NIS colloquium

X-ray induced modifications in materials: applications and challenges, 6-7 April, 2017, Torino

National Institute of Materials Physics

Bucharest-Magurele, