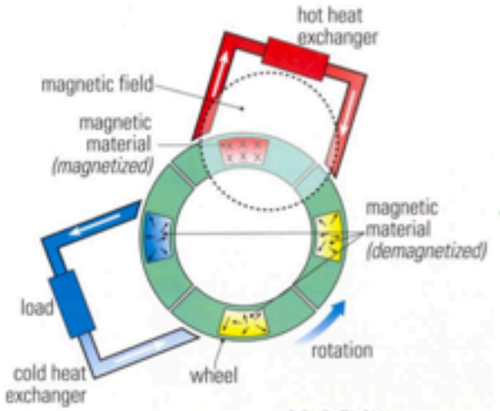
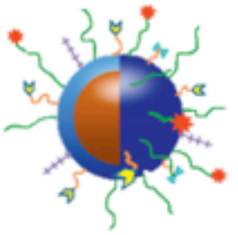
UNIVERSITÄT BIELEFELD
Faculty of Physics

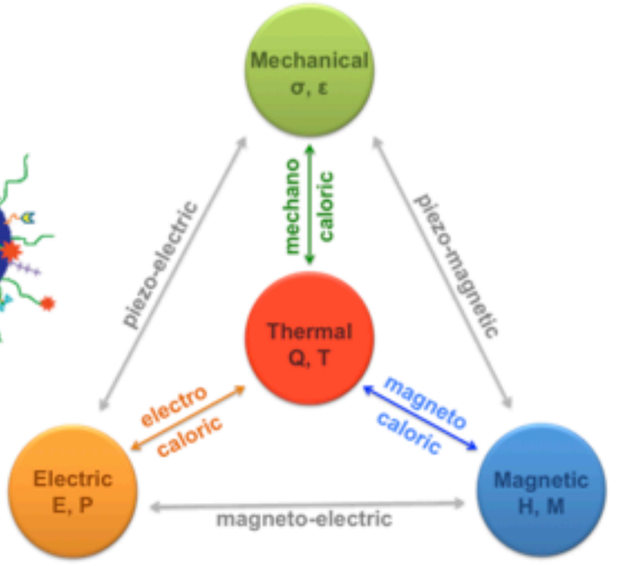
HZB Helmholtz Zentrum Berlin

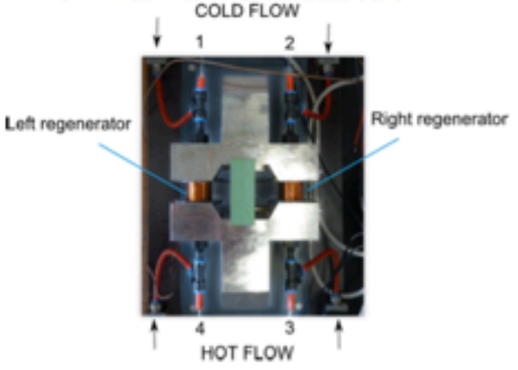
Magnetic Energy Materials:
on phase transitions, caloric effects & more

Luana Caron

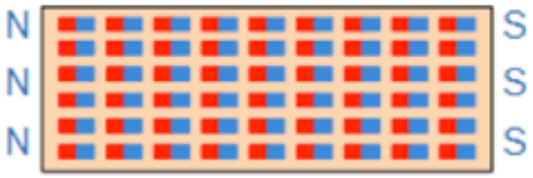


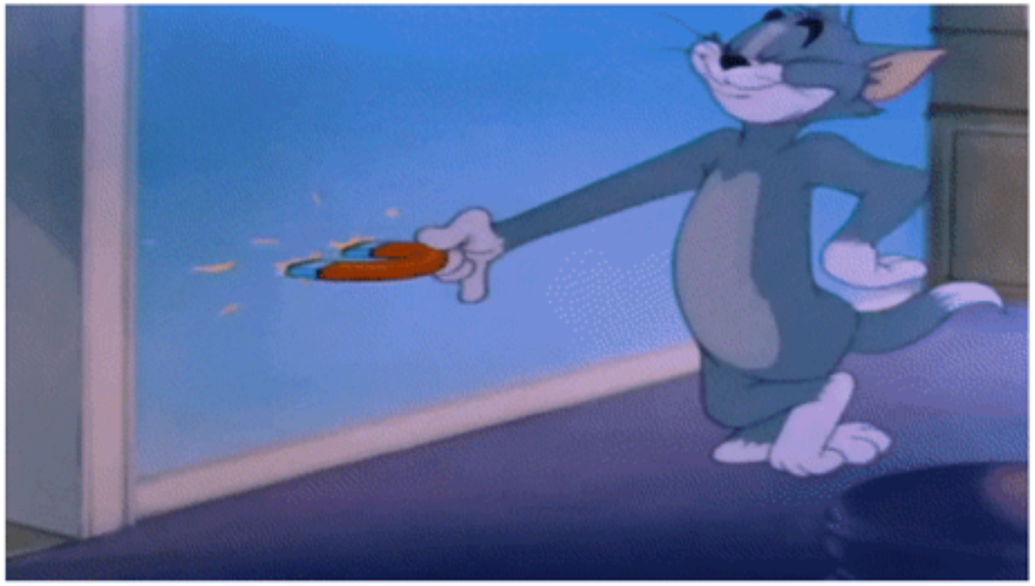


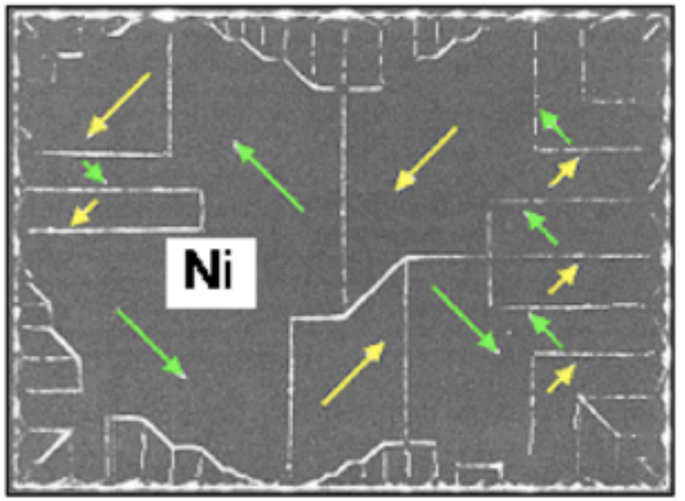


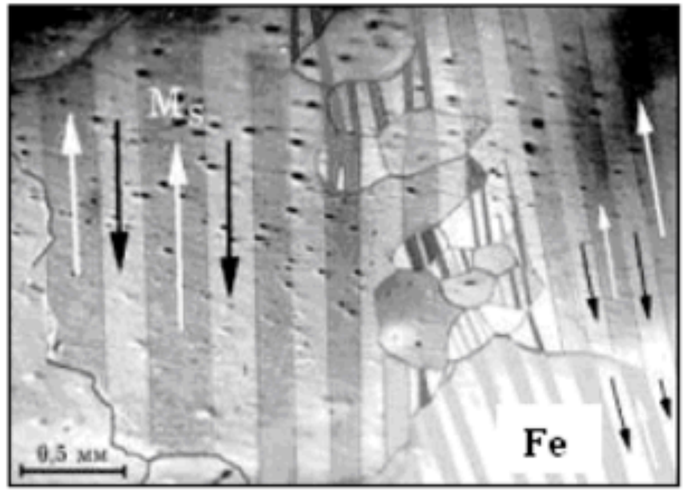


Magnetism









Magnetism

Is literally everywhere…

https://pixfeeds.com/images/4/274772/1200-519925378-compass-on-wood.jpg

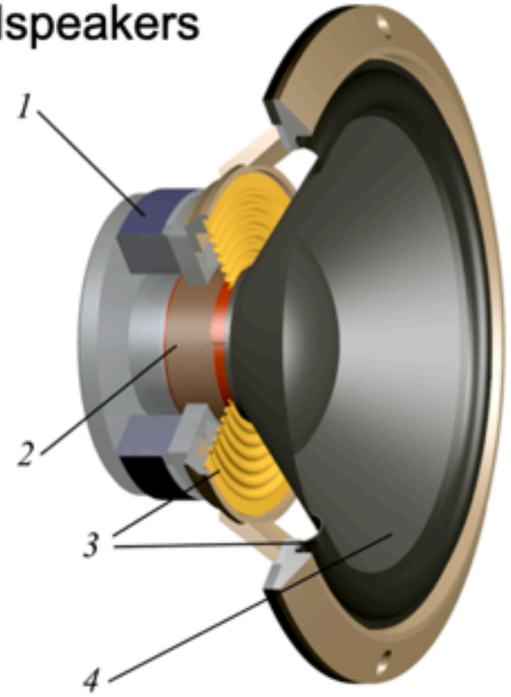
Motors, transformers and generators

https://pixfeeds.com/images/4/274772/1200-168325384-electric-motor.jpg

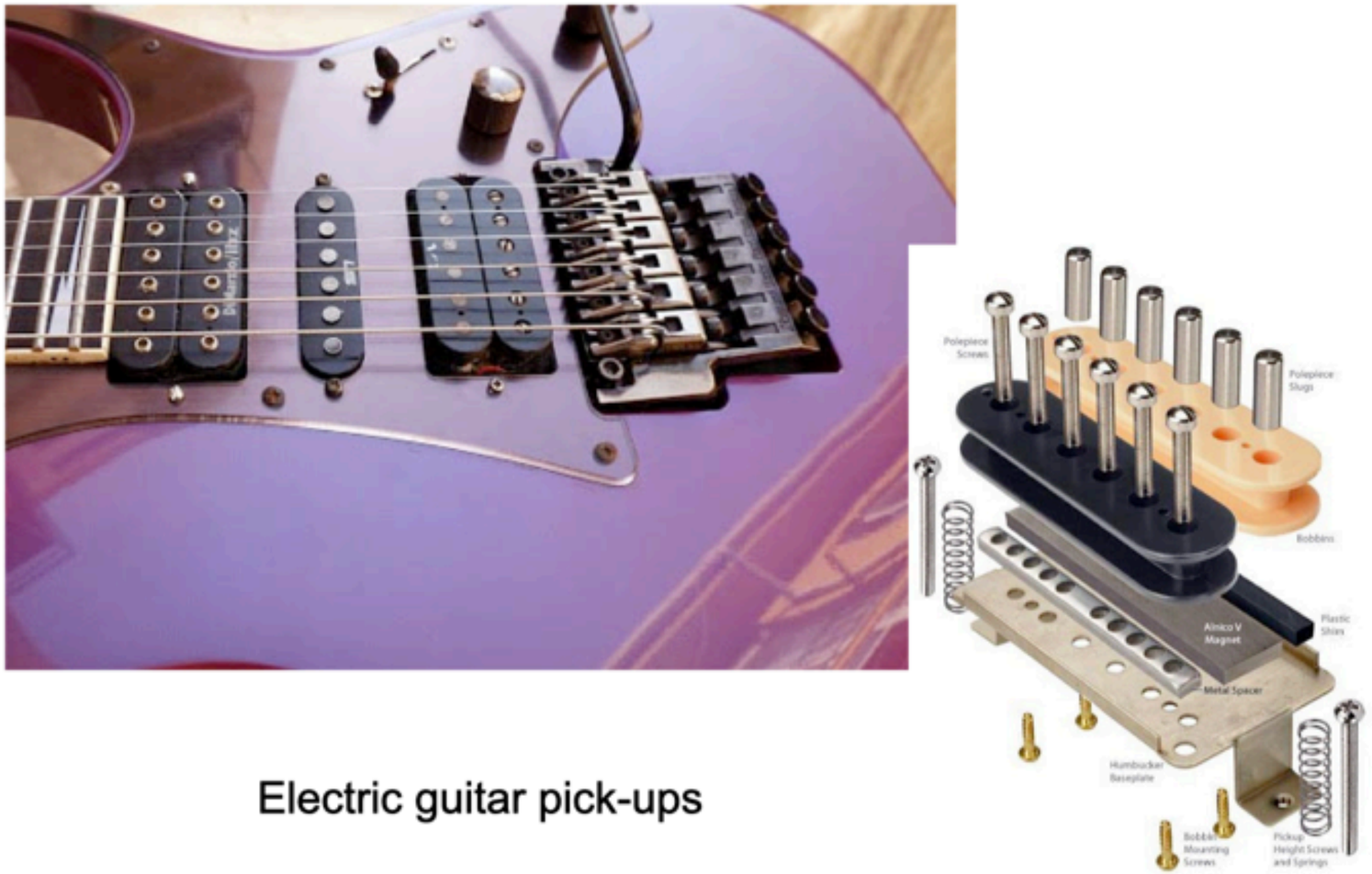
Magnetism

Is literally everywhere…

Loudspeakers



By Svjo - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=30341185



Electric guitar pick-ups

http://darthphineas.com/2019/07/humbucker-modifications/

Magnetism

Is literally everywhere…

Magnetic storage media

https://pixfeeds.com/images/4/274772/1200-453529367-floppy-disks-and-hard-drive.jpg

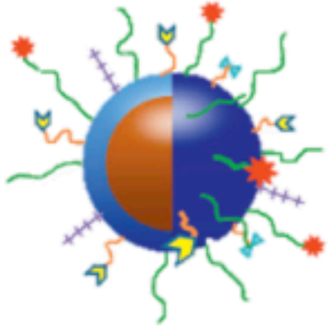
Maglev

https://pixfeeds.com/images/4/274772/1200-93174795-maglev-train.jpg

Magnetism

Is literally everywhere…

Magnetic resonance imaging

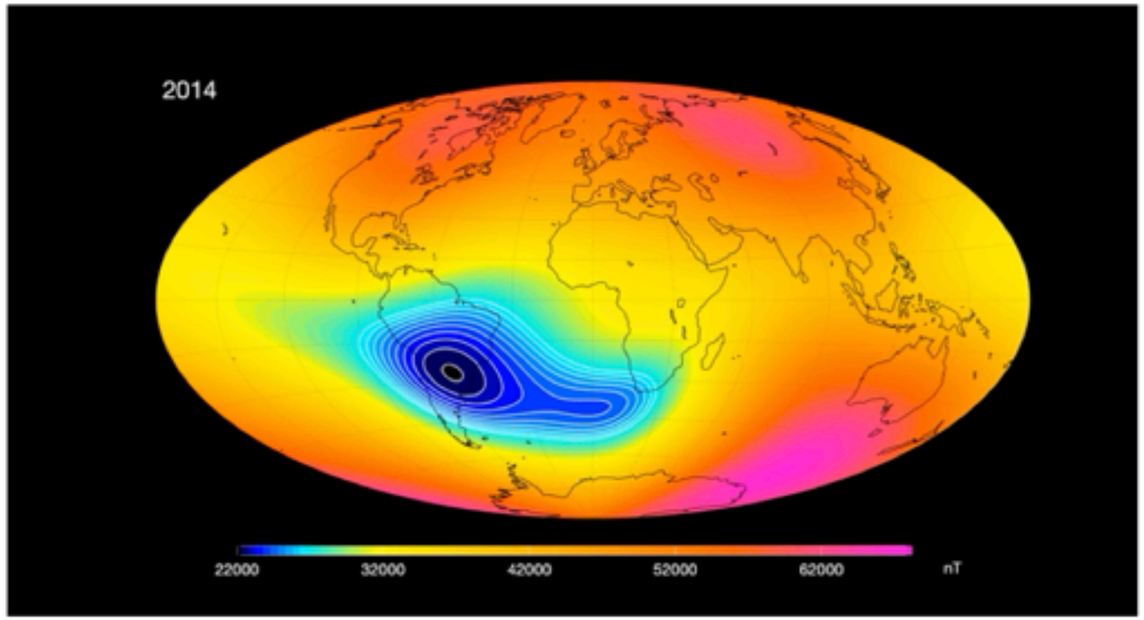


Magnetic nanoparticles

https://pixfeeds.com/images/4/274772/1200-503664242-patient-in-scanner.jpg

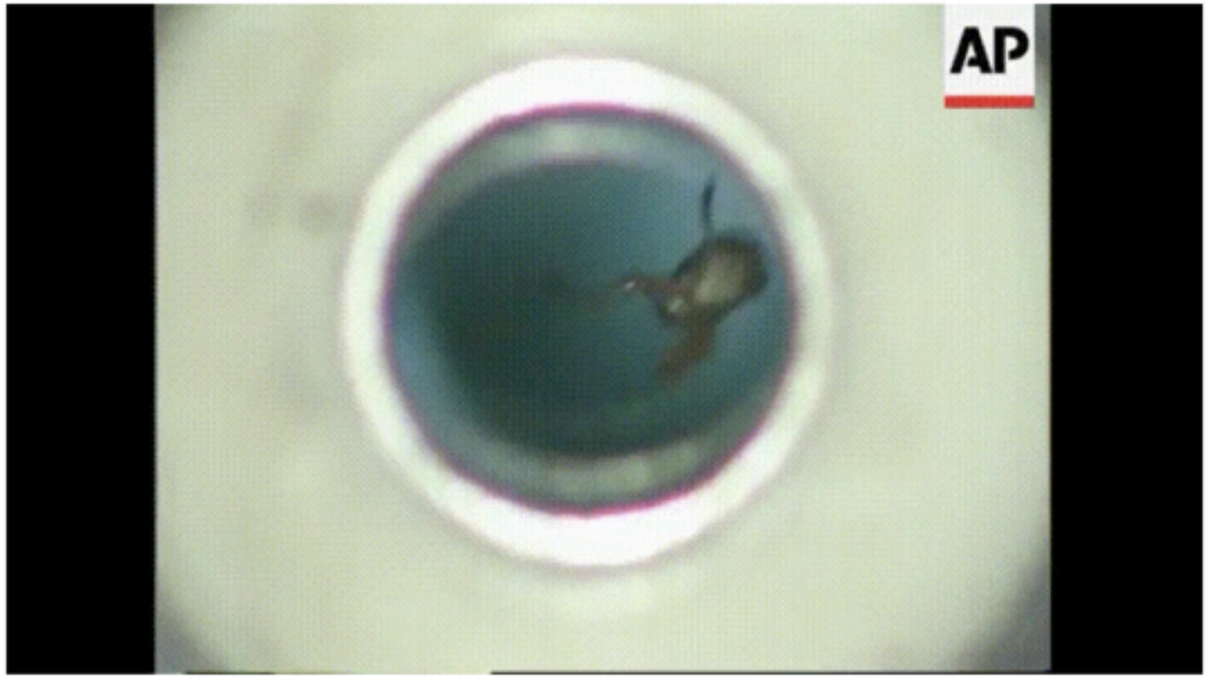
Magnetism

And everything is actually magnetic…



https://www.youtube.com/embed/YohXS_nka-U

diamagnetic



http://www.aparchive.com/metadata/youtube/f760c710bc6ebc4556bfd7fb75d70404#

Andre Geim - 2010 Ignobel

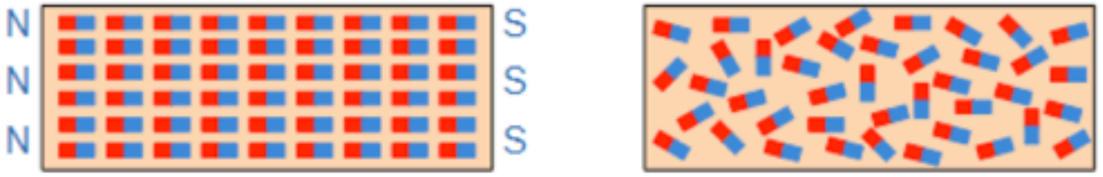
Magnetic order

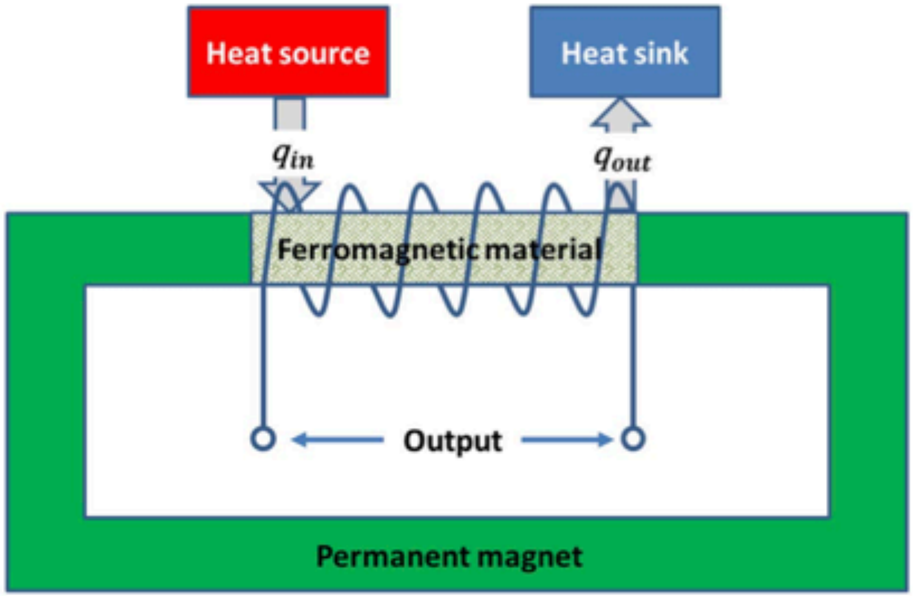
Magnetic order X Temperature

All magnetically *ordered* materials will have a transition to a magnetic *disordered* phase.

