UCDAVIS
DEPARTMENT OF PHYSICS

Creating and Tuning materials

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My first time with science

Why is a piece of paper falling down slowly?

- small weight?
- shape?

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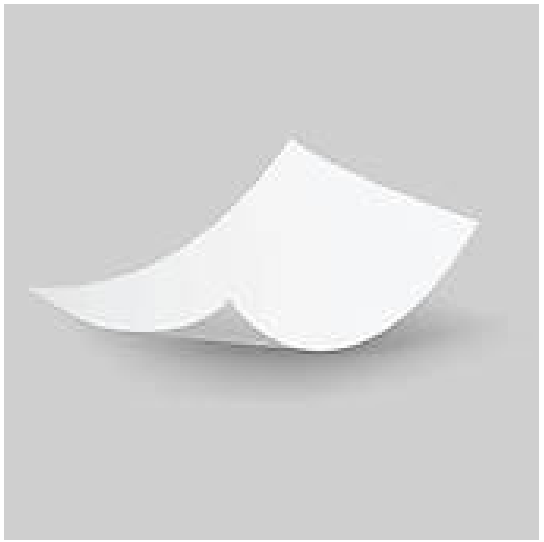

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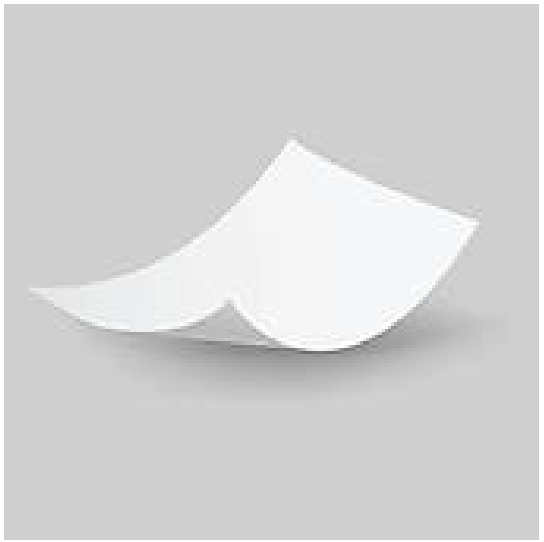

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Shape!

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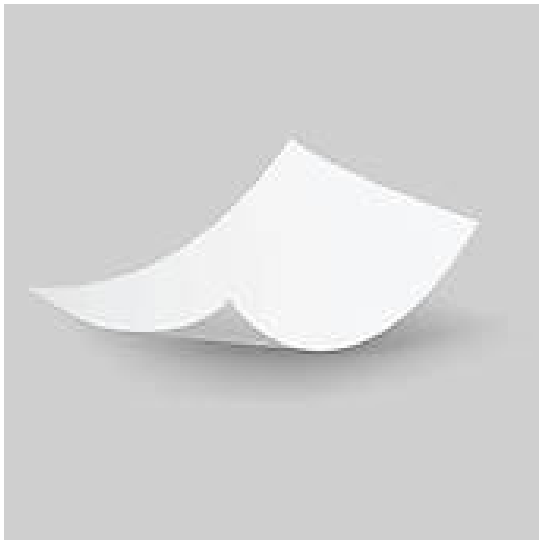


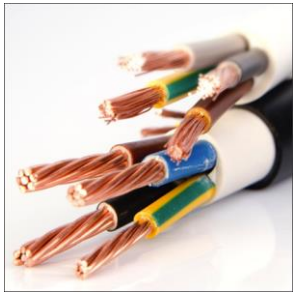
- small weight?
- shape?

tuning material: change a parameter to change the properties

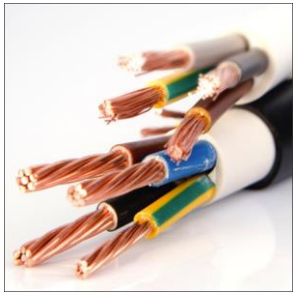
Shape!

Many properties of matter

Many properties of matter

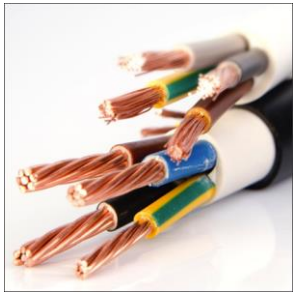


Many properties of matter



Everything was simple…



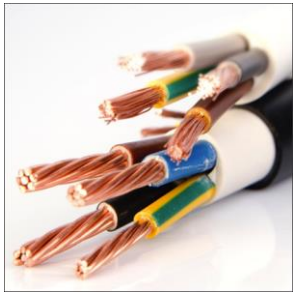








It is complicated…



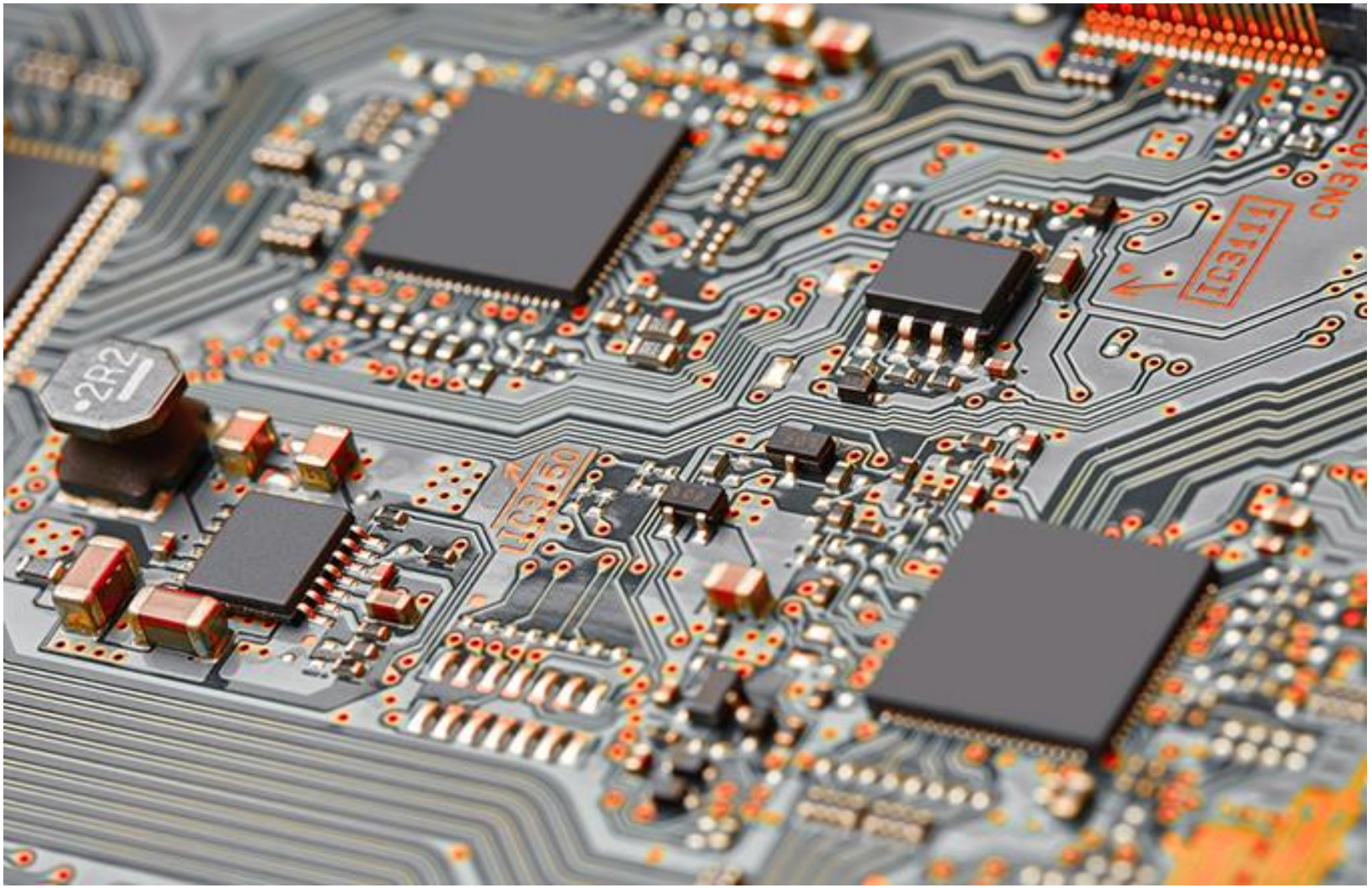





Gel

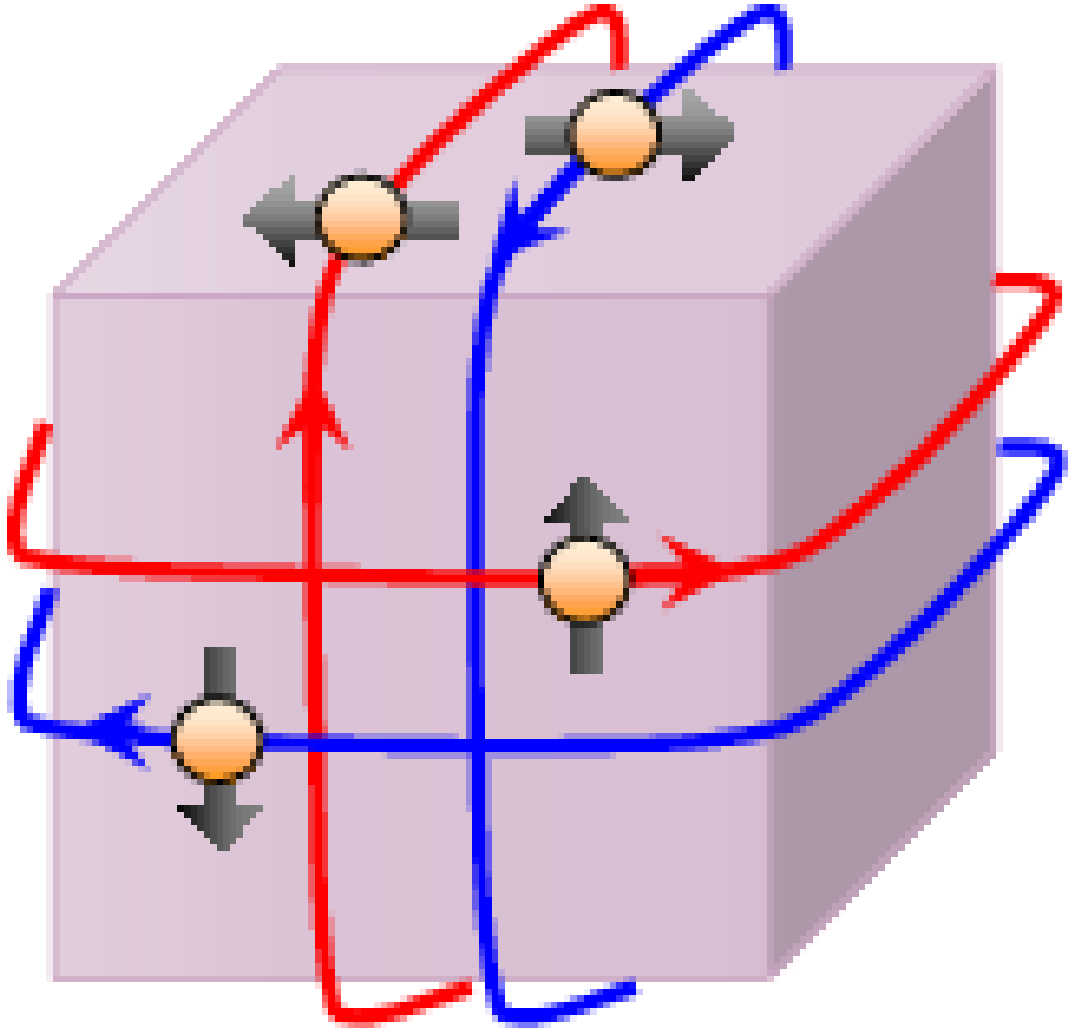
Gel: not quite a solid, not quite a liquid

Semi-conductors



semi-conductor: not quite a conductor, not quite an insulator

Topological Insulators



topological insulator: insulating on the inside, conducting on the surface

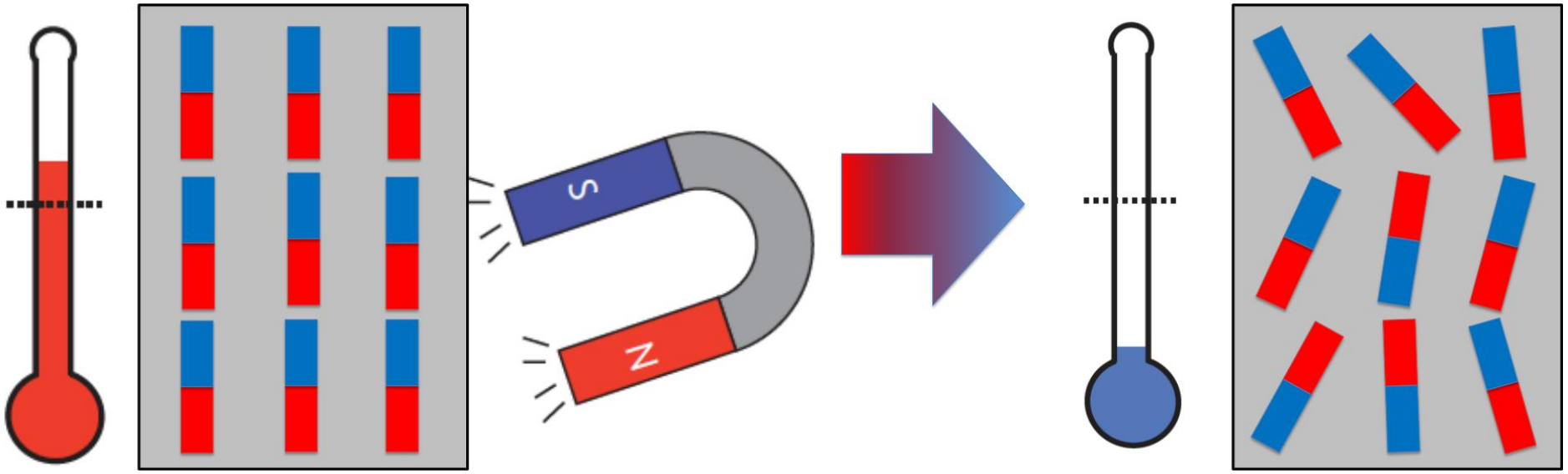
Photovoltaic materials

photovoltaic materials: produce electricity from light

Thermoelectric materials

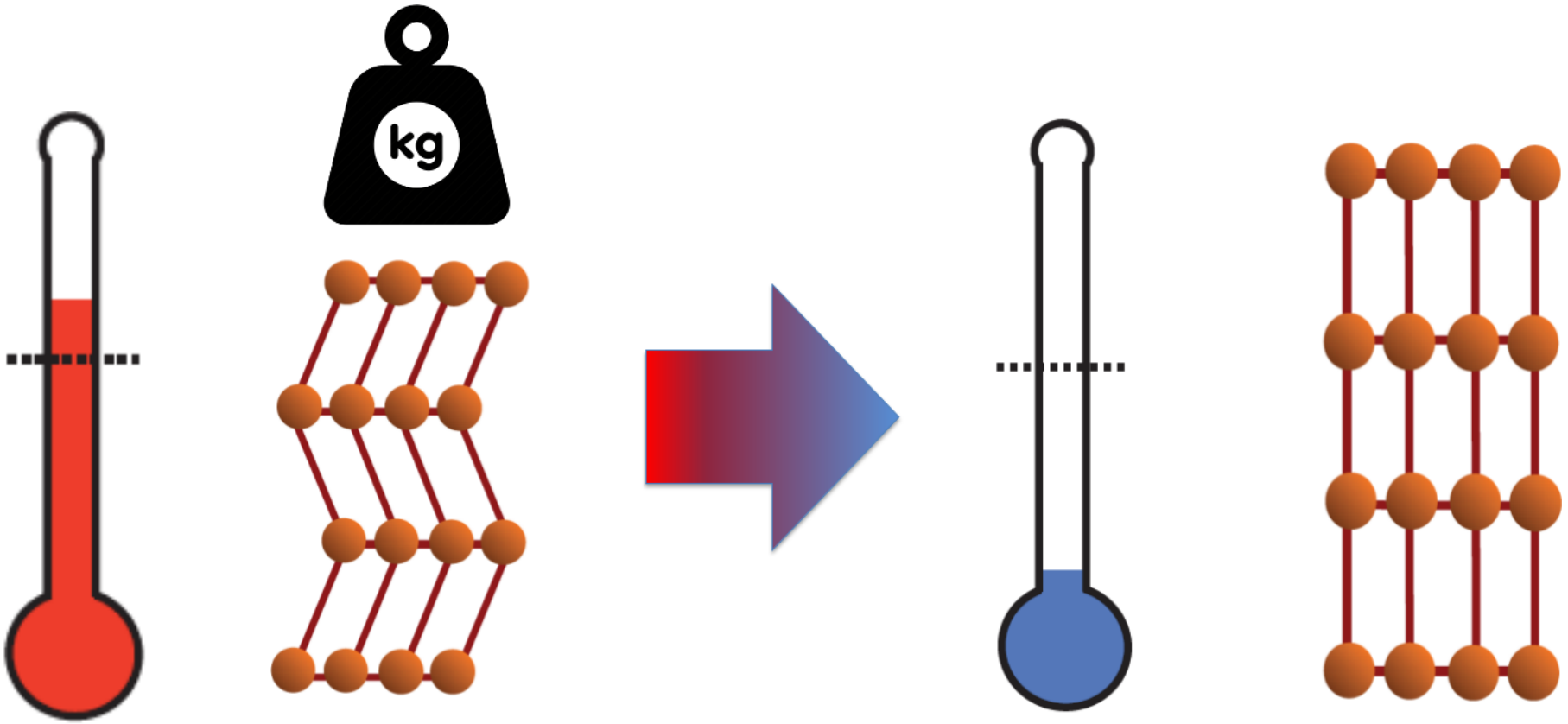
thermoelectric materials: produce electricity from temperature variation

Magnetocaloric materials



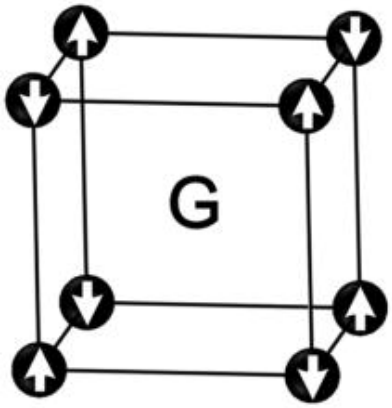
Magnetocaloric materials: cool down from magnetic field variation

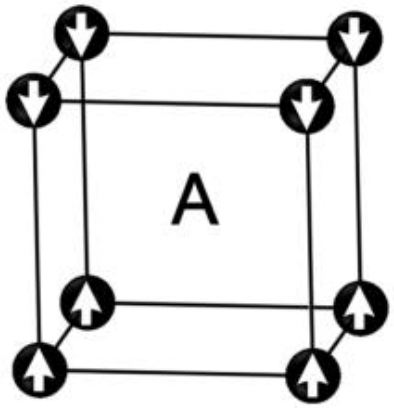
Elastocaloric materials

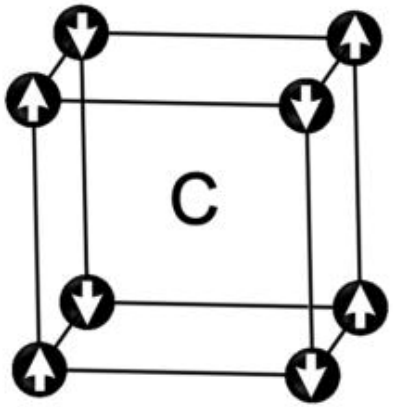


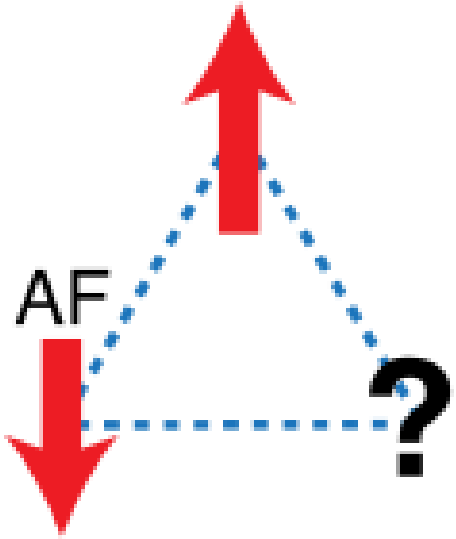
Elastocaloric materials: cool down from pressure variation

Magnetic materials







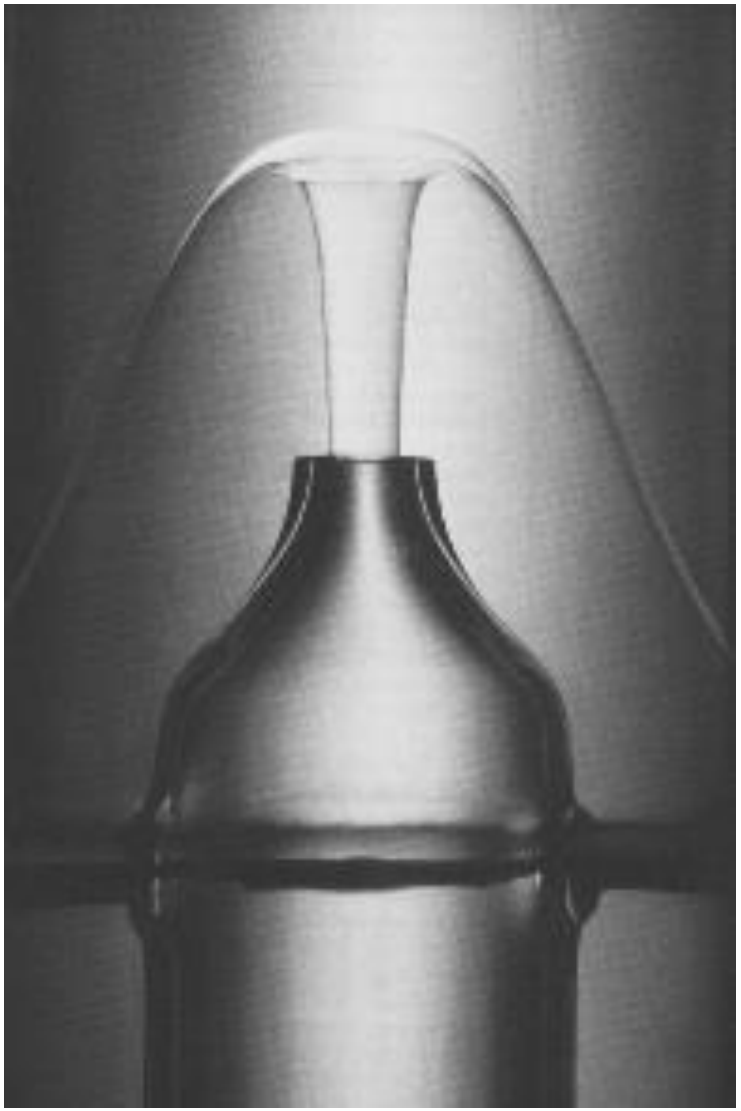


ferromagnetic, antiferromagnetic (G-type, A-type…), paramagnetic, diamagnetic, frustrated…

Liquid crystals

liquid crystals: align their molecules under an electric field

Superfluidity

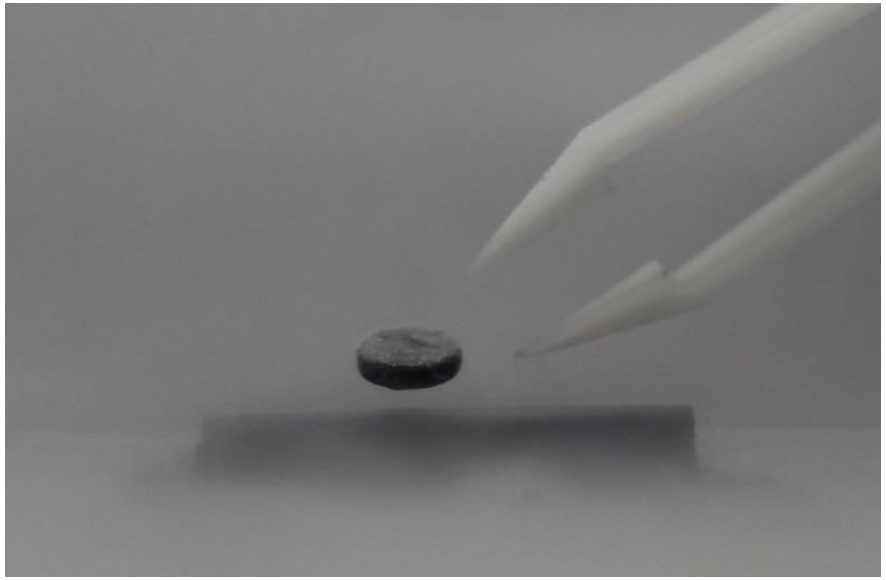


superfluid: does not have any viscosity. When put into a glass, it flows out on its own.

Shape memory alloys

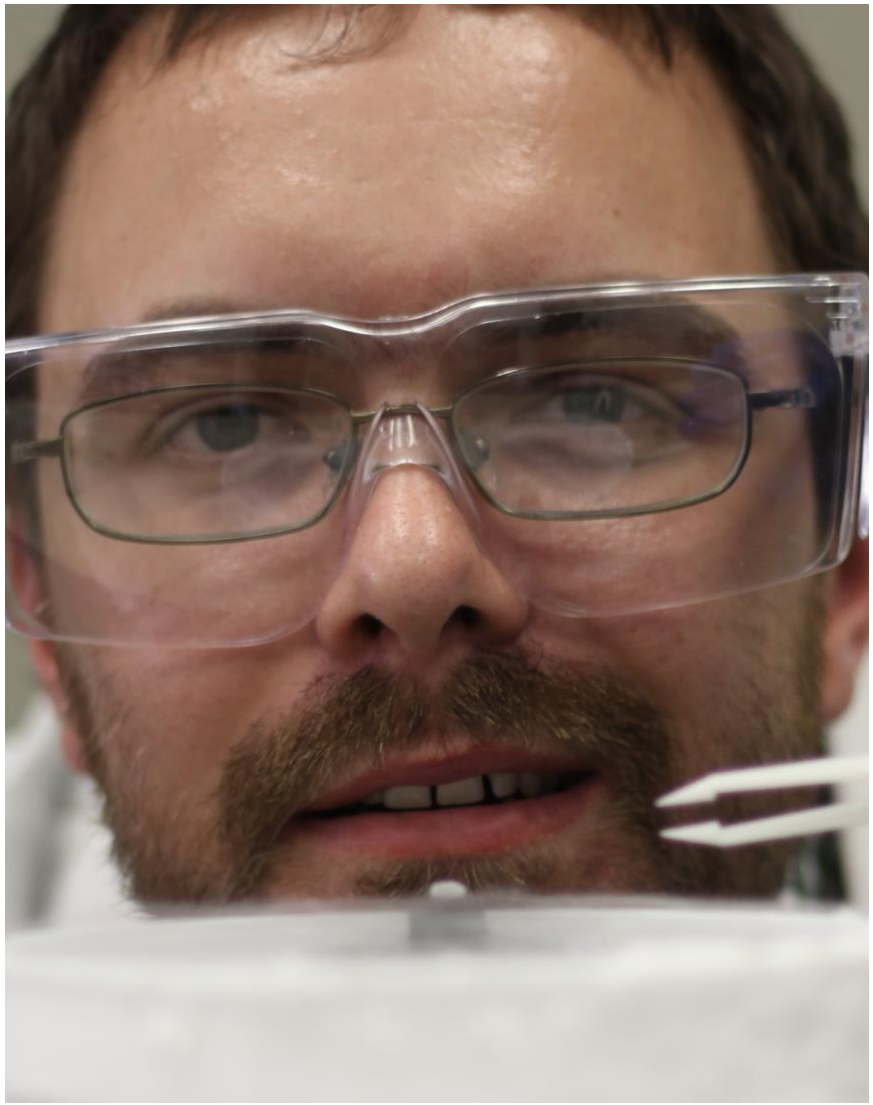
Shape memory alloys: memorize their shape.
You change their shape, and they come back to their previous shape.

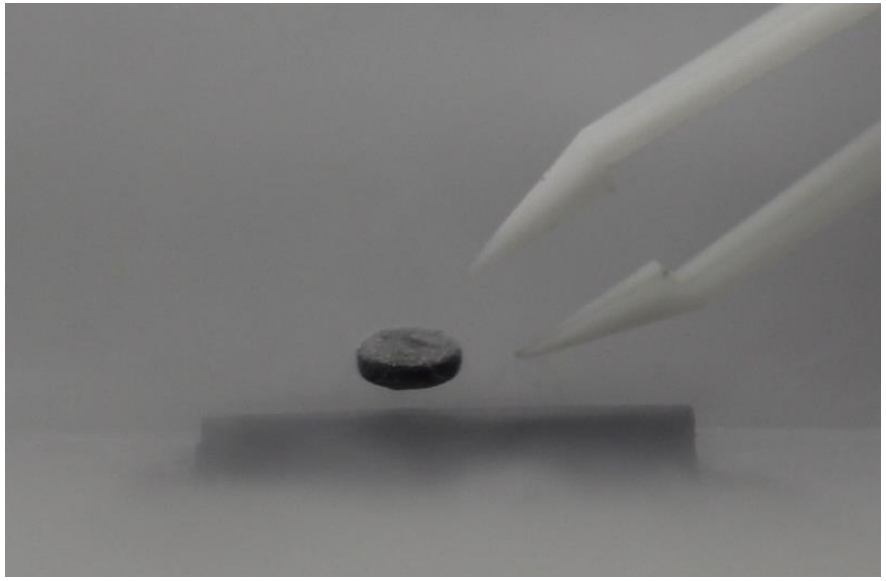
Superconductors



superconductors: that don’t have any resistance to the electrical current
expel magnetic field

Superconductors





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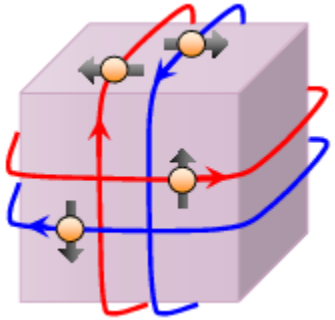
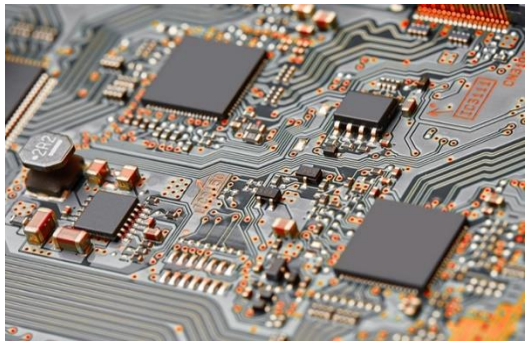
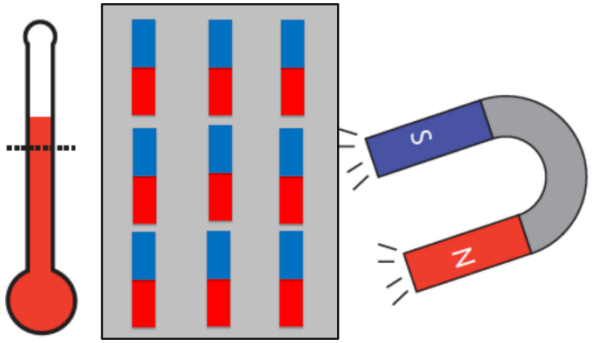
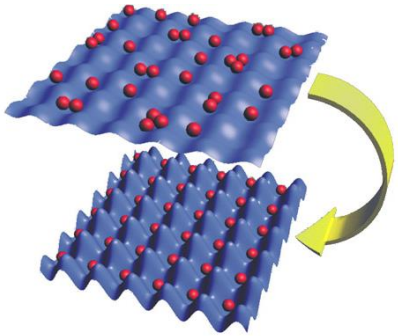
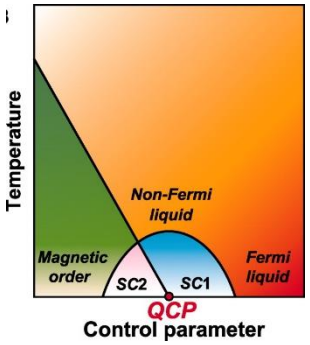
Big potential and key questions

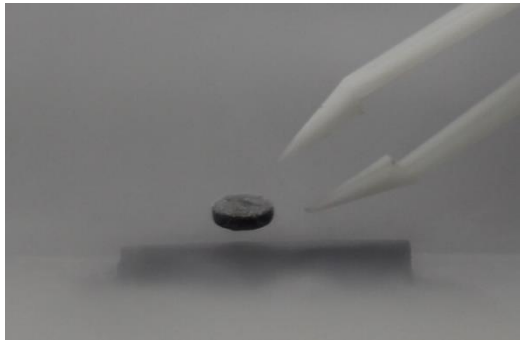


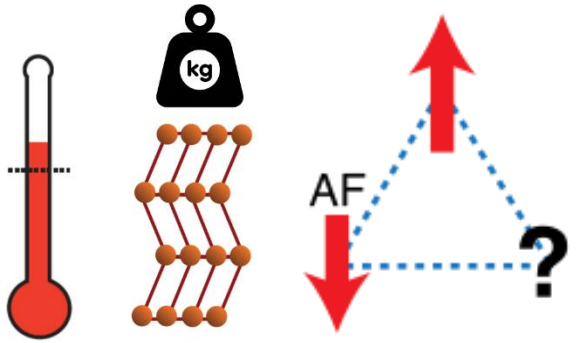


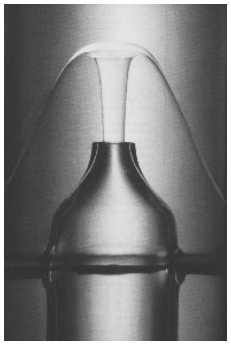












Condensed Matter Science: study all kinds of materials

Big potential and key questions












Materials at the edge of an instability

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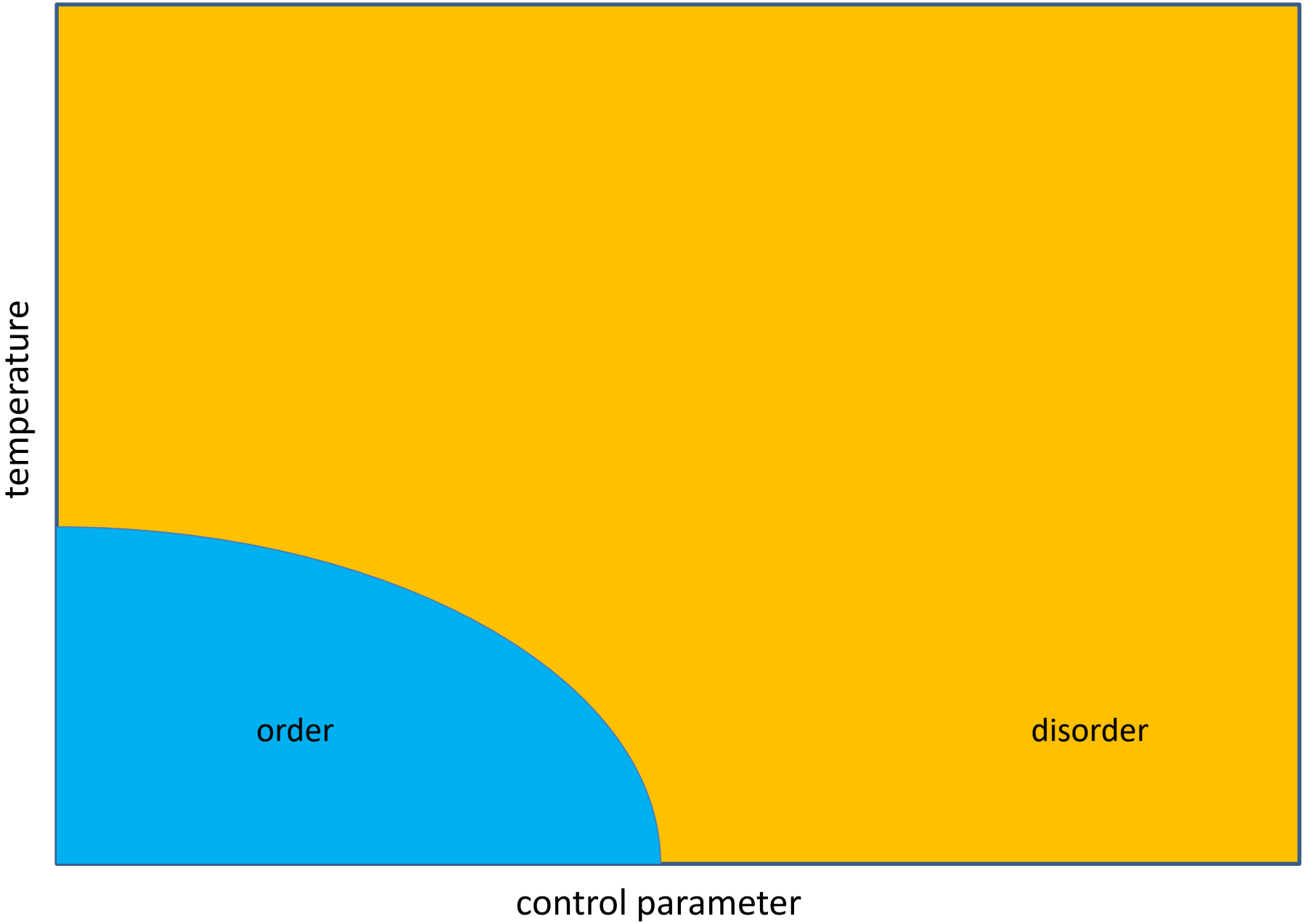
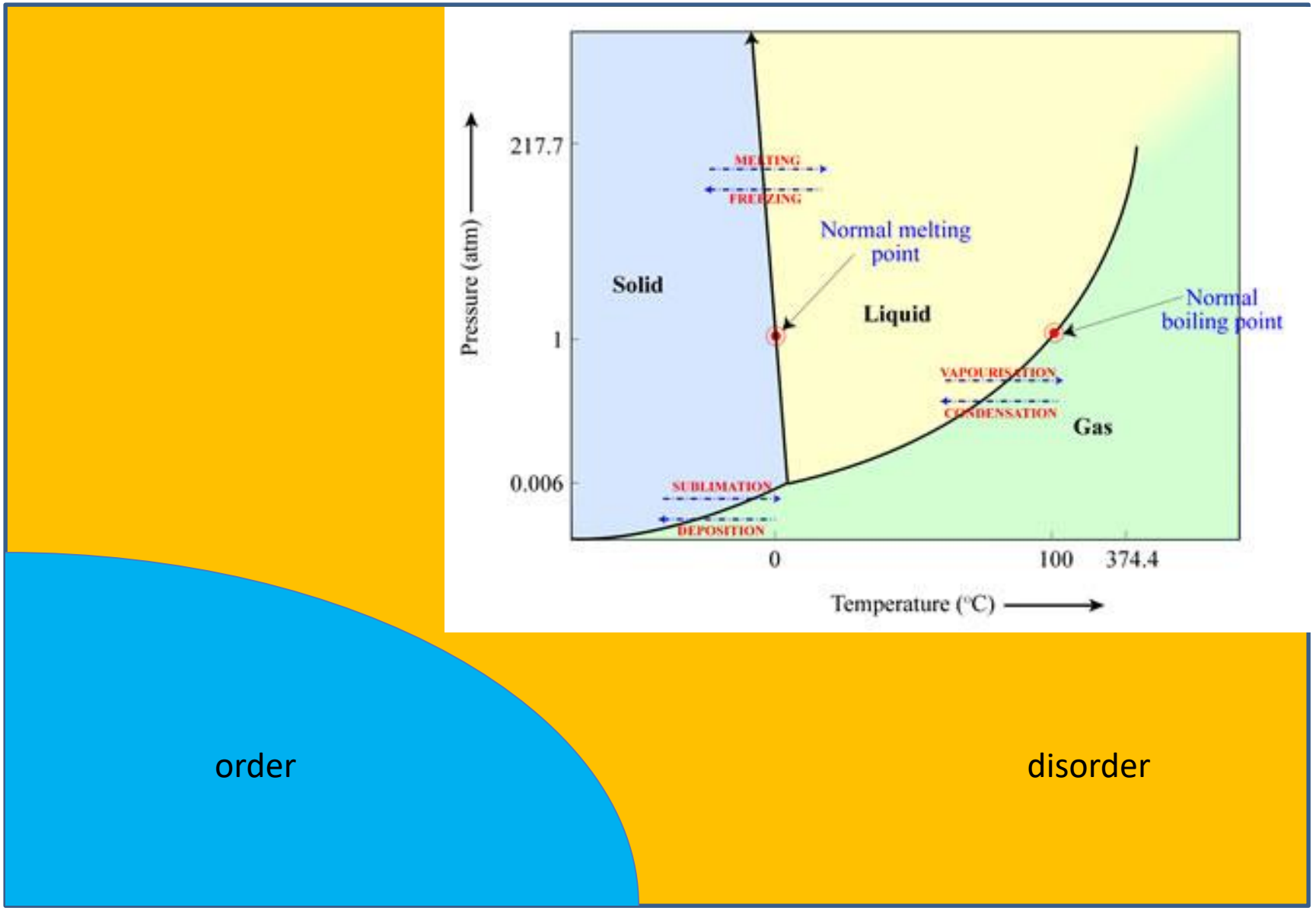
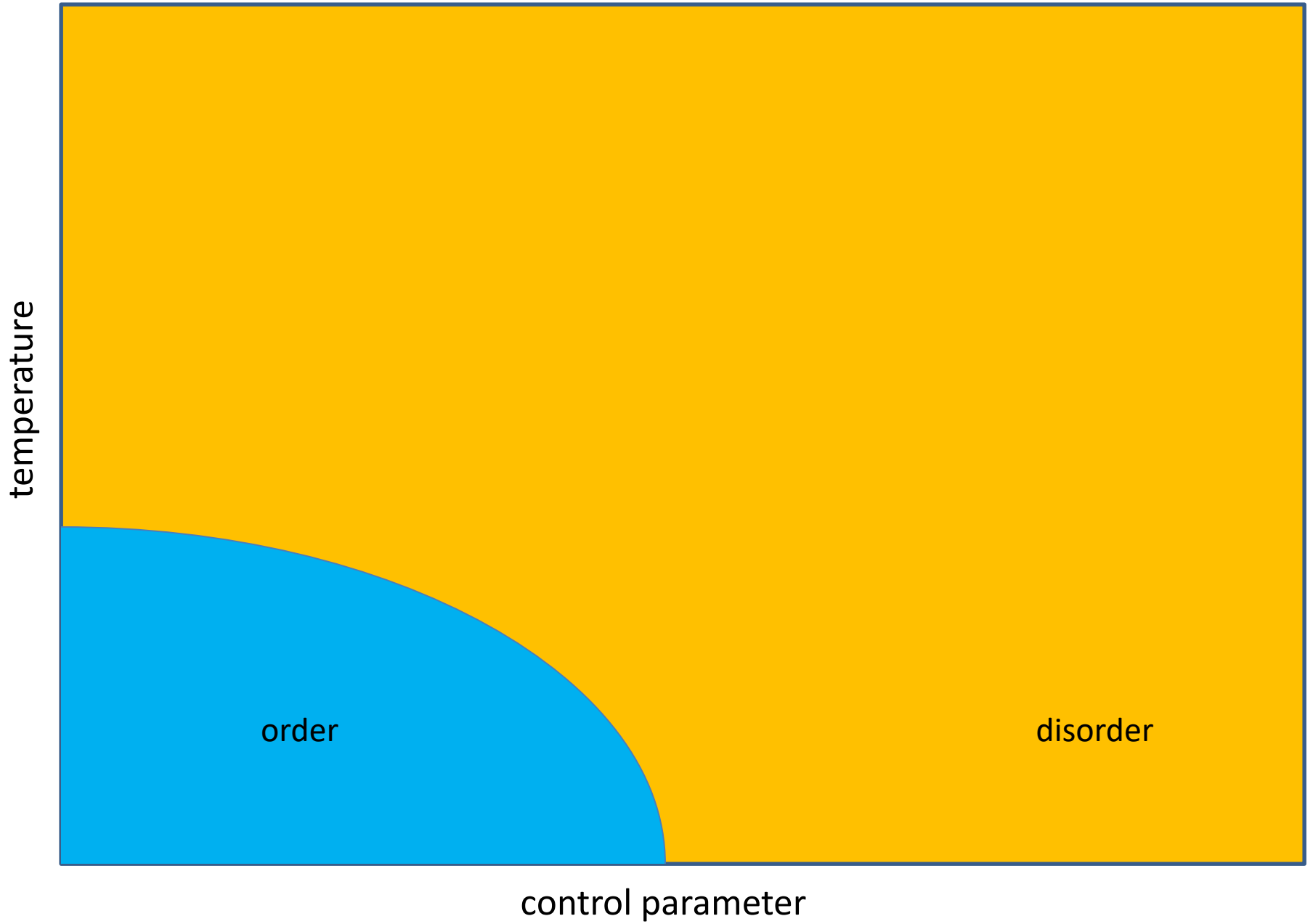


Materials at the edge of an instability



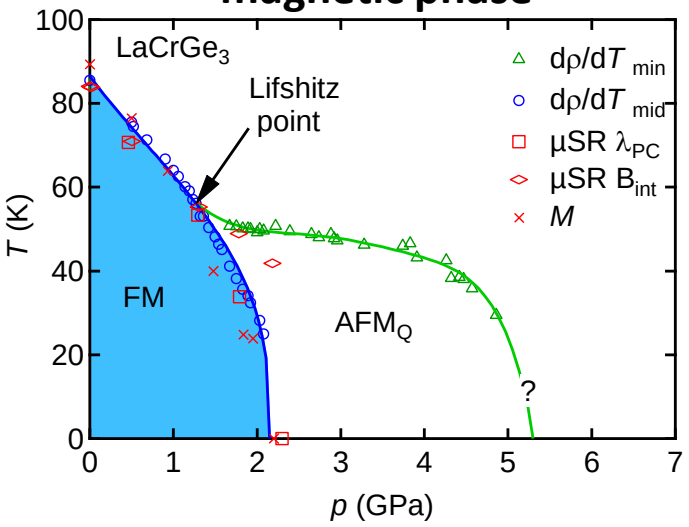
Kill the order



Kill the order: the phoenix rises from the ashes

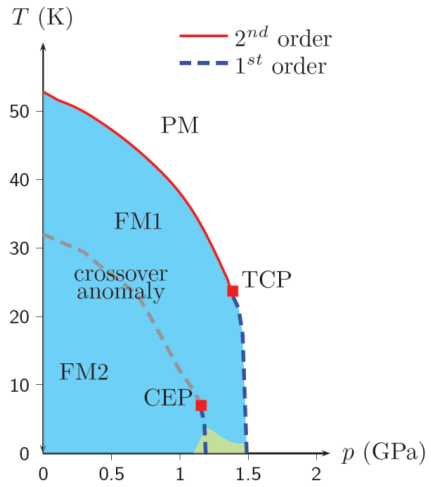
Materials under high pressure

Modulated magnetic phase



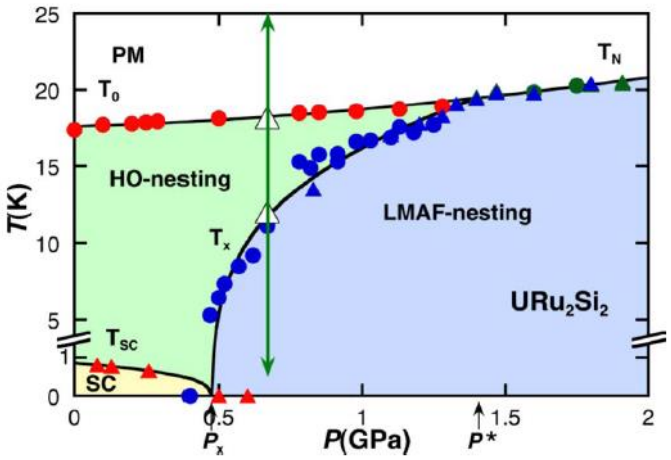
Taufour V. *et al.* Phys. Rev. Lett. **117** 037207 (2016)

Superconducting ferromagnet: UGe_2



Taufour V. *et al.* Phys. Rev. Lett. **105** 217201 (2010)

Hidden Order in URu_2Si_2

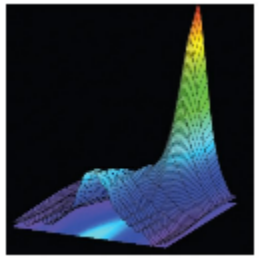


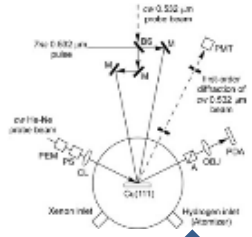
A. Villaume *et al.* Phys. Rev. B **78**, 012504 (2008)

In the beginning,… there was a sample

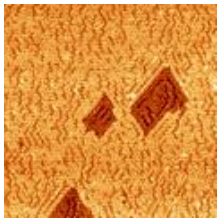
All kinds of measurements to study these new phases (at UC Davis and elsewhere):

nuclear magnetic resonance



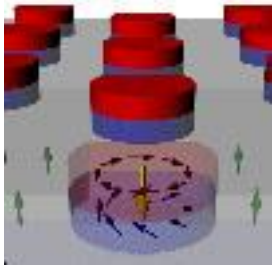


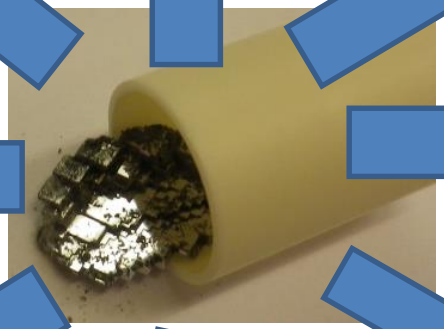
optical studies

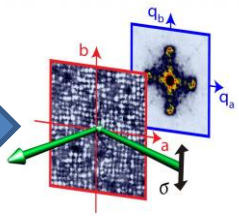


scanning probe microscopy

magnetism and spin transport

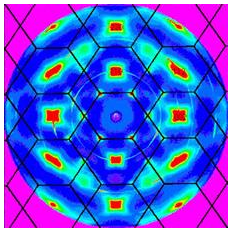


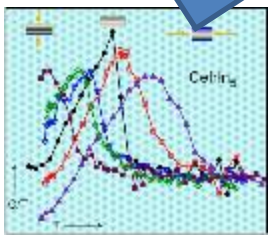




scanning tunneling spectroscopy x-ray scattering

neutron scattering



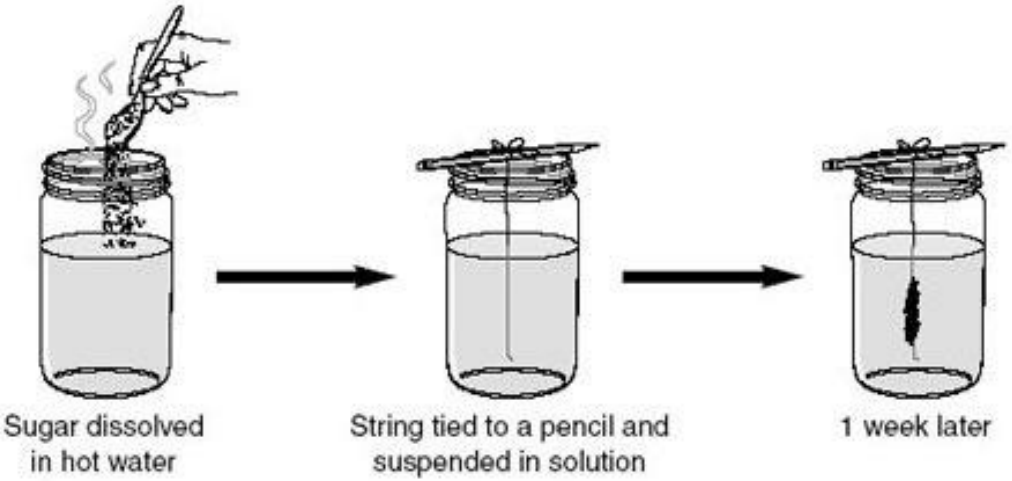


low temperature uniaxial pressure

your favorite technique and subject here

How do we grow sugar crystals?

How do we grow sugar crystals?



sugar

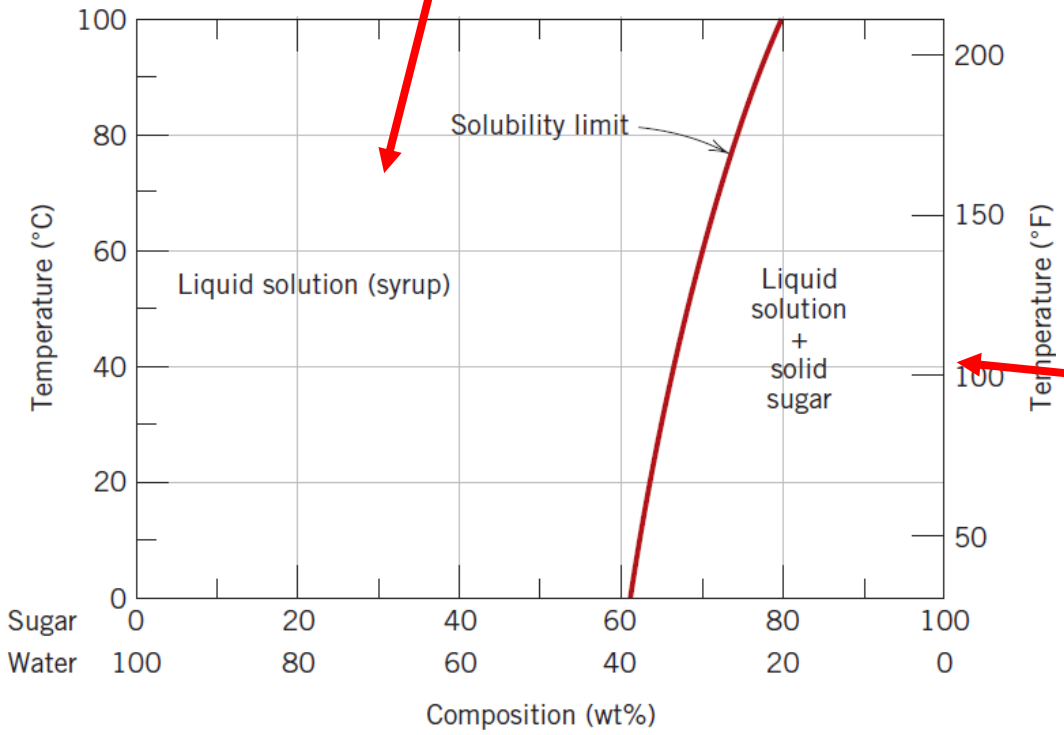
water

heat

Compositional diagram is like a map

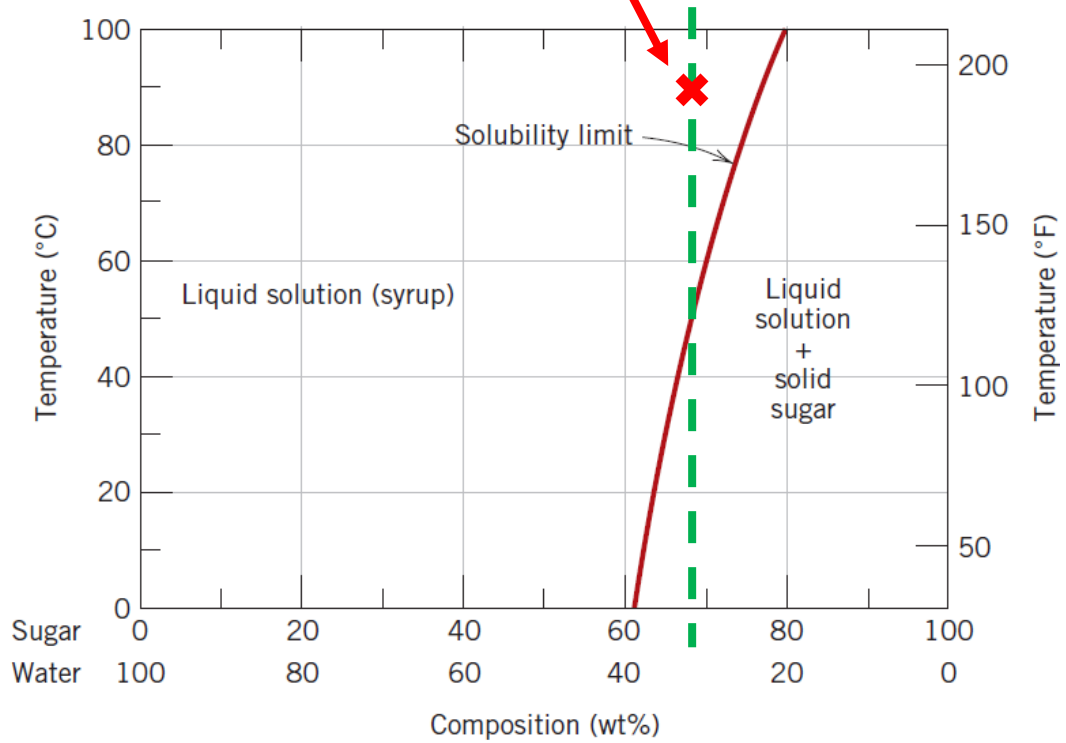
liquids

solids



Reading the map…

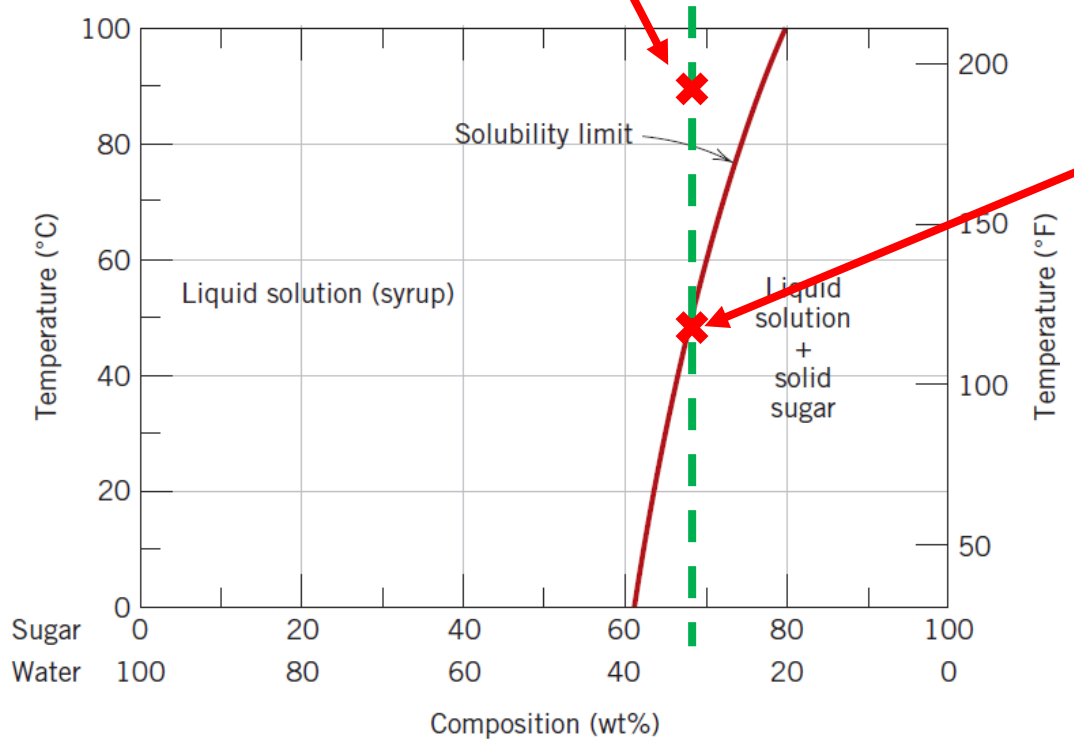
hot liquid



Reading the map…

hot liquid

start to grow a crystal



Reading the map…

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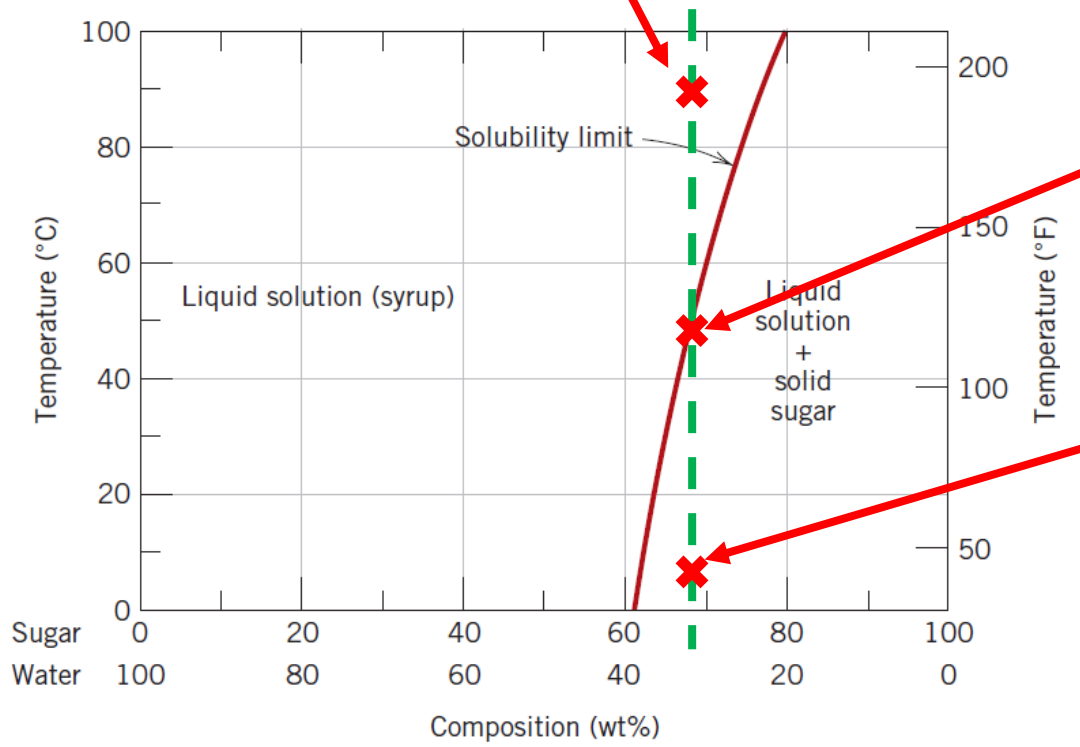
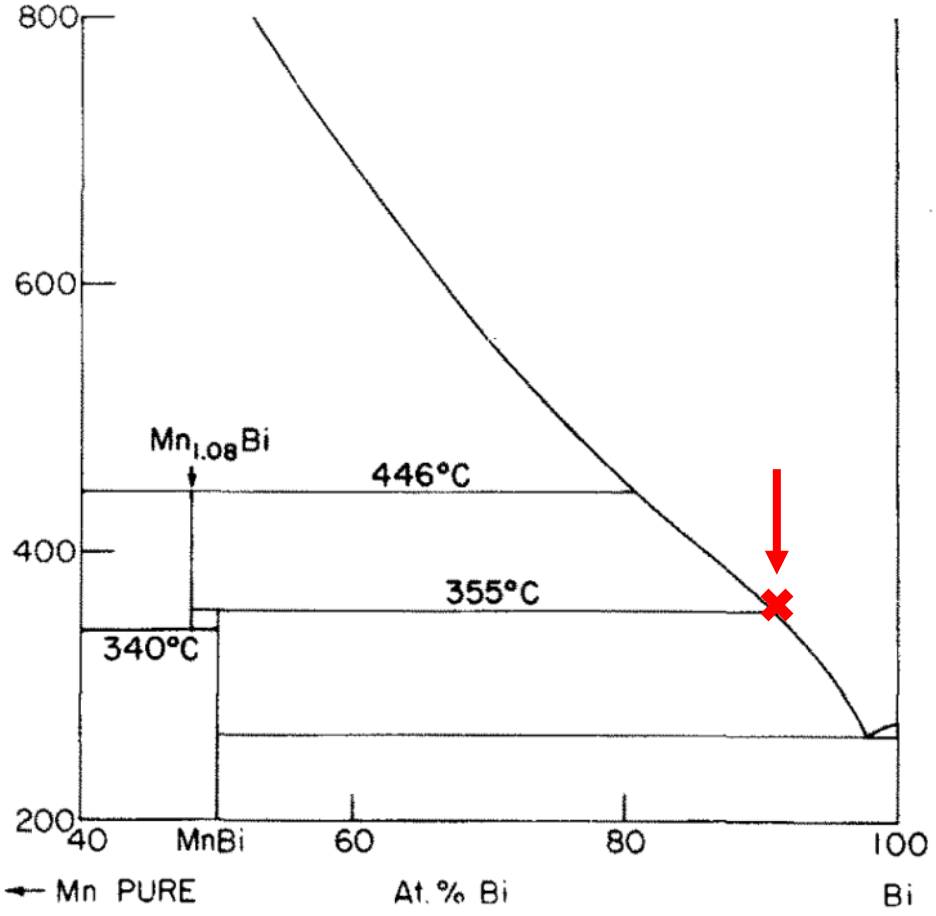
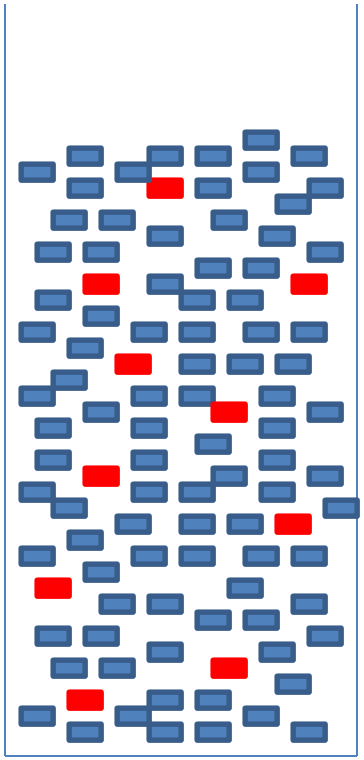


ready to enjoy!

Solution growth: example of MnBi





T. Chen *et al.* J. Appl. Phys. **45** 2358 (1974)

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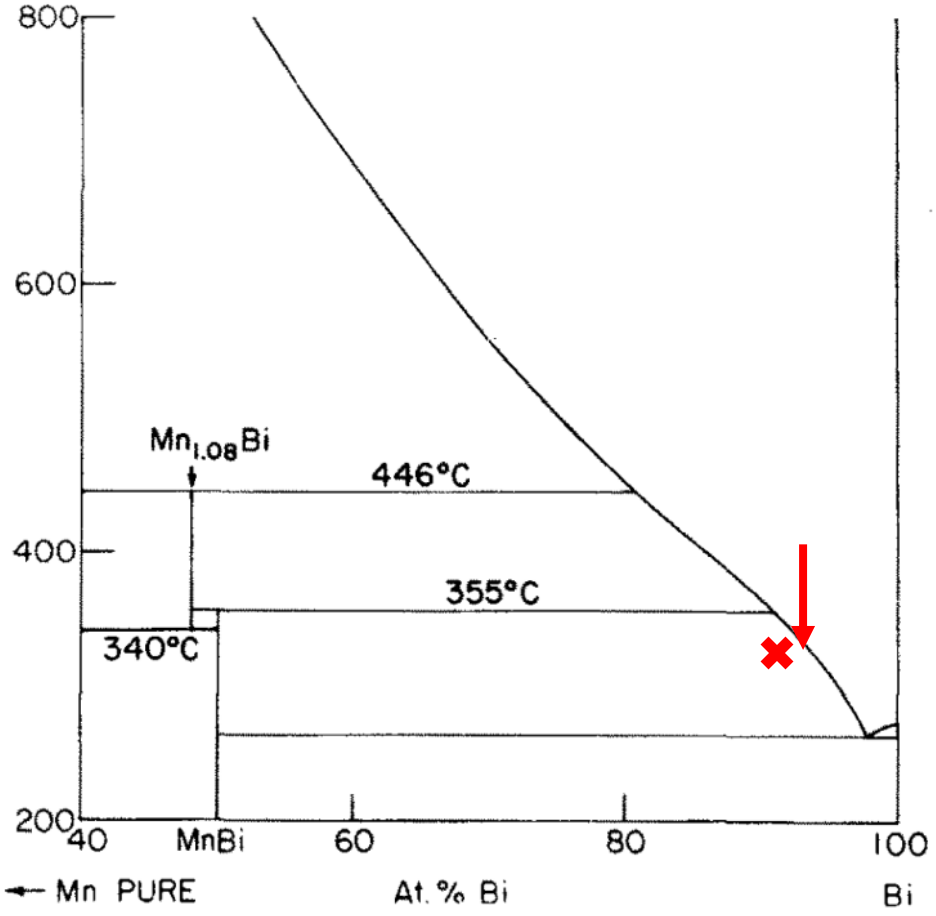

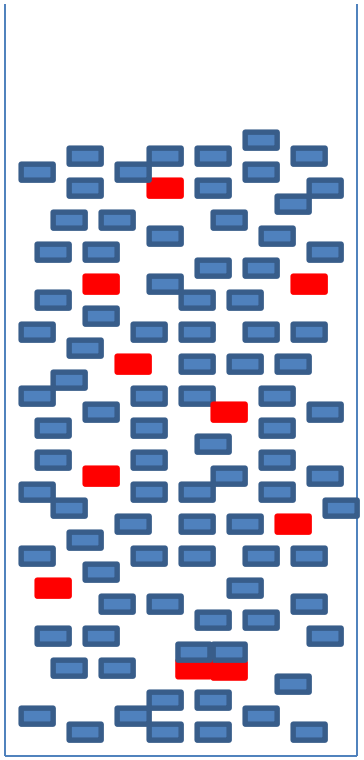

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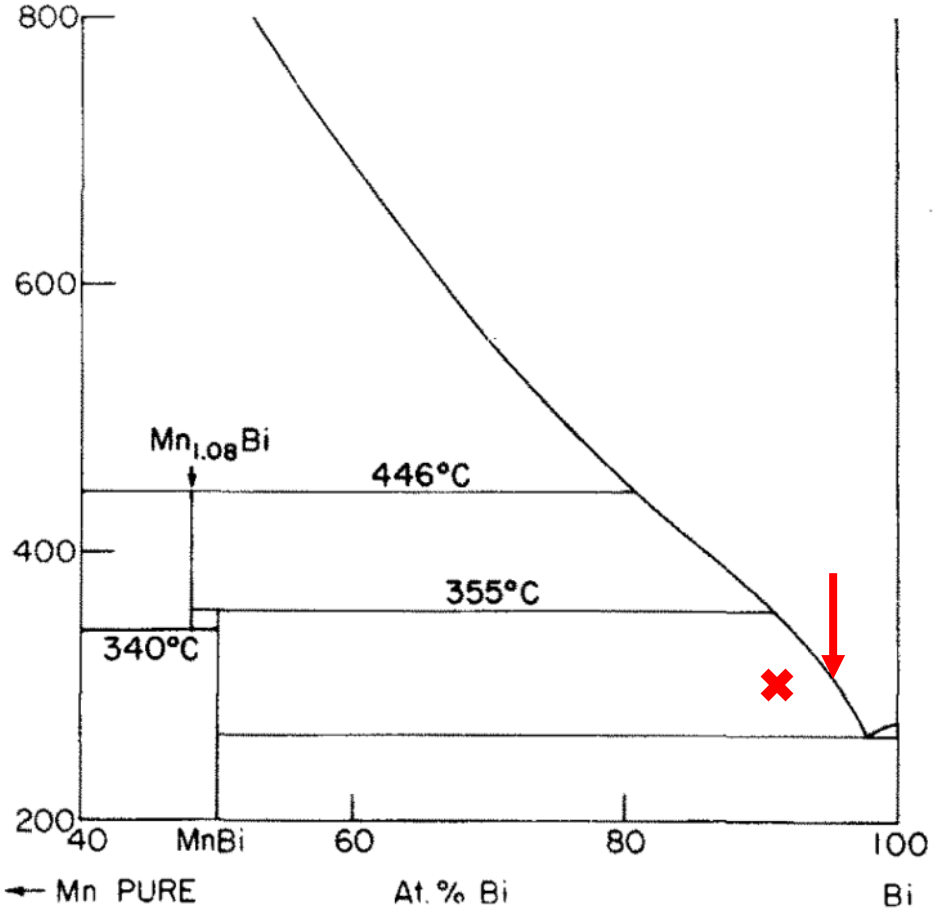

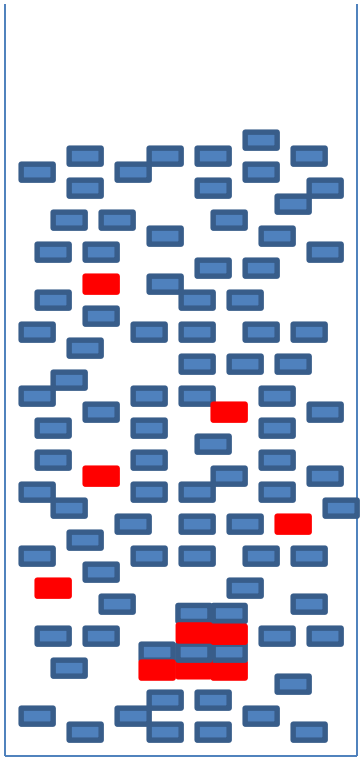

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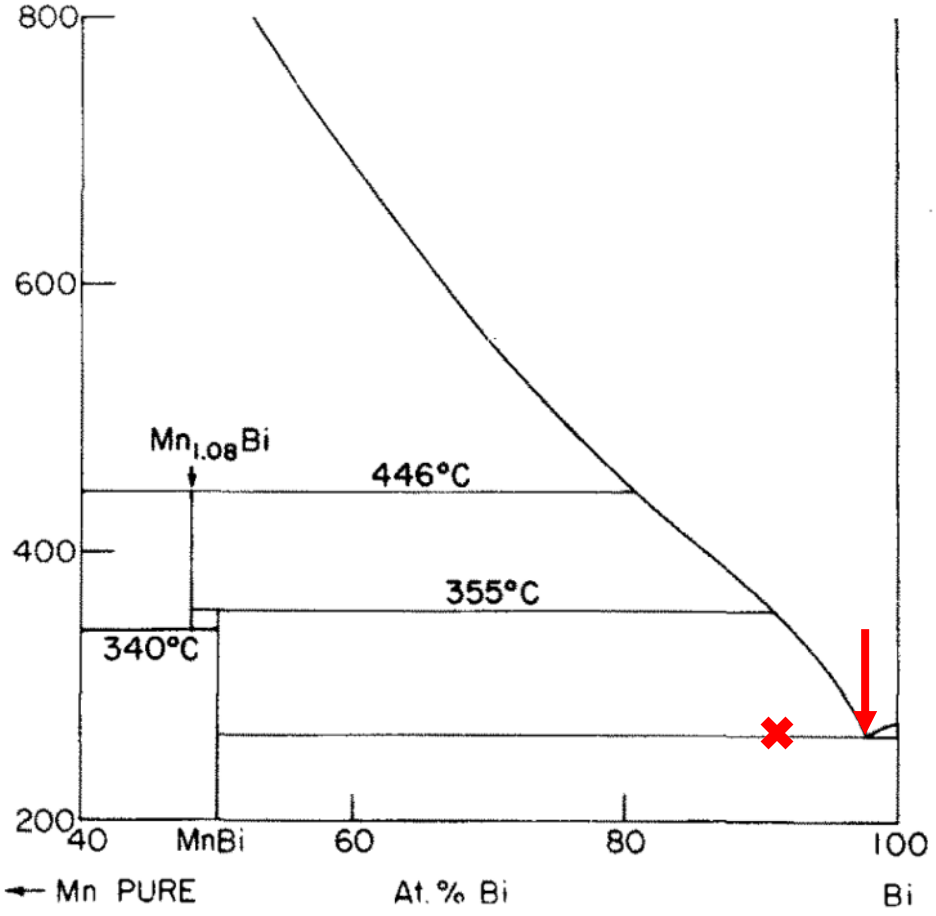

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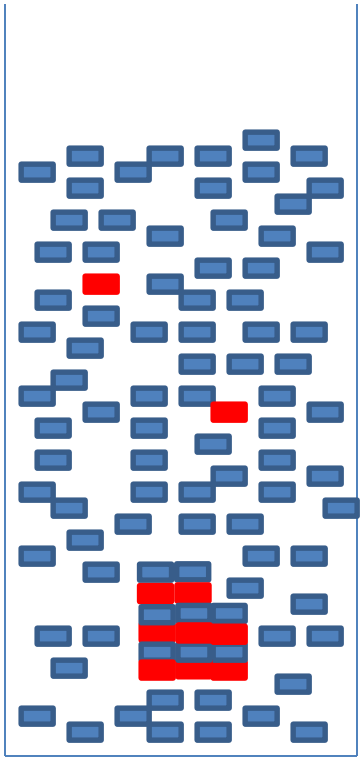
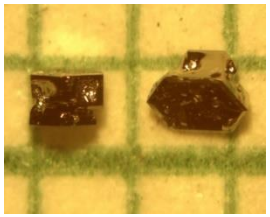
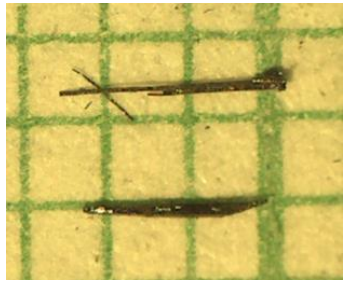
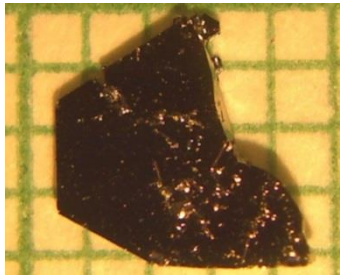




MnBi

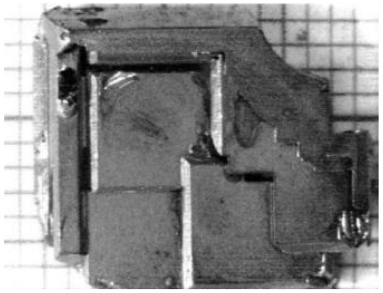


$(Mn_{0.85}Co_{0.15})_{20}Bi_{21}$

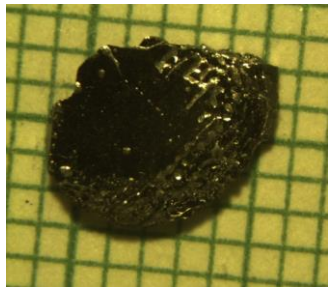


$Mn_{1.05}Rh_{0.02}Bi$

We grow many compounds to study their properties

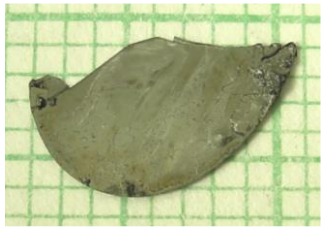


$CeCu_2Ge_2$

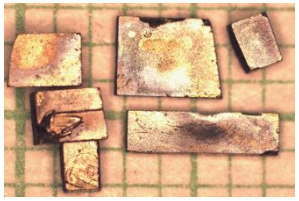


$GdCo_2Ge_2$

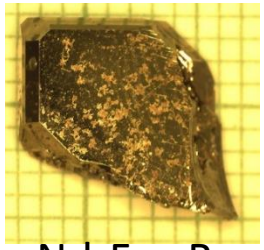
ZrMnP



$CaKFe_4As_4$

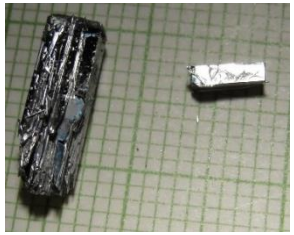


Fe_5B_2P



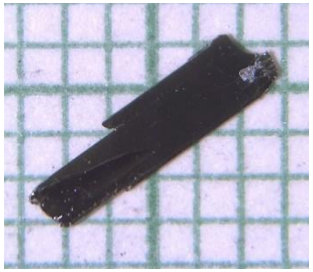
$Nd_2Fe_{14}B$

Fe_3Sn_2

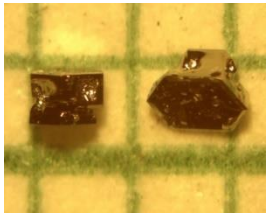


$(Fe_{0.7}Co_{0.3})_2B$

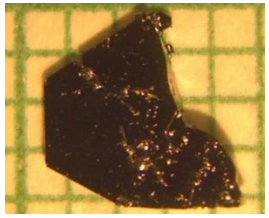
HfMnP



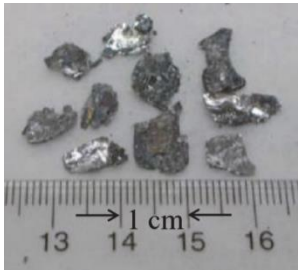
$LaCrSb_3$



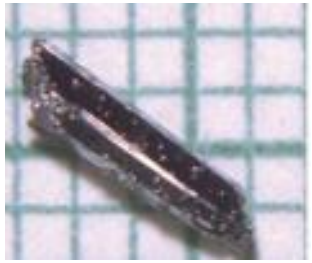
MnBi



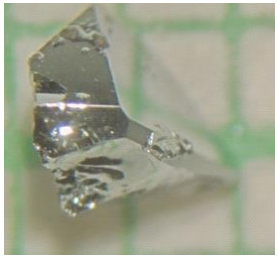
$Mn_{1.05}Rh_{0.02}Bi$



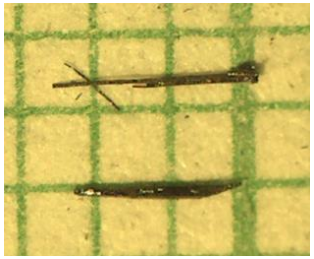
KFe_2As_2



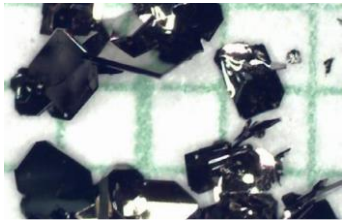
$LaCrGe_3$



$CeZn_{11}$

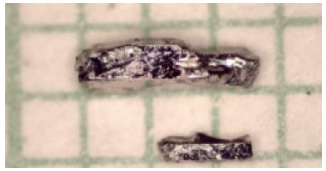


$(Mn_{0.85}Co_{0.15})_{20}Bi_{21}$



FeSe

$Bi_2Rh_3S_2$



$Rh_9In_4S_4$

your next crystal here

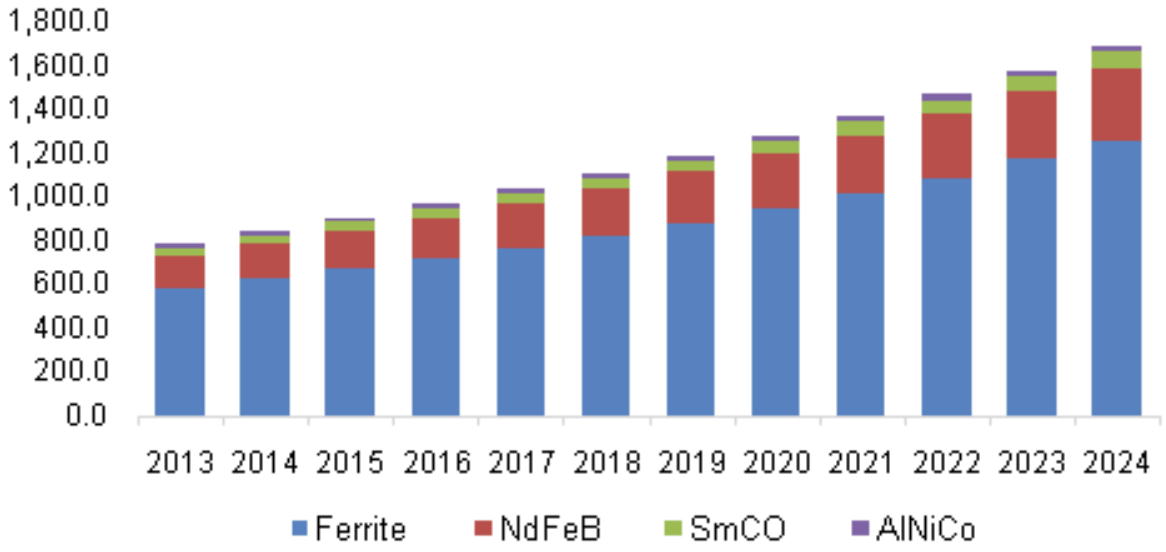
Permanent magnets market

permanent magnet market: $18,800 million by 2018

permanent magnet market report:
http://www.marketsandmarkets.com

and growing fast…

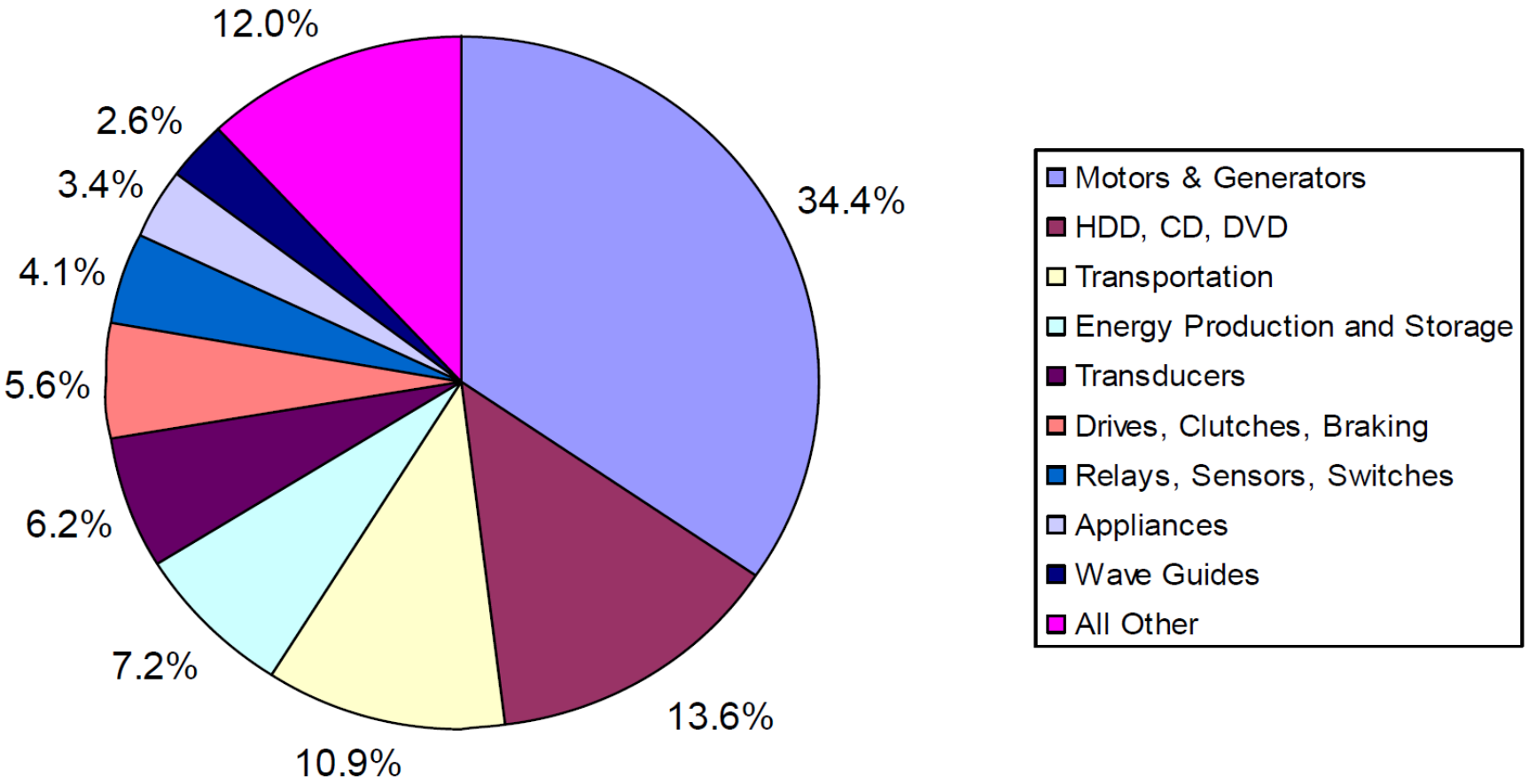
Global permanent magnet market volume (kilo tons)



http://www.grandviewresearch.com

Rare-earth magnets by applications

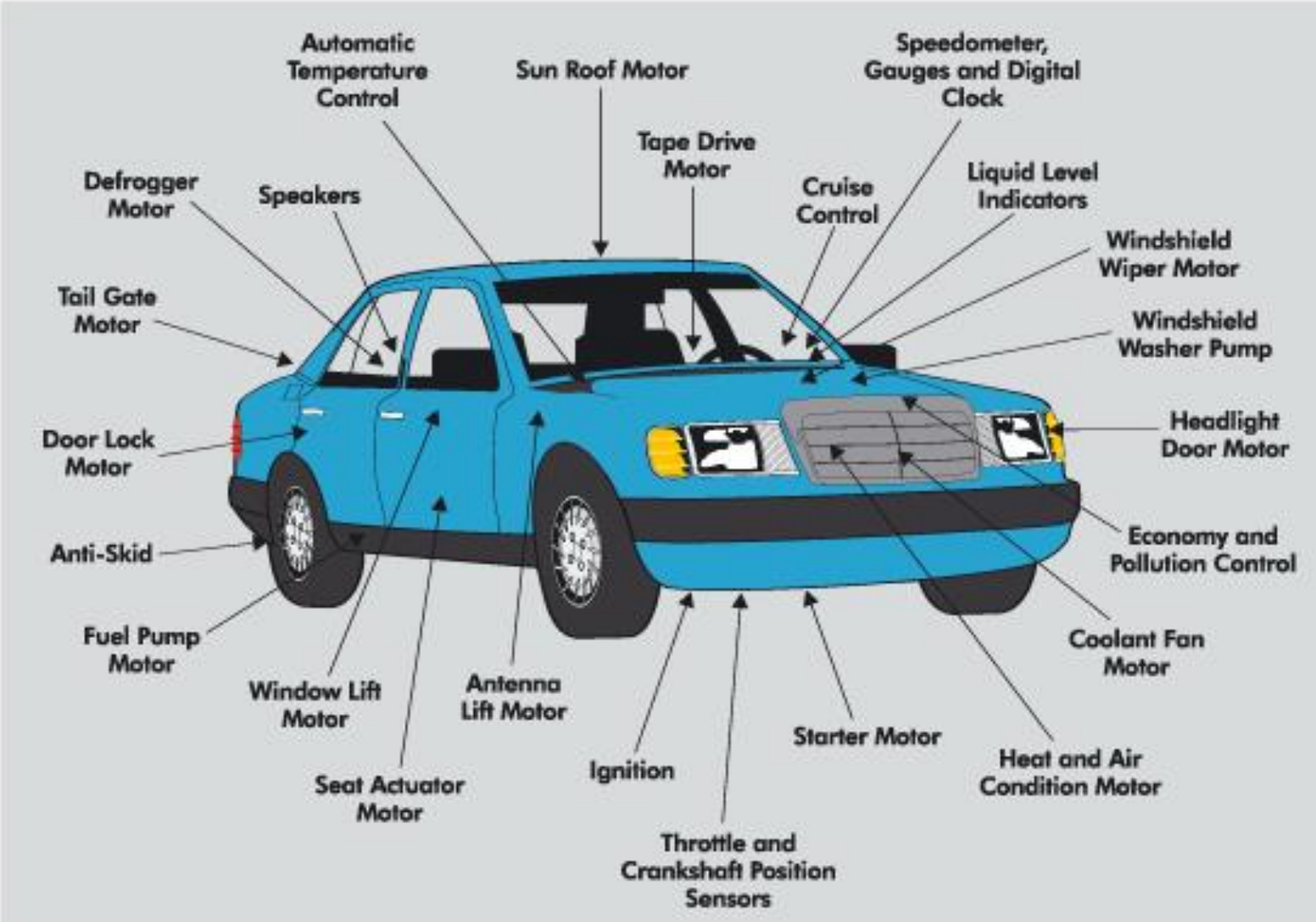
rare-earth magnets by applications (2012)



Suzanne Shaw and Steve Constantinides
8th international Rare-earth conference

Permanent magnets in cars

Example of the use of up to 100 magnets in high-quality cars



Permanent magnets in cars

electric vehicles, hybrid electric vehicles (motor systems often rely on NdFeB magnets)

Permanent magnets in wind turbines

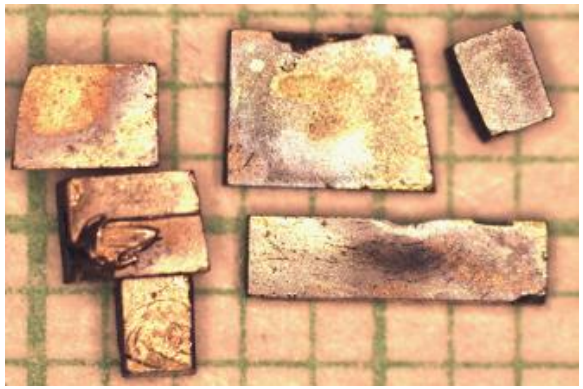
land-based

induction (no permanent magnet)
half-speed (200 kg magnets/MW)

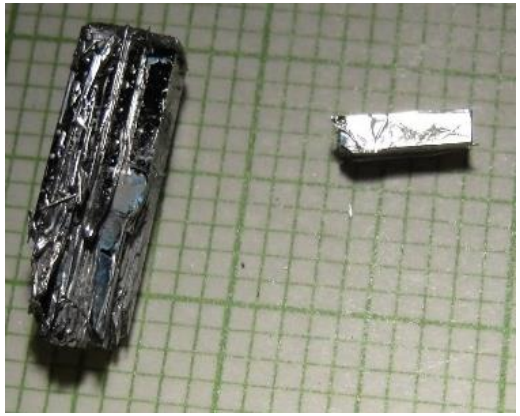
offshore

half-speed (200 kg magnets/MW)
direct drive (600 kg magnets/MW)

New Magnets

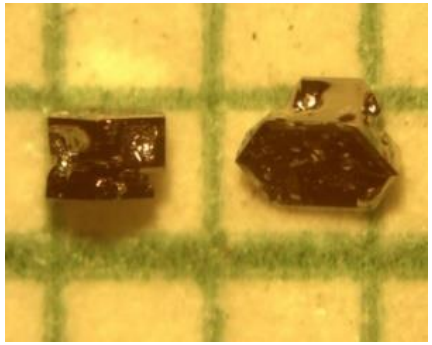


Fe_5B_2P

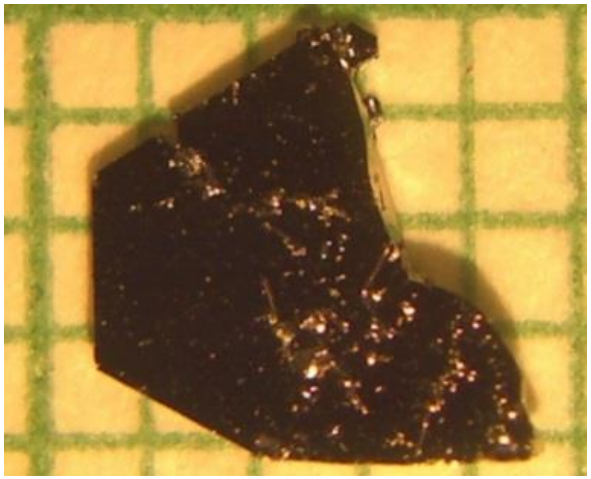


$(Fe_{0.7}Co_{0.3})_2B$

ZrMnP



MnBi



$Mn_{1.05}Rh_{0.02}Bi$

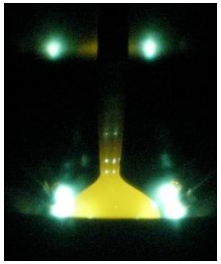
HfMnP

Critical Materials Institute
AN ENERGY INNOVATION HUB

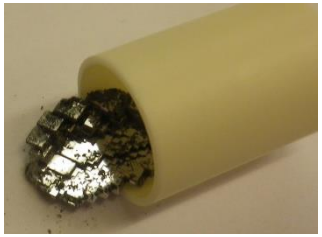
Creating and Tuning materials

chemical substitutions

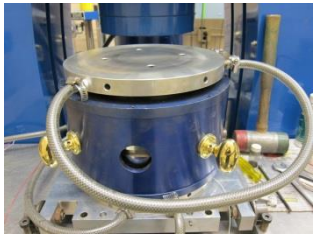
Czochralski technique



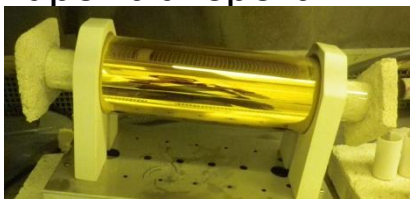
solution growth



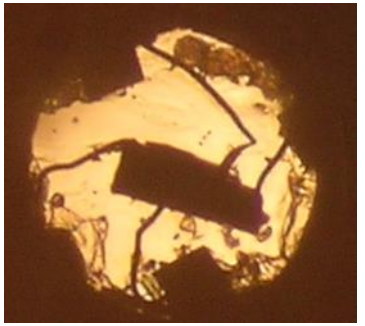
high-pressure synthesis



vapor transport



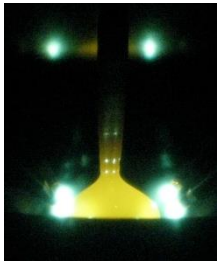
pressure



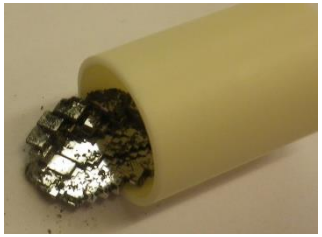
Creating and Tuning materials

chemical substitutions

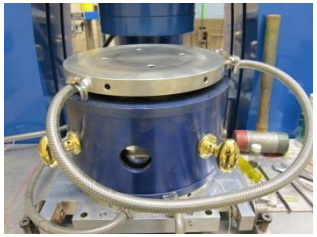
Czochralski technique



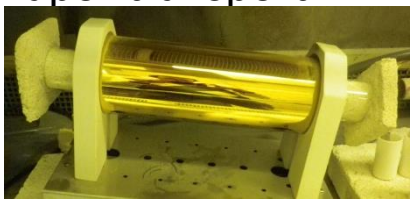
solution growth

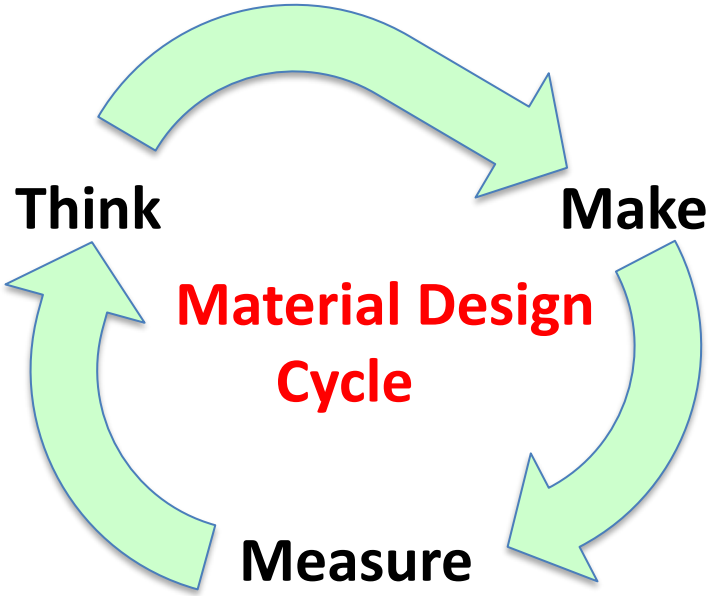


high-pressure synthesis

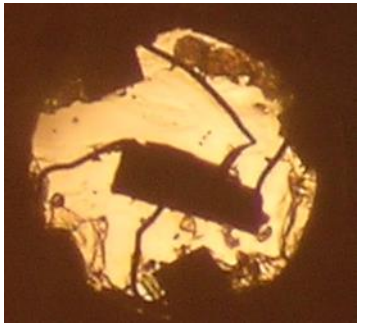


vapor transport





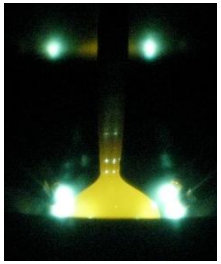
pressure



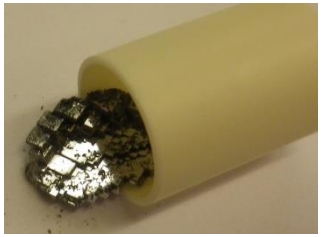
Creating and Tuning materials

chemical substitutions

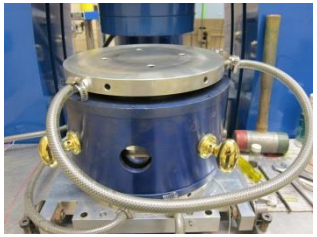
Czochralski technique



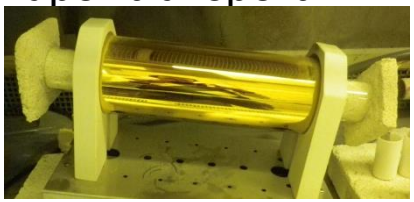
solution growth

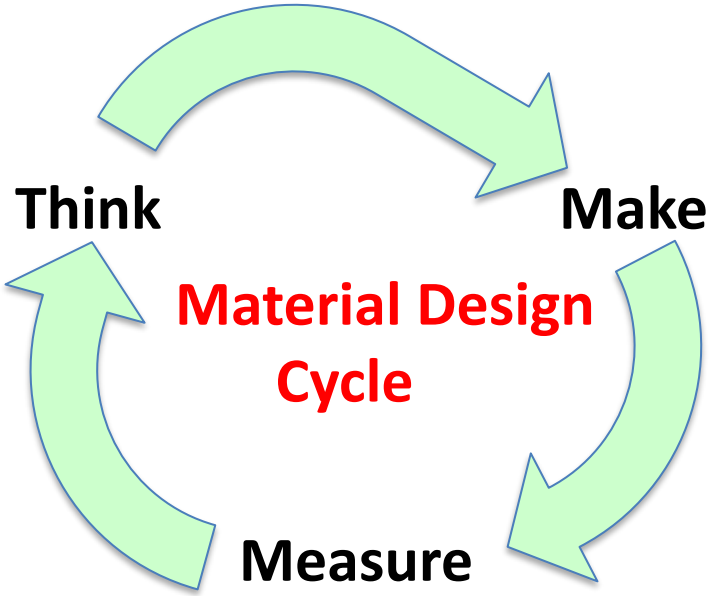


high-pressure synthesis



vapor transport





Thank you for your attention!

pressure