity.
SXR Opportunity: Need to better understand complexity of the interface, since BTO twinned.

Field-Effect Doping: C.Ahn et al. *Nature* Aug 28, 2003

Alternative Materials Opportunities

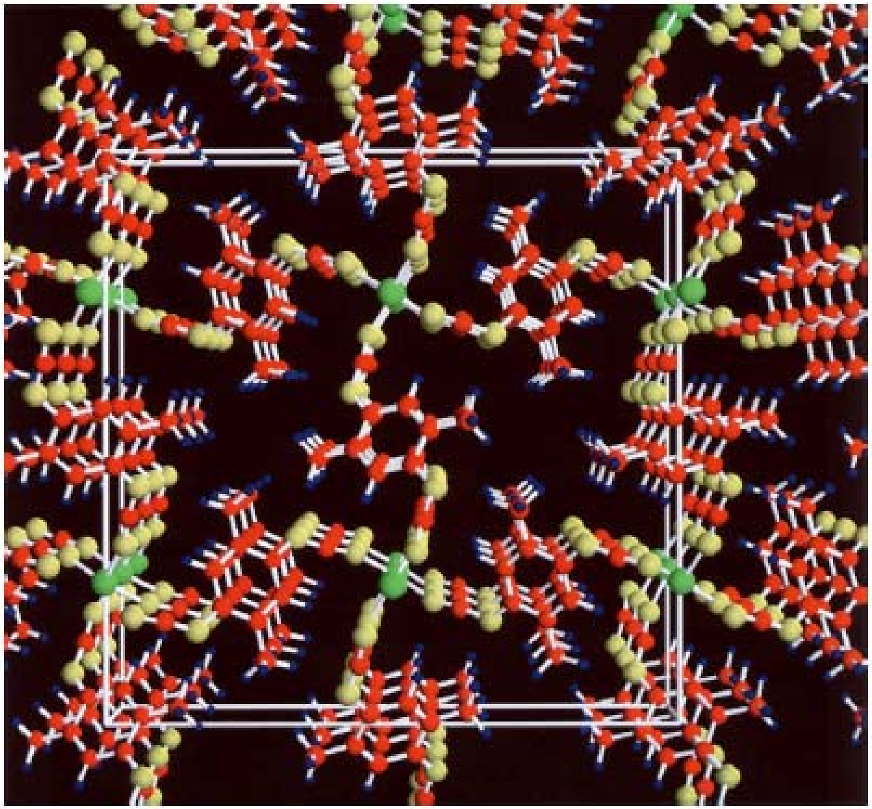
Metal-Insulator Transition
Charge Order
Magnetism
Spin-Peierls Transition
Ferroelectricity
Superconductivity
Magnetoresistance

~~Transition Metal Oxides~~

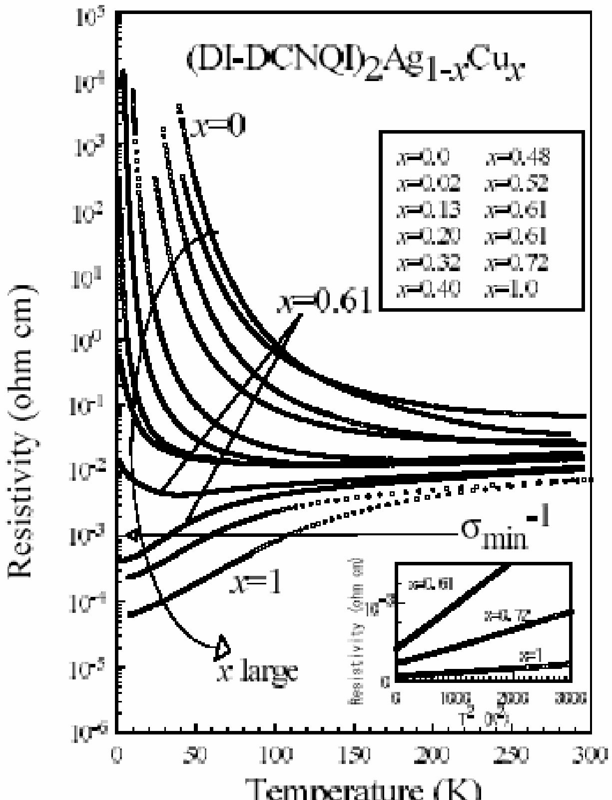
Doping
Structural modifications
Response to fields

Organics!

d-Orbital "doping" in 1-D $(DI\text{-}DCNQI)_2Ag_{1-x}Cu_x$

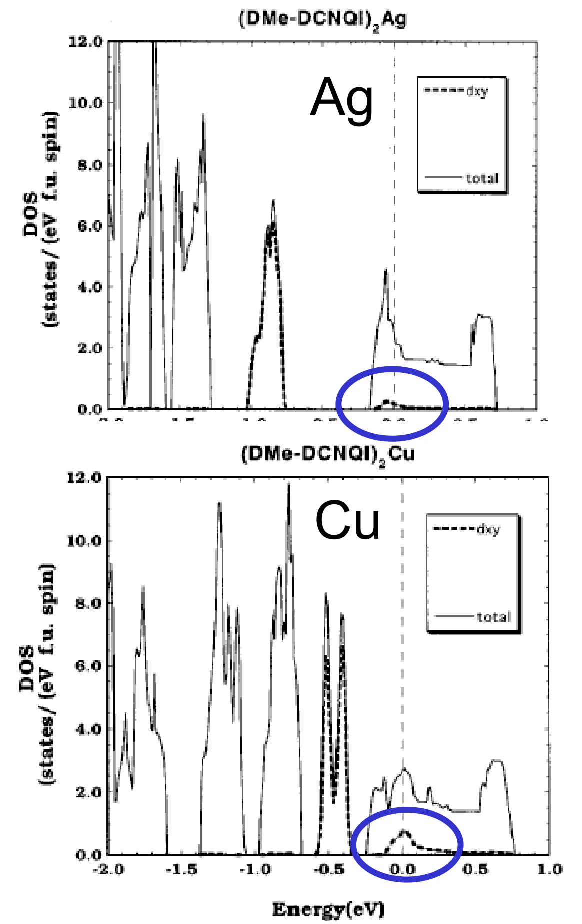


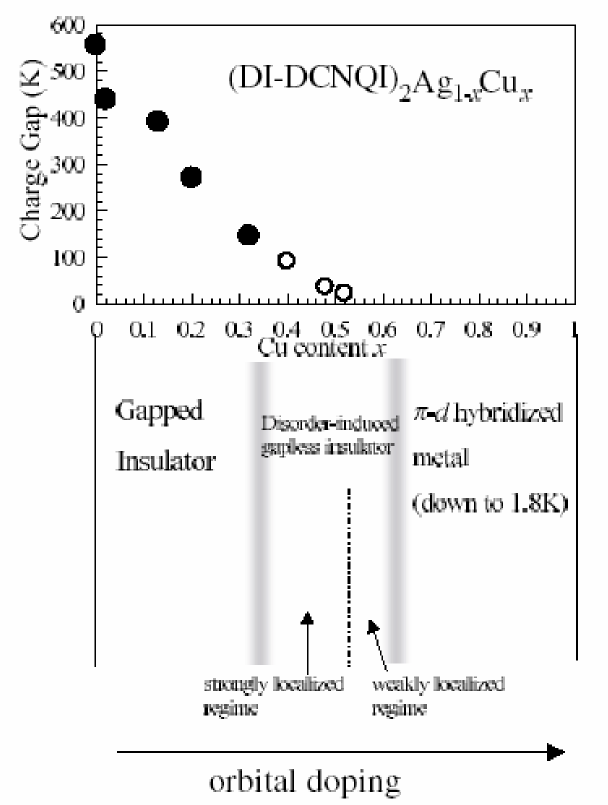
- Molecules stack parallel to c
- Metal links chains in 3-D
- MIT as function of Ag/Cu



d-Orbital "doping" in 1-D (DI-DCNQI)$_2$Ag$_{1-x}$Cu$_x$

T. Itou et al. PRL 889, 246402 (2002)





Cu$^+$ *d* to organic π manifold better overlap than Ag$^+$ = more three-dimensional

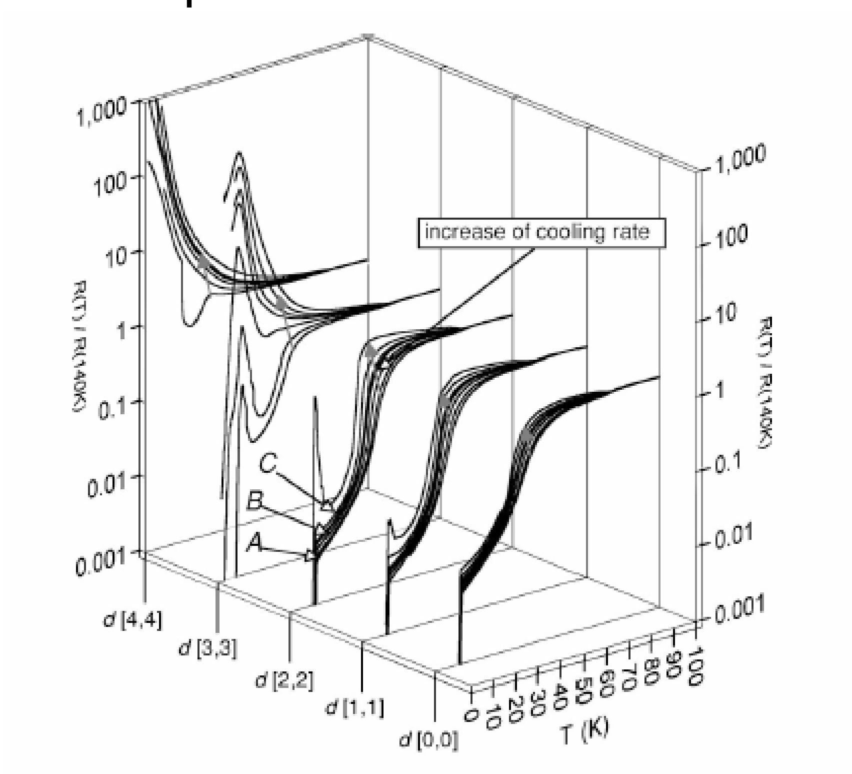
π-d states in Coulomb-gapped insulator

➡ VRH

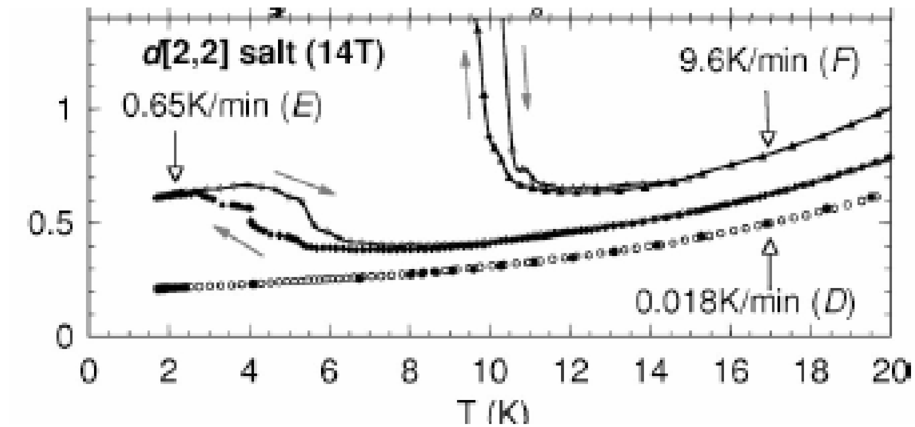
➡ metal

Phase Control by Chemical Modification

Modifying deuterium content in κ-(BEDT-TTF)$_2$[N(CN)$_2$]Br drastically impacts electronic states



H. Tanaguchi et al. PRB 67, 014510 (2003)



Cooling Rate Dependence in High Field

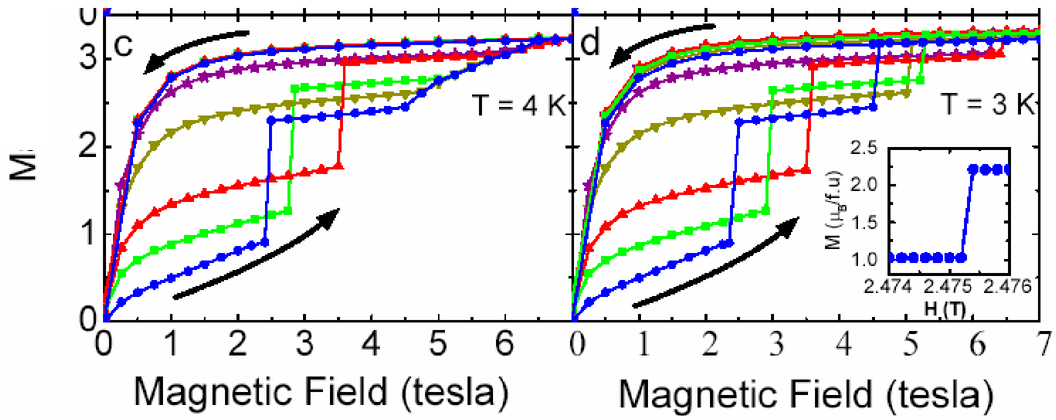
Slow: Superconductor - Metal

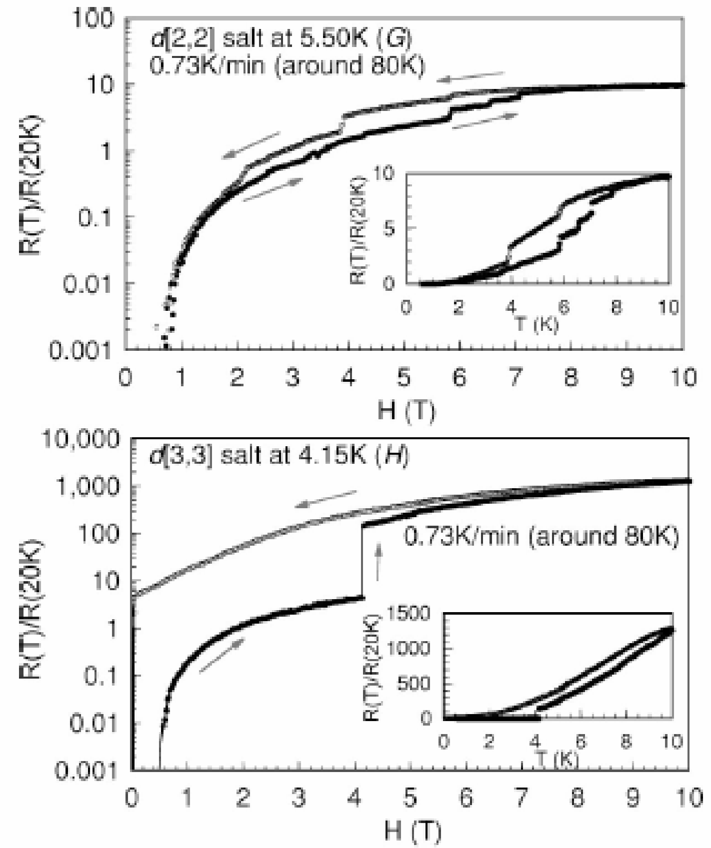
Fast: Superconductor - Insulator

Subtle rearrangement of BEDT-TTF impacts *U/W* near first order SC-AFI boundary

Organics and Manganites: A Parallel?

Mahendiran et al. PRL 89, 286602 (2002)





<u>Ultra-sharp magnetization steps reflect phase segregation</u>

- $Pr_{0.65}(Ca_y,Sr_{1-y})_{0.35}MnO_3$ -- FM/CO-AFI

Organic salt -- AFI/PM (?)

An Opportunity for Synchrotron Science

Experiments Related to Organics/Correlated Electrons
(includes fullerenes)

	1999	2000	2001
ALS	1	1	6
APS	0	3	2
NSLS	?	4	?
SSRL	?	4	2
Synth. Met. (ISI count)	1466	445	1348

Source: Data available at facility websites (Activity Reports, Publication Lists)

Summary

Symbiosis between materials growth and scattering science

- Push envelope in in-situ studies of xtal growth
- Don’t rely on cm^3 crystals
- Bring bulk science to interfaces
- Look beyond traditional “hard” materials --
  Organic chemistry is extremely rich, high level of stoichiometry, structure control