Magnetic phase transitions

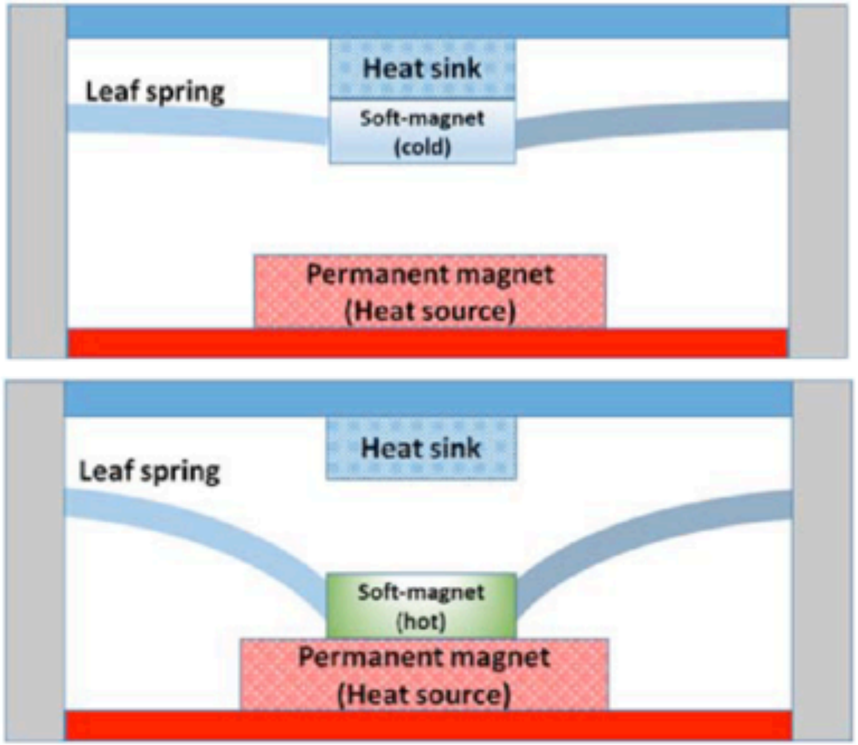
Magnetic order X Temperature





Thermomagnetic generator

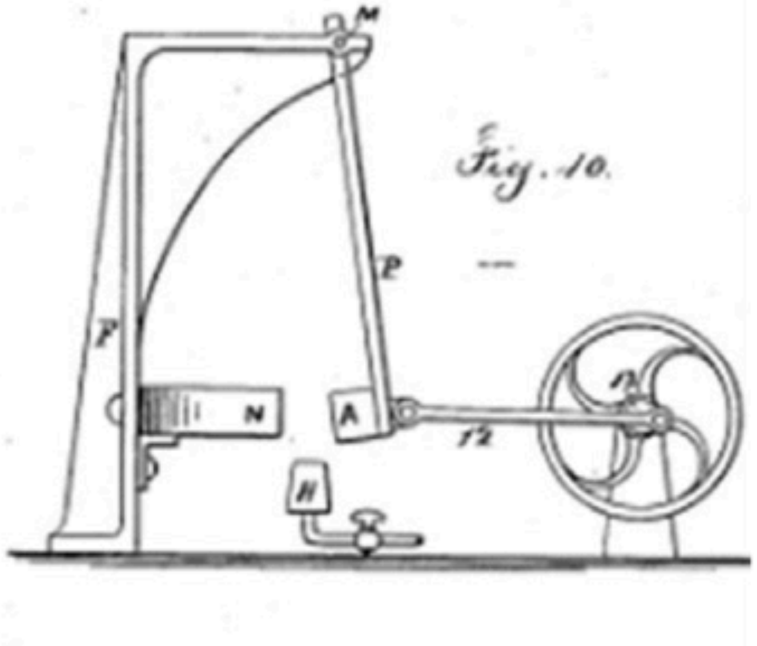
Thermomagnetic actuator

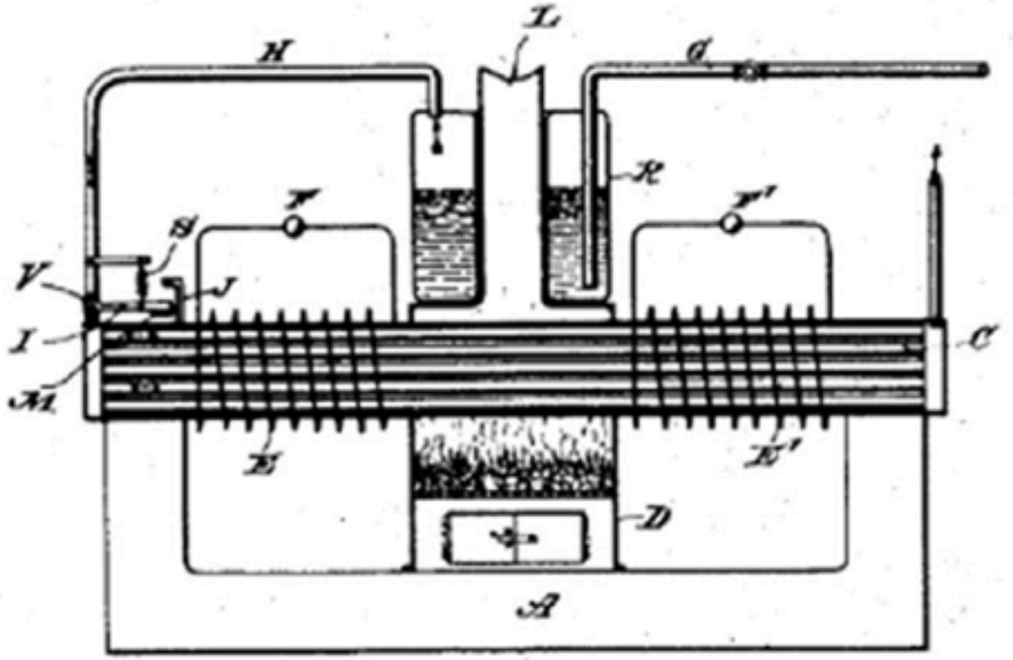


Kishore et al. Materials 2018, 11(8), 1433

Magnetic phase transitions

The thermomagnetic generator is not a new idea:

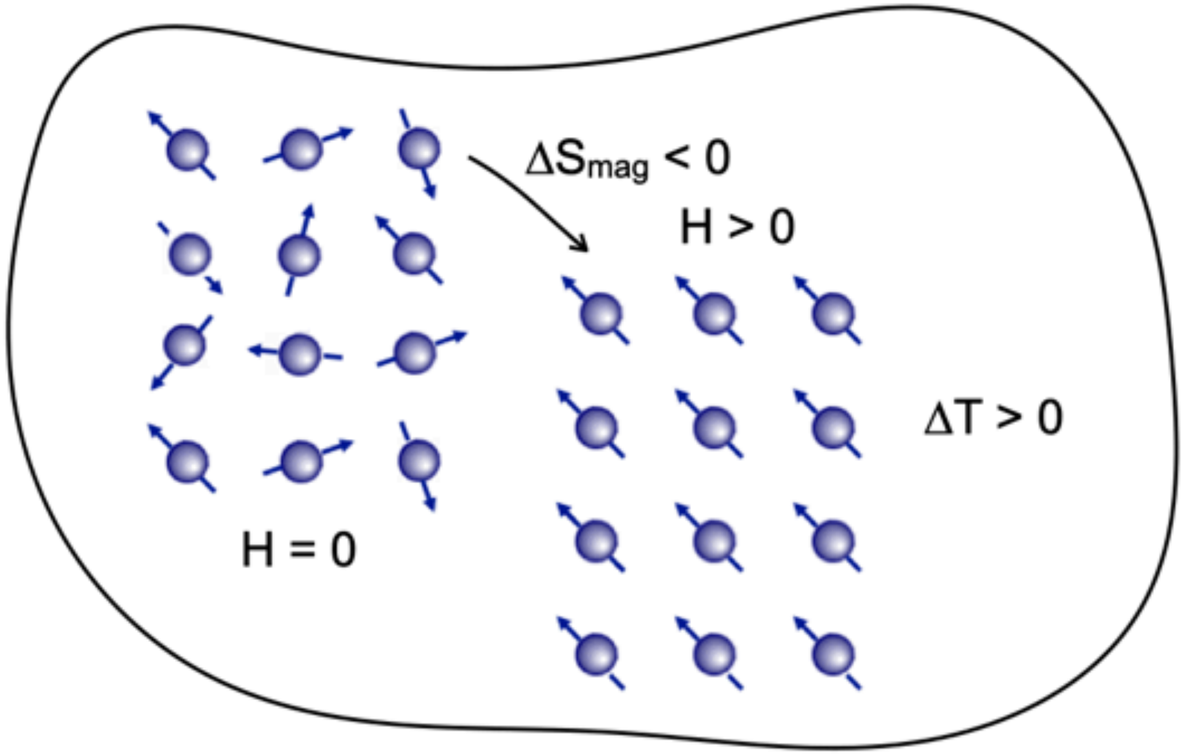




Tesla 1890

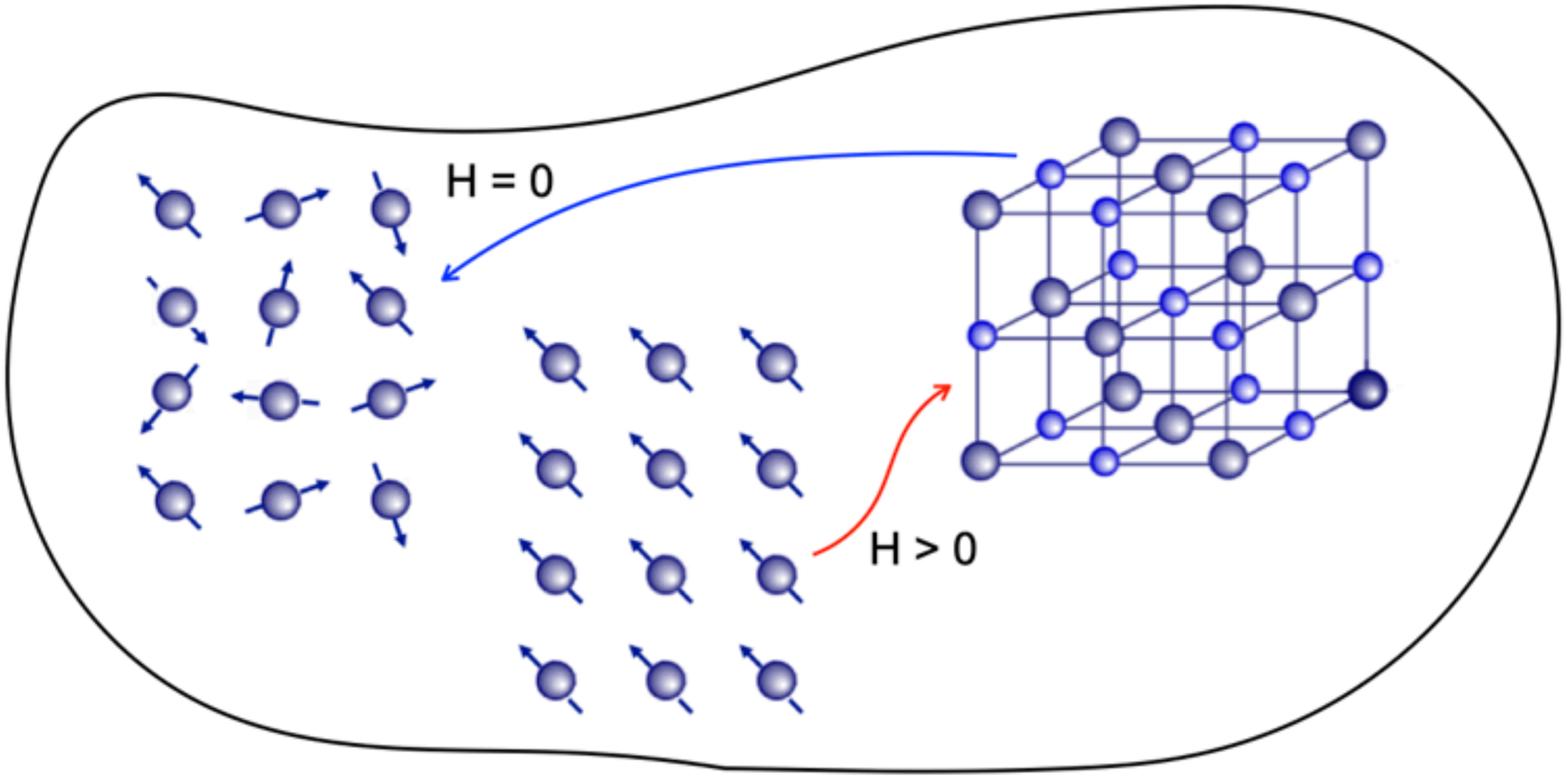
Magnetocaloric effect

Is the change in temperature observed when a magnetic material is placed on magnetic field.



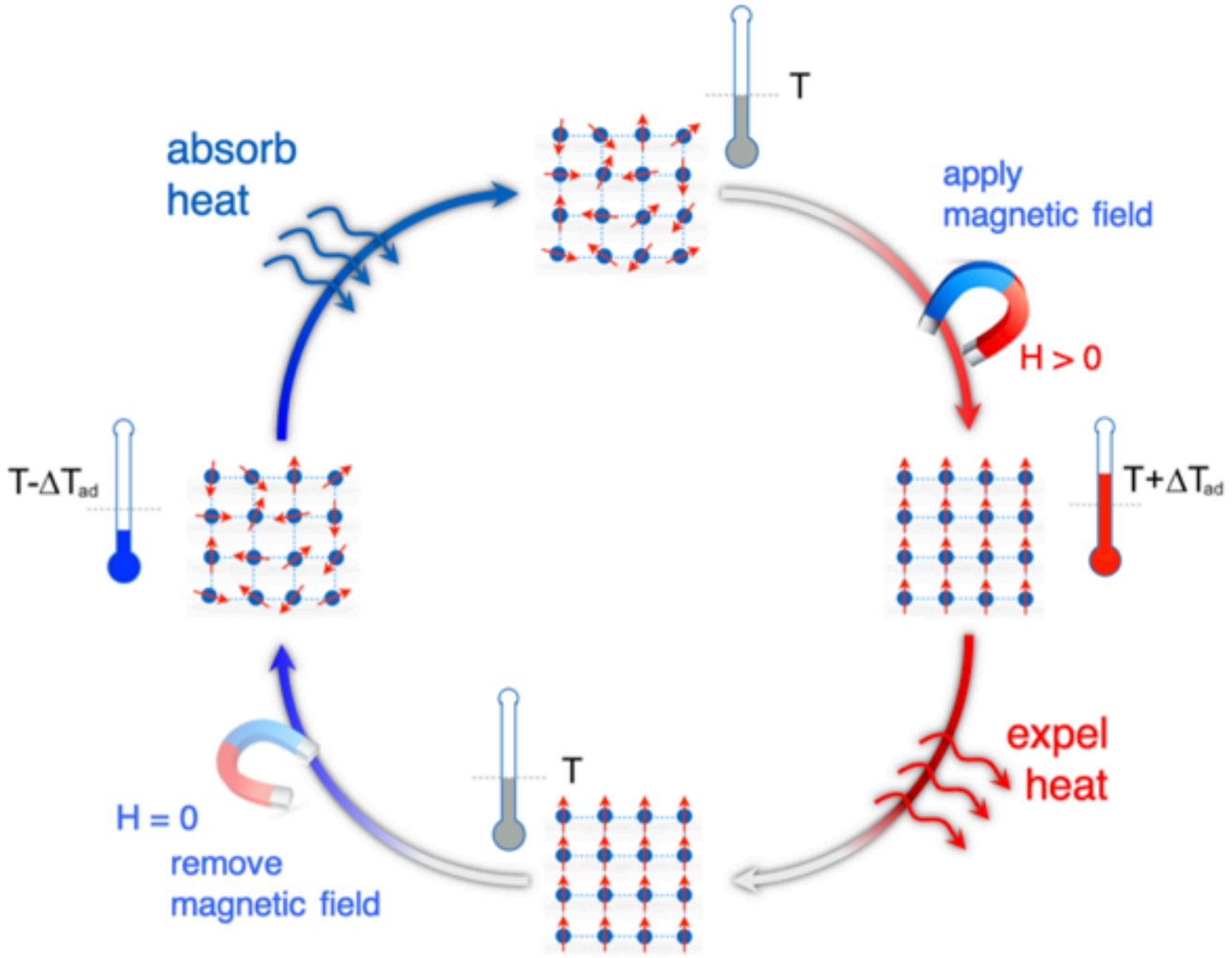
Magnetocaloric effect

Is the change in temperature observed when a magnetic material is placed on magnetic field.



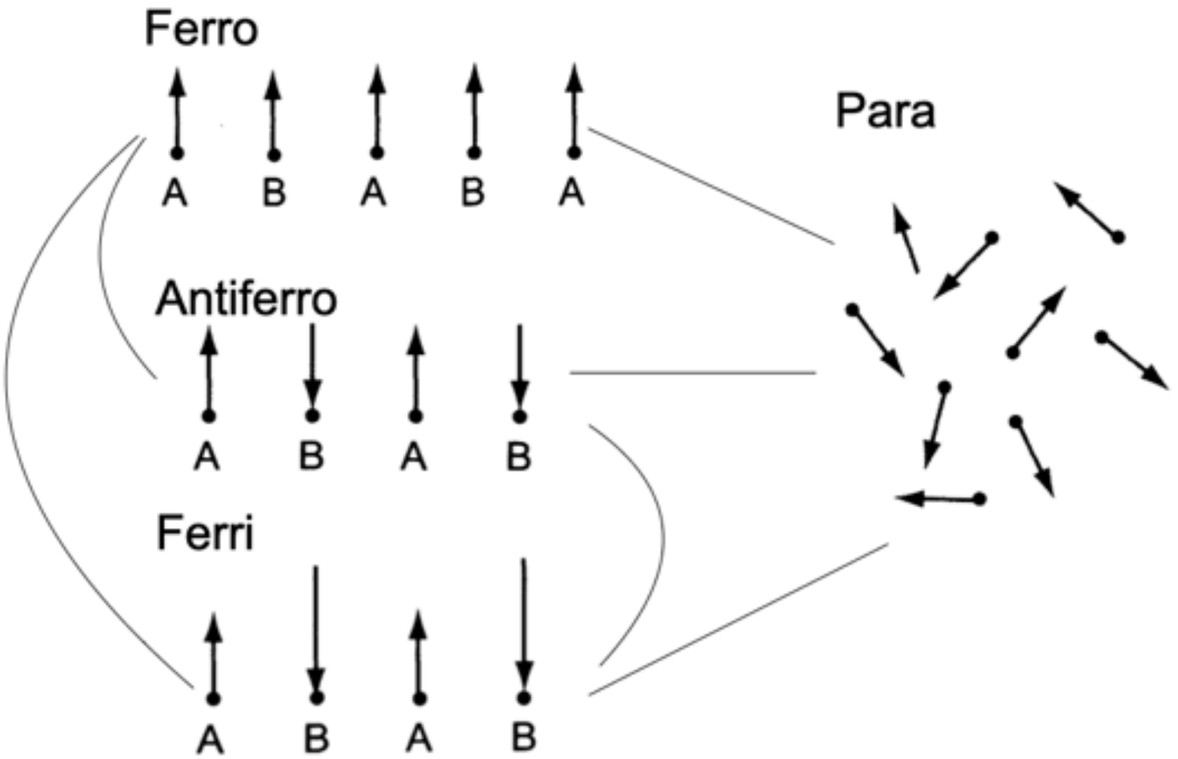
The effect will be larger around phase transitions.

Magnetocaloric effect

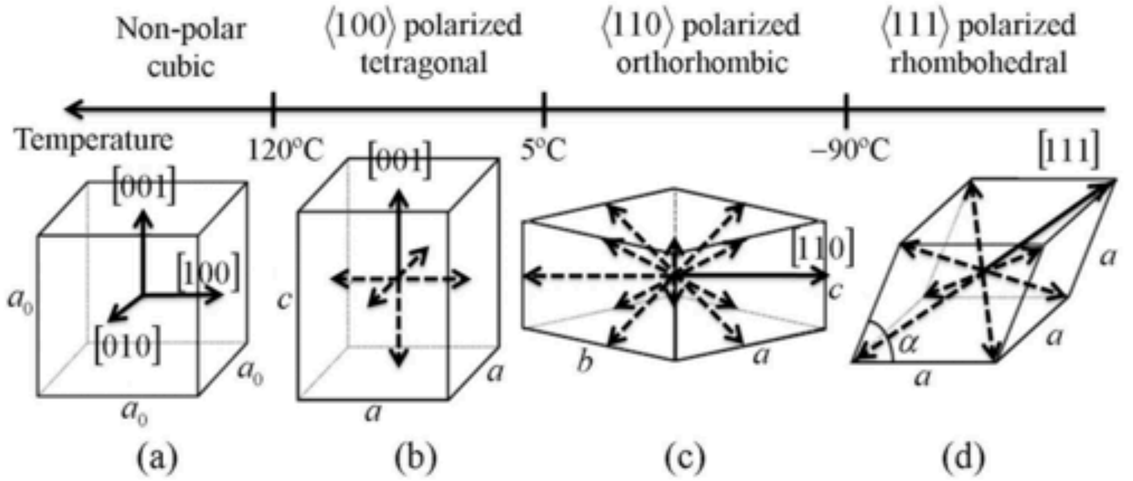


Phase transitions

My aim is to understand phase transitions so that we can design better materials for applications.



Because atoms are part of a crystal structure that will also change



http://dx.doi.org/10.3390/ma4020417

Making samples

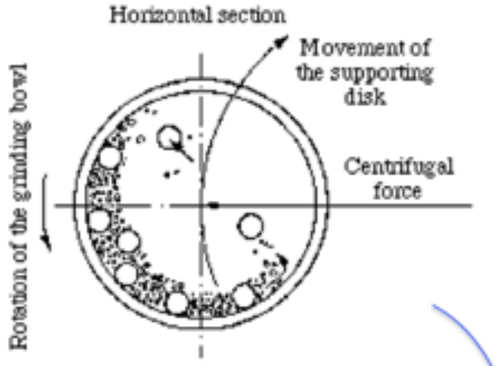
P

+

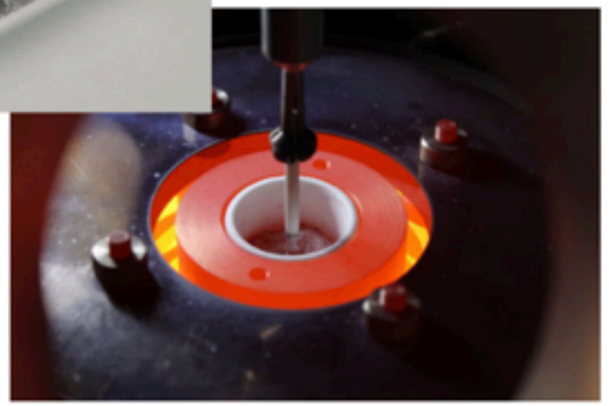
Fe

arc melting

ball milling

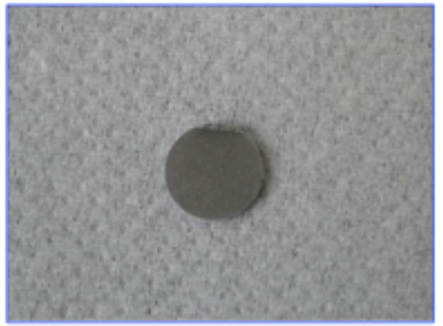


quartz



resistive furnace

sample



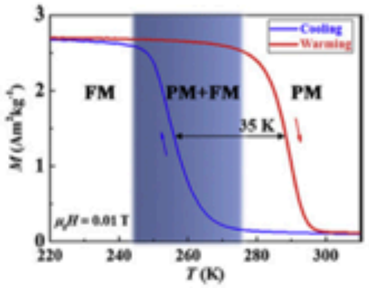
UNIVERSITÄT BIELEFELD
Faculty of Physics

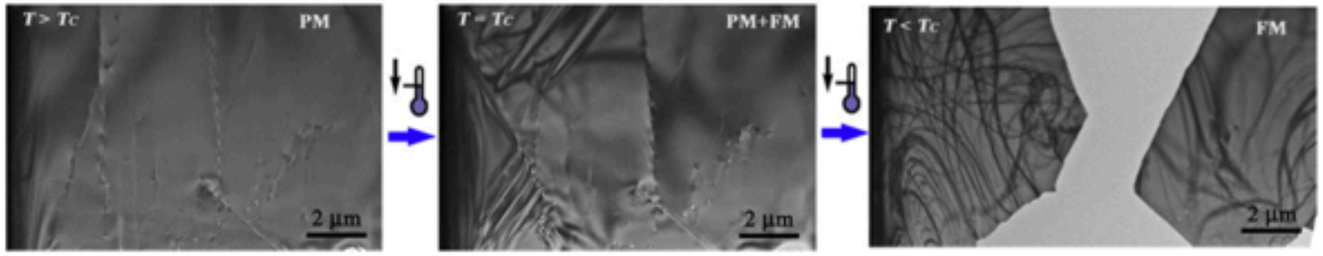
HZB Helmholtz Zentrum Berlin

Making samples

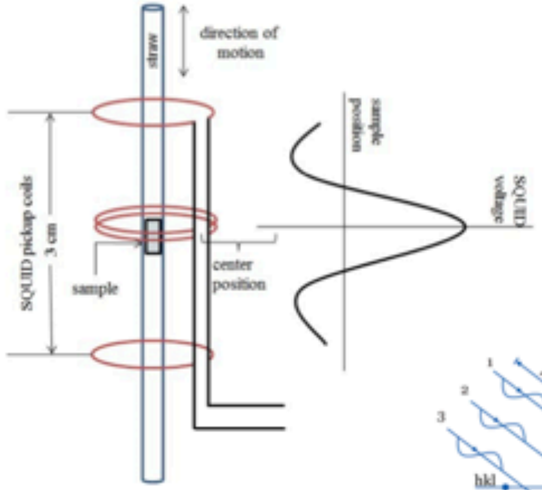
sample

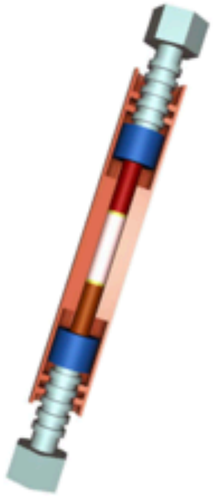
electron microscopy

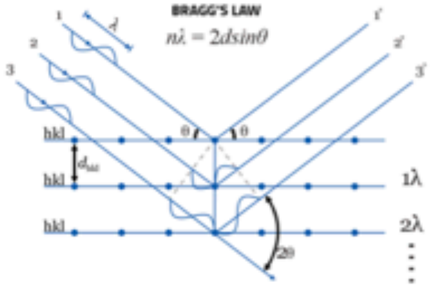




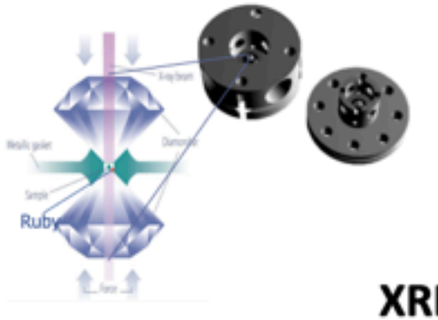
SQUID



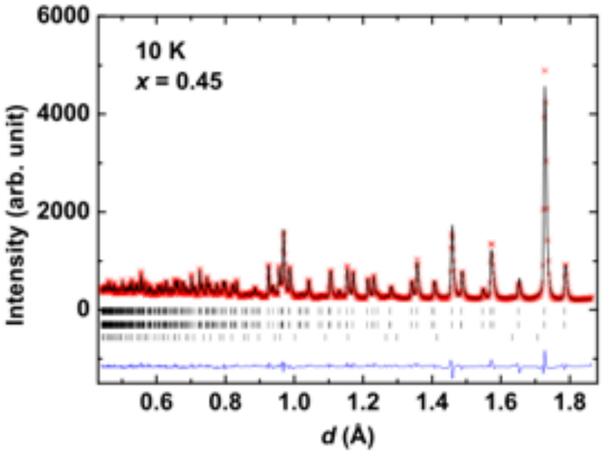


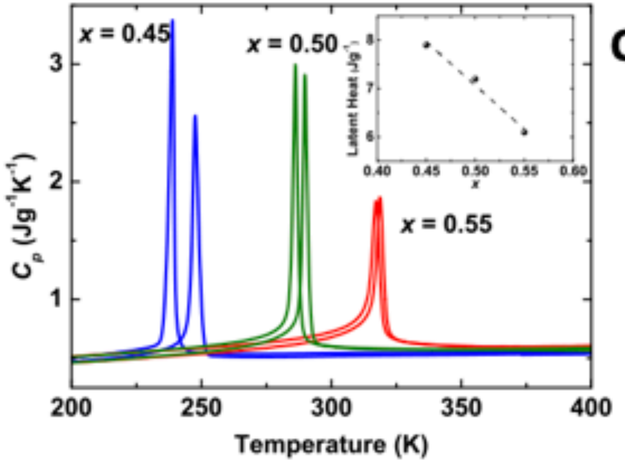


Pressure



XRD





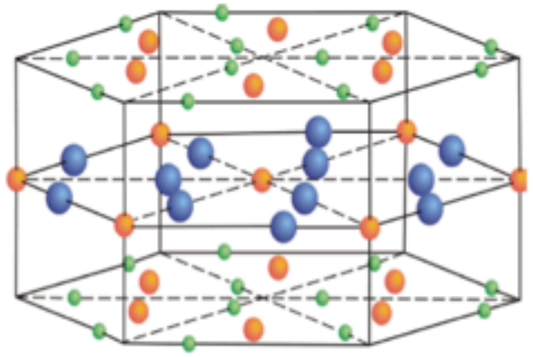
C_p

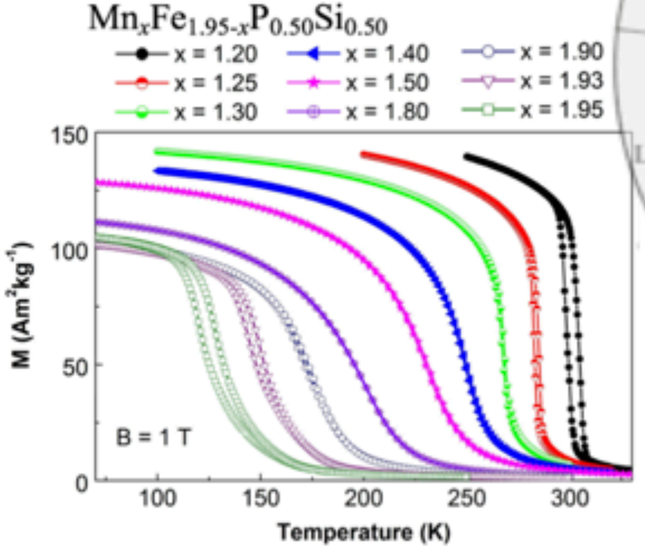
- MOKE
- Mössbauer
- spectroscopy …
- neutron diffraction
- μSR spectroscopy

UNIVERSITÄT BIELEFELD
Faculty of Physics

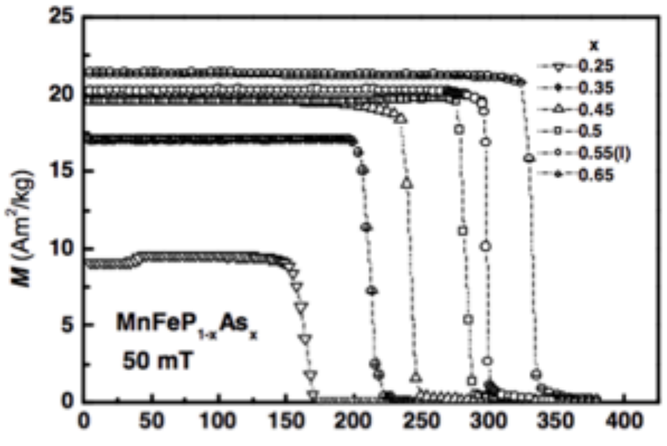
HZB Helmholtz Zentrum Berlin

Tailoring phase transitions

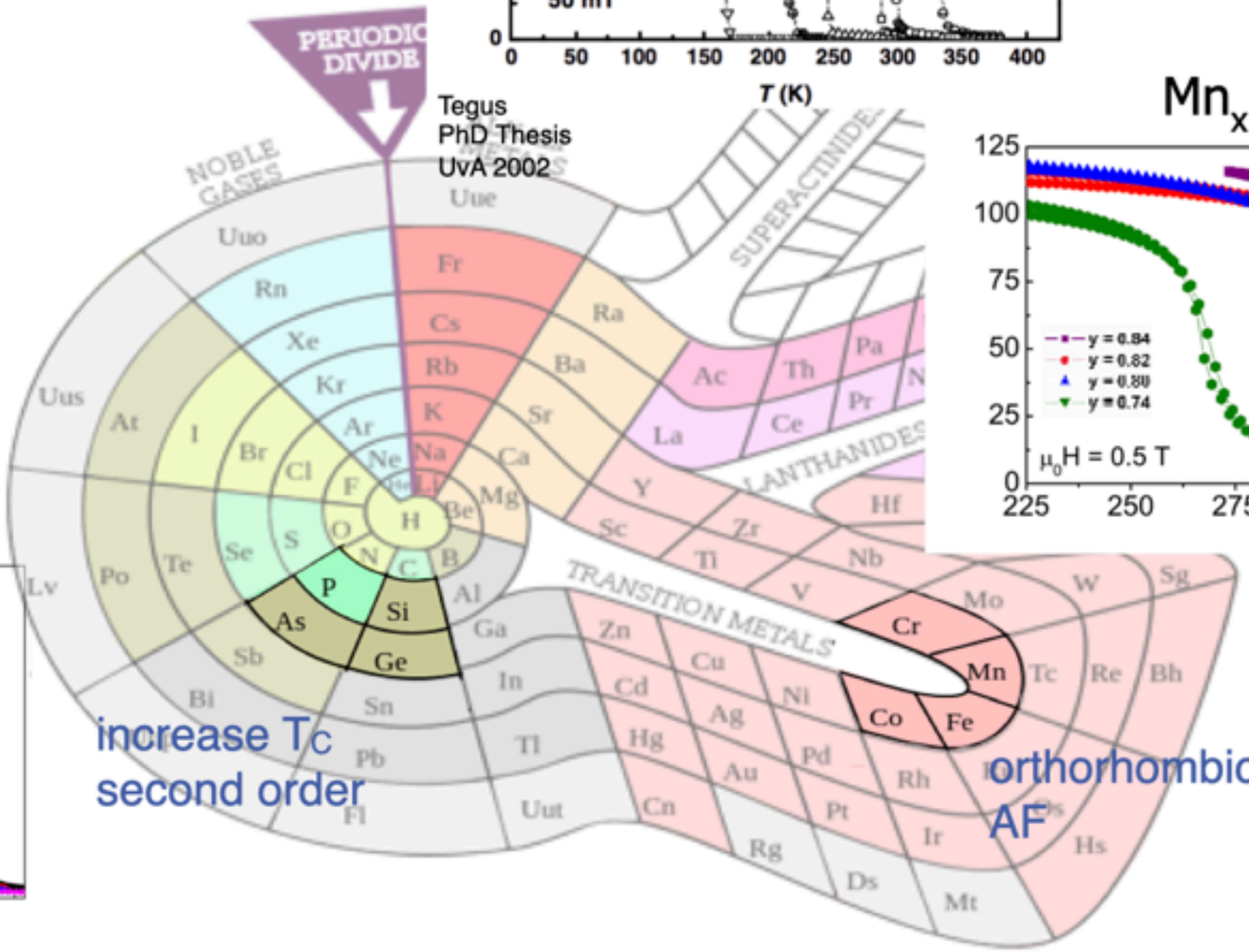




APPLIED PHYSICS LETTERS **99**, 092511 (2011)

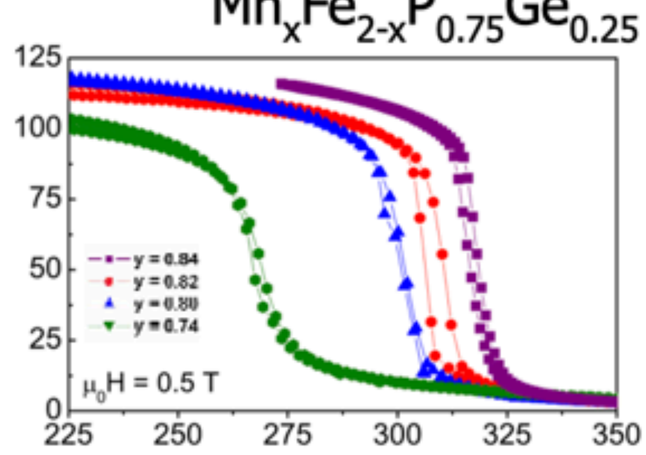


Tegus
PhD Thesis
UvA 2002



increase T_C
second order

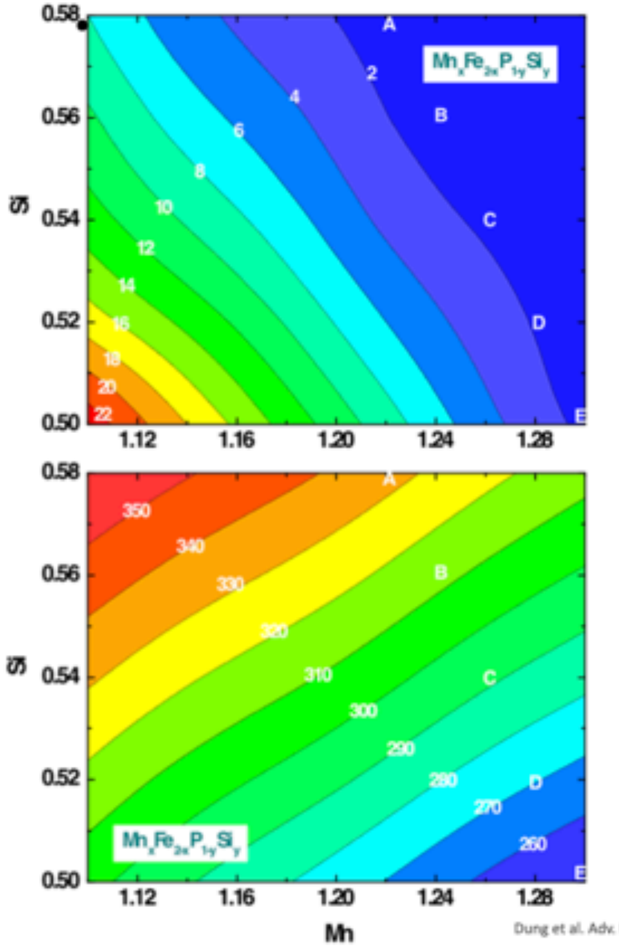
orthorhombic
AF

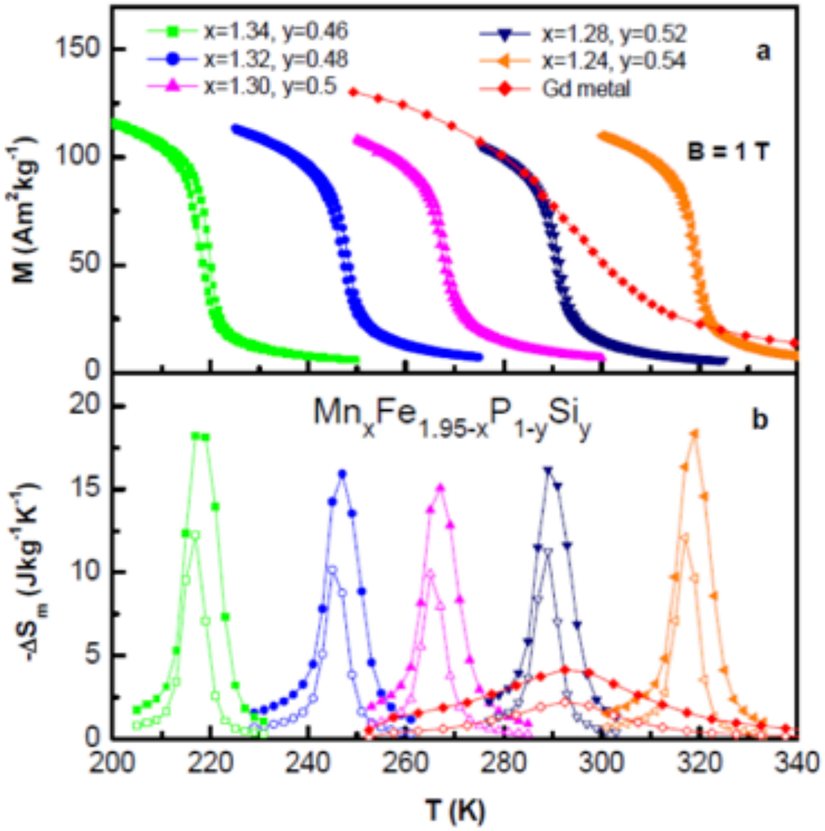


N.T. Trung
PhD Thesis
TUDelft 2010

Tailoring phase transitions

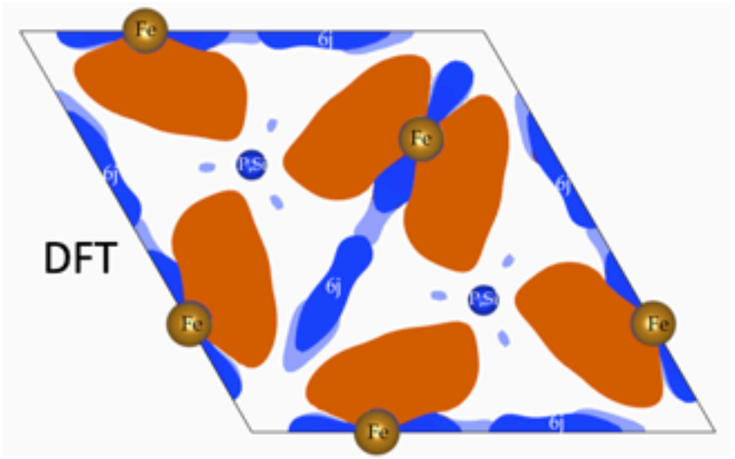
- tailor T_C, ΔS & hysteresis

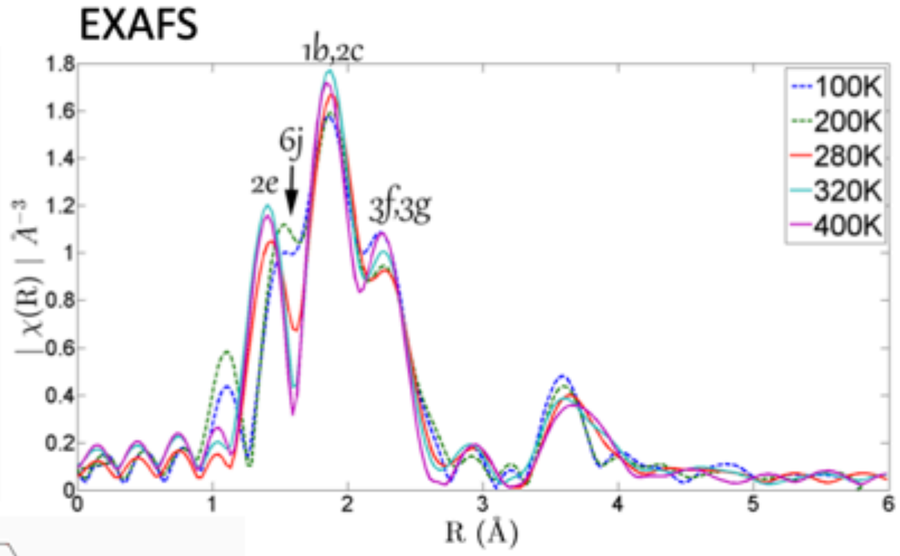


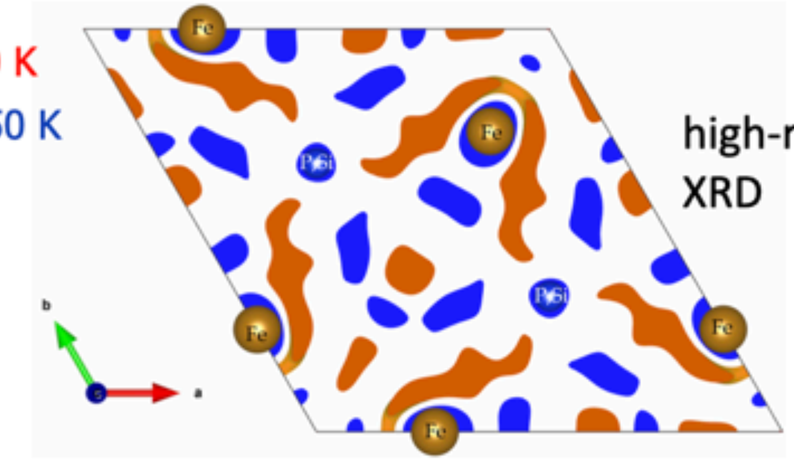


Dung et al. Adv. Energy Mat. (2011)

Understanding phase transitions

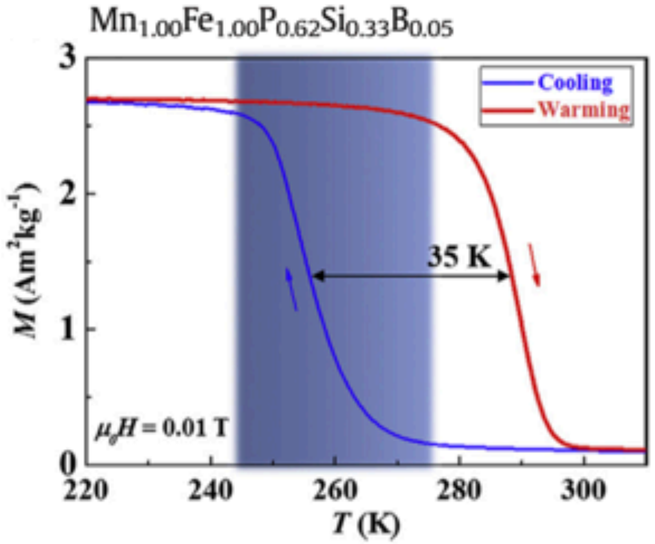






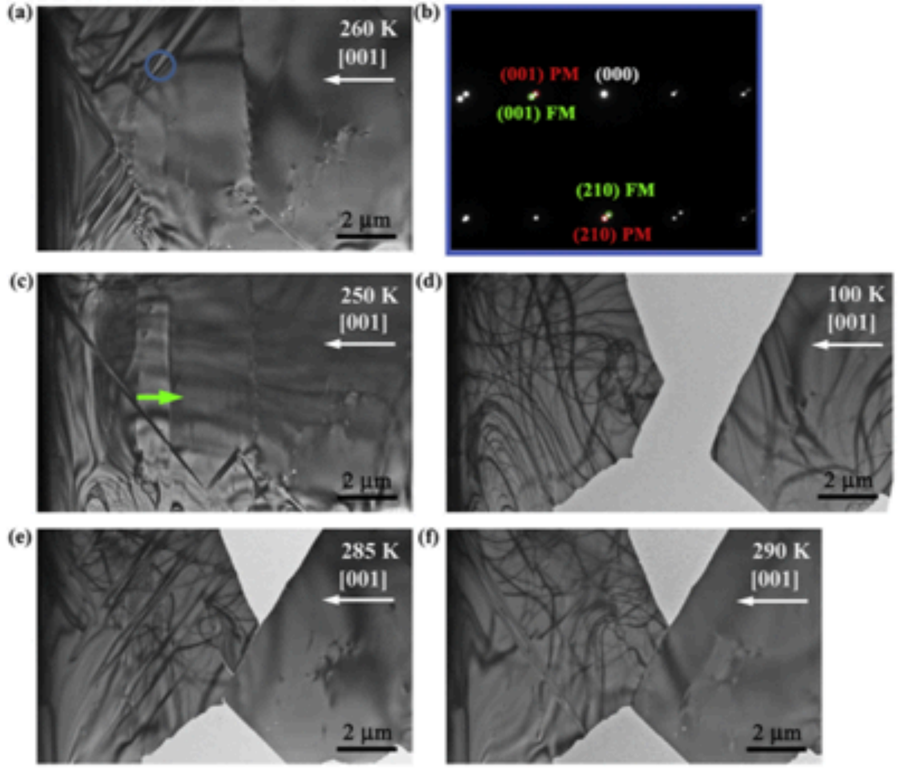
Chemistry of Materials 28, 4901 (2016).

Understanding phase transitions



Isosymetric phase transition with characteristics of a martensite transition!

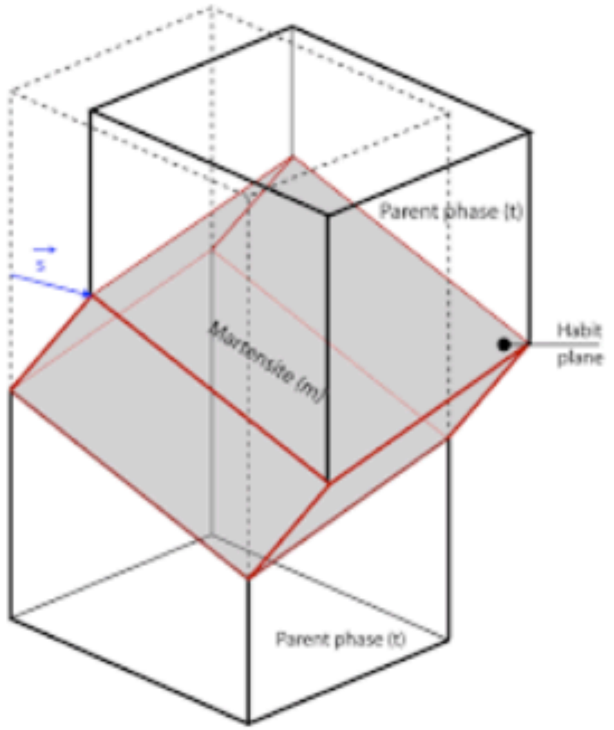
Mn_2Sb-based: tetragonal isosymetric!



X.-F. Miao et al. / Scripta Materialia 138 (2017) 96–99

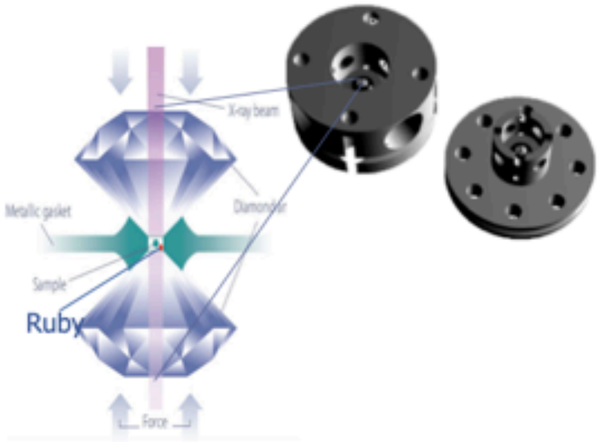
**Collaboration with Dr. Inga Ennen*

What is the mechanism of isostructural phase transitions?

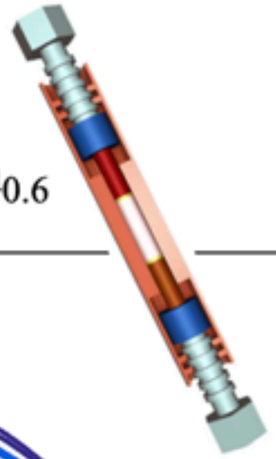


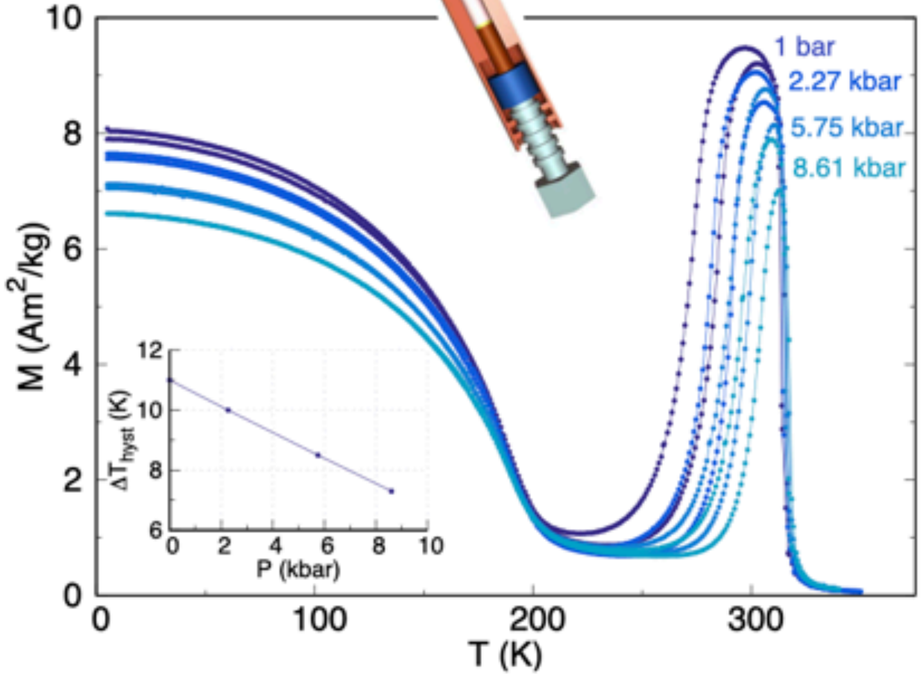
https://doi.org/10.1111/j.1551-2916.2009.03278.x

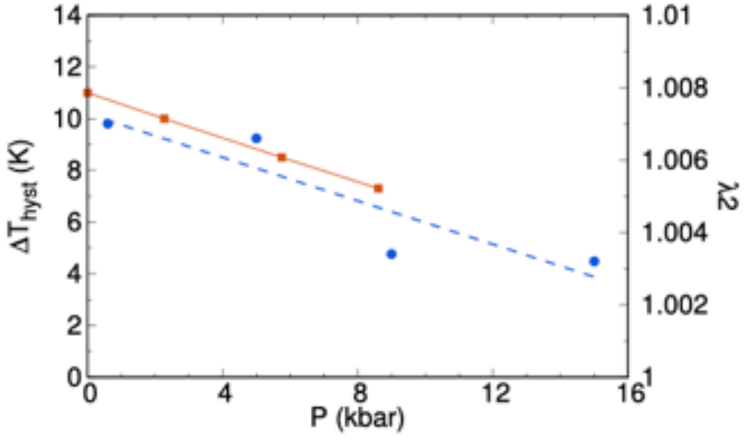
Understanding phase transitions

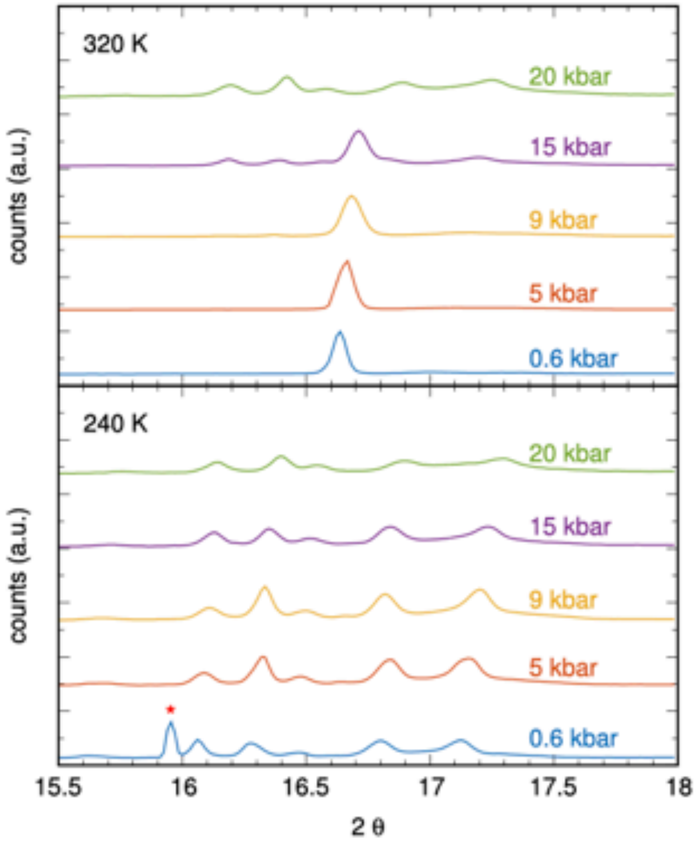


Structural compatibility at the phase transition



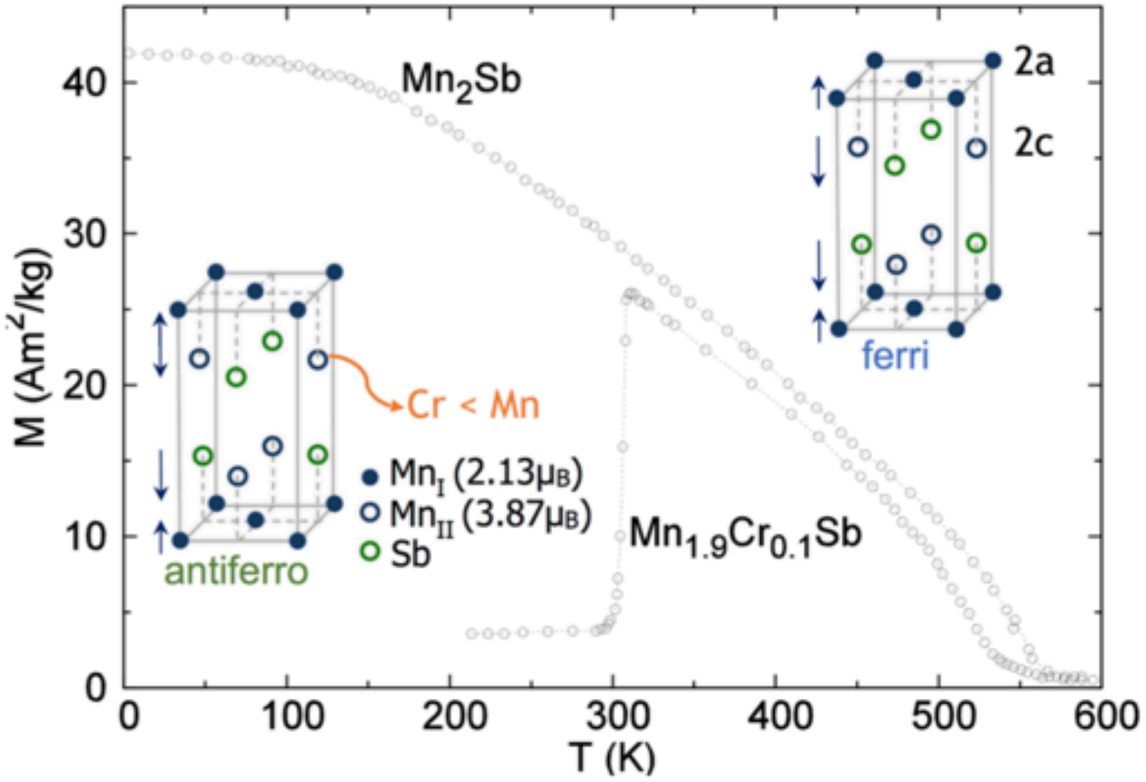






Understanding phase transitions

Mn_2Sb-based compounds: what triggers exchange inversion?



Structural vs. electronic effect

Neutron diffraction

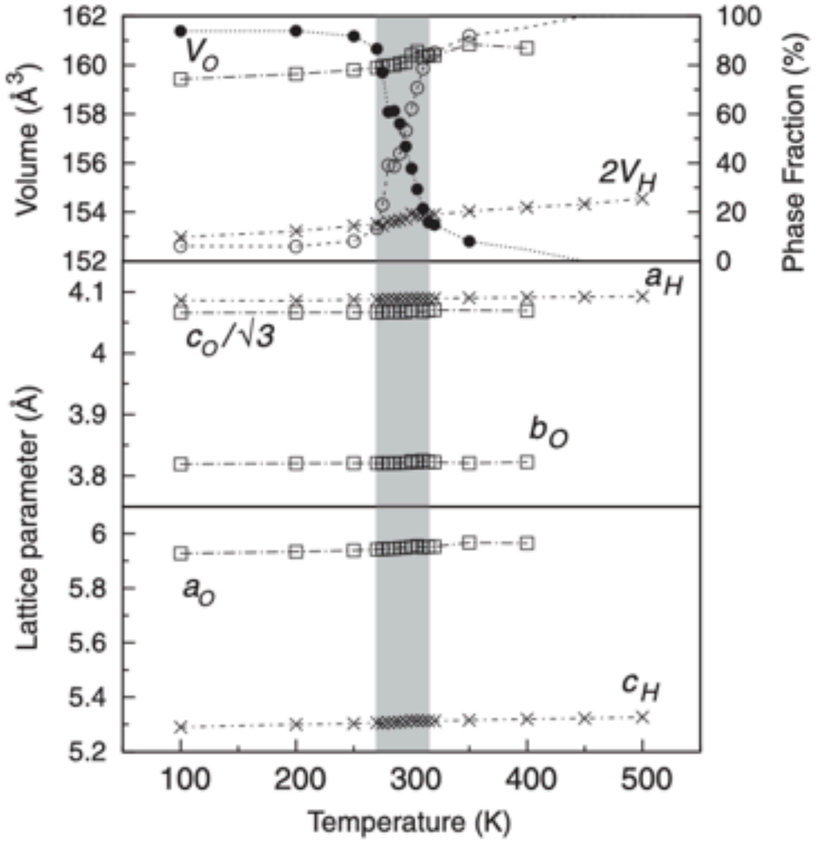
XMCD
High-res. XRD

** Collaboration with Prof. J. Staunton - Warwick*

Barocaloric effect

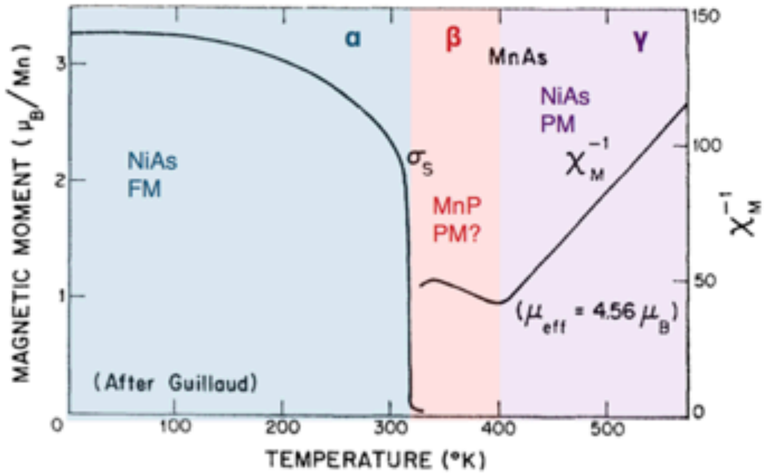
Study the barocaloric effect in different compounds

$Mn_{0.93}Cr_{0.07}CoGe$



Large ΔV ⟶ large BCE

MnAs

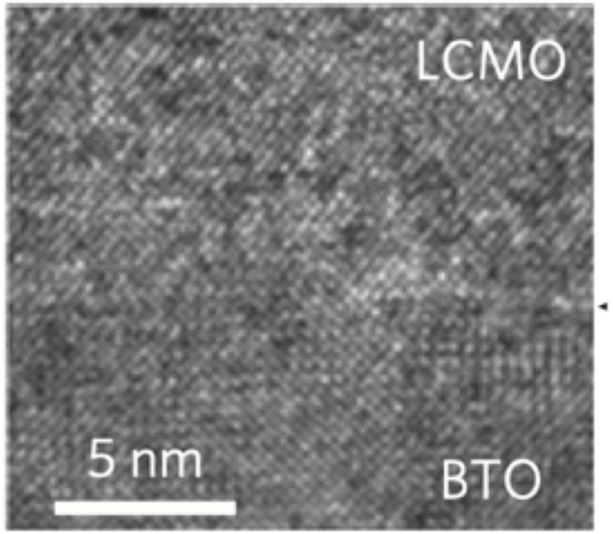


Simple 1st assessment:

- dTc/dP from magnetization
- Cp at ambient pressure

**Calorimmetry under pressure in collaboration with Pol Lloveras – Univ. Politec. Catalunya*

Multicaloric effects

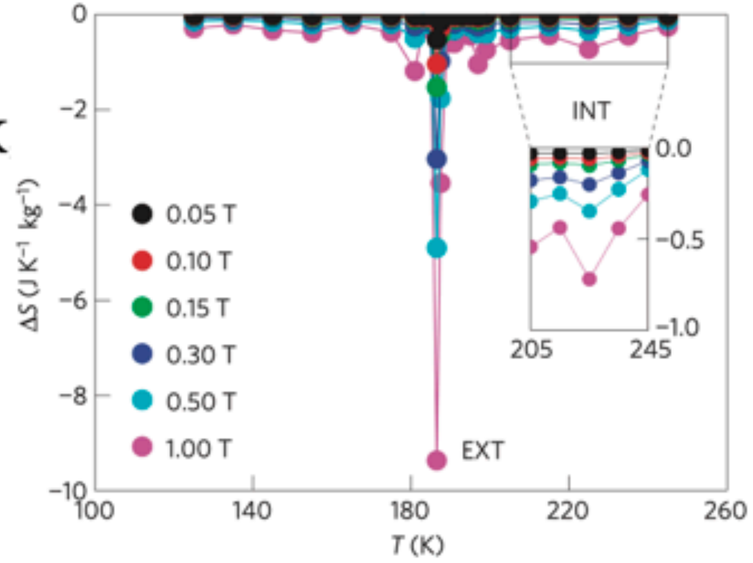


$La_{0.7}Ca_{0.3}MnO_3$

$T_C^{LCMO} \sim 259\,K$

$BaTiO_3$

$T_{R-O} \sim 200\,K$

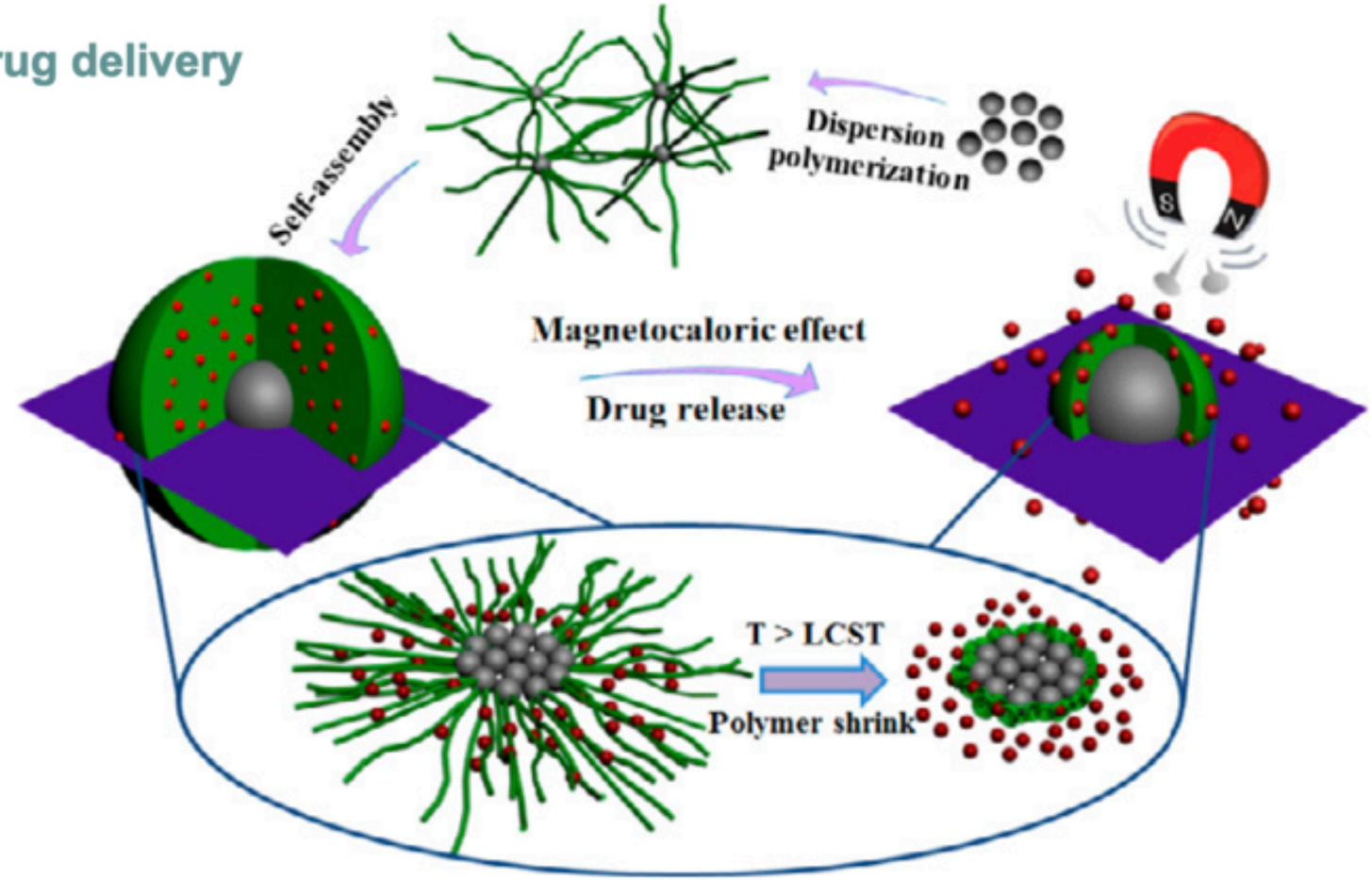


- Apply strain on a magnetoelastic or ferroelectric transition
- Core/shell nanoparticles V/A to strain a material?
- "trigger" a structural transition

Nature Materials 12, 52 (2013)

Nanoparticles

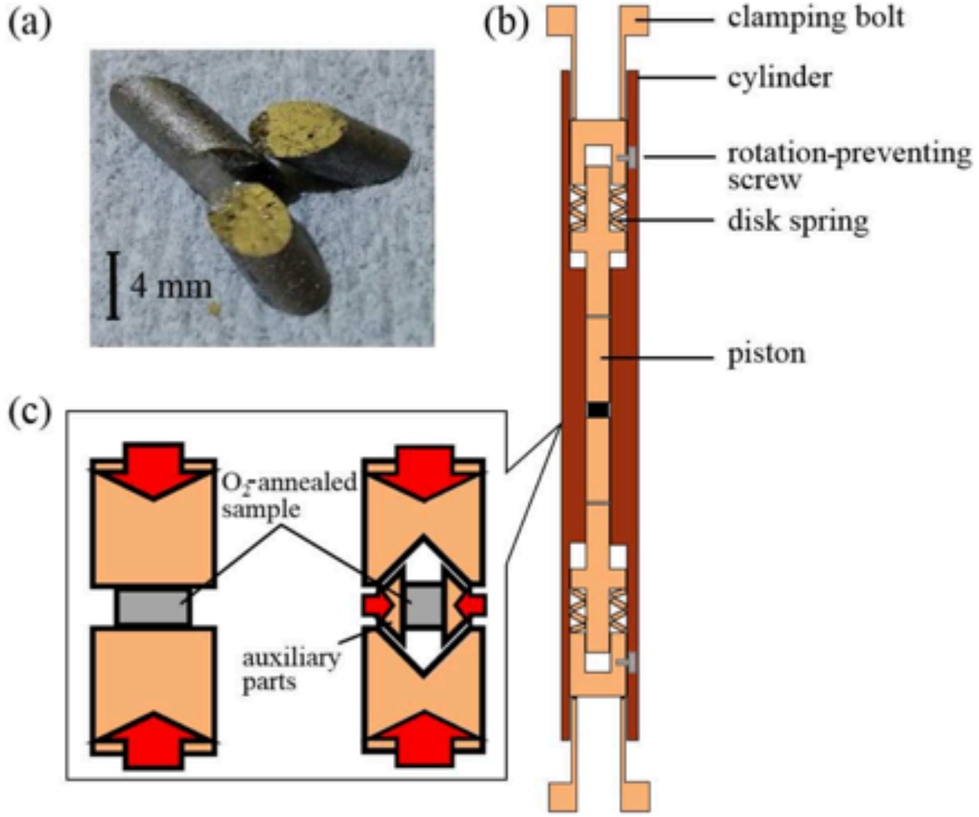
Hyperthermia & drug delivery



https://doi.org/10.1088/0957-4484/23/50/505706

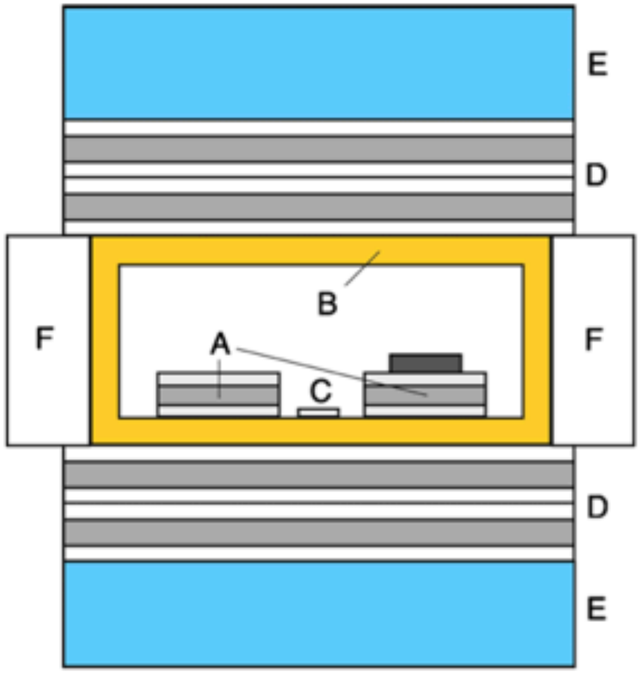
Developing instrumentation

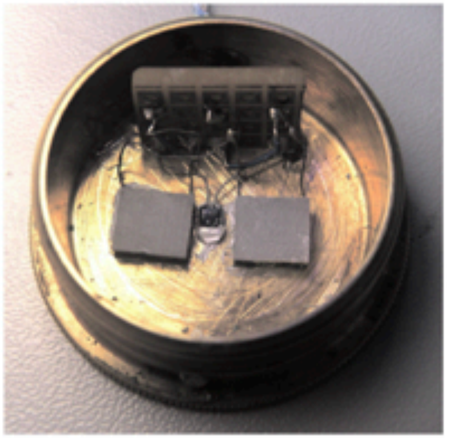
Uniaxial pressure



arXiv:1803.00782v2 [cond-mat.supr-con] 22 Mar 2018

In-field DSC





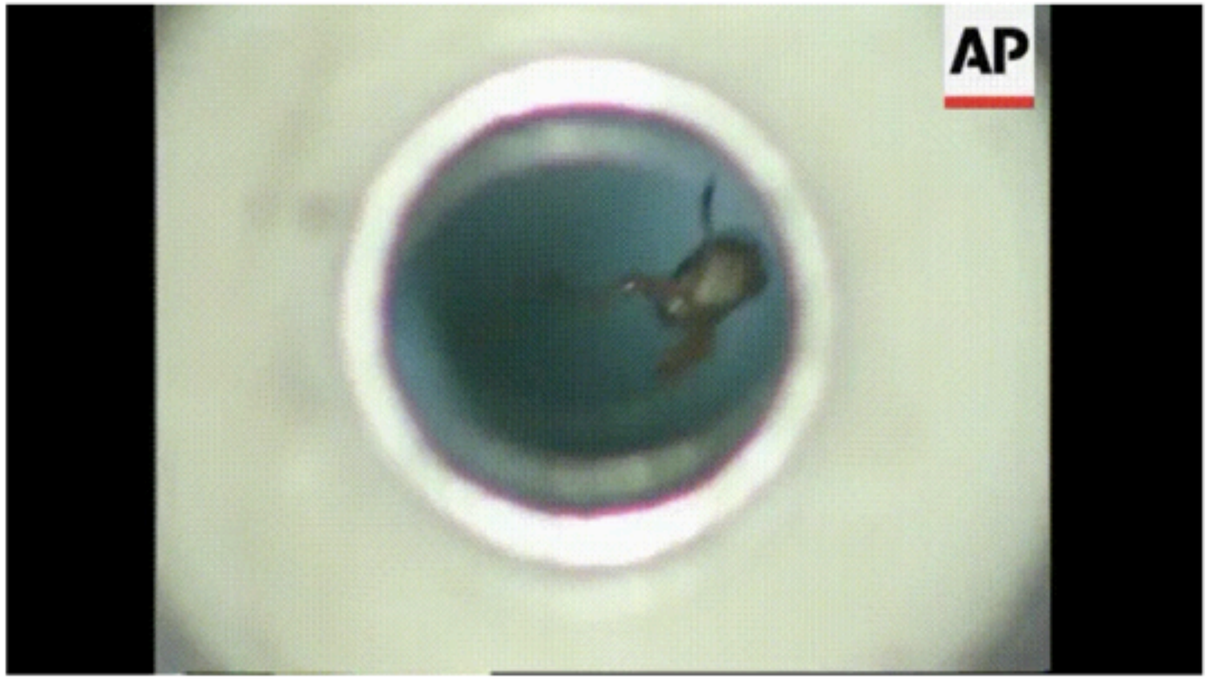
Rev. Sci. Instrum. **81**, 113904 (2010)

Objectives:

- understand critical phenomena
- Design better materials for applications

Materials physics' toolkit:

- synthesis techniques
- Characterization techniques



Thank you!

lcaron@physik.uni-bielefeld.de
D2-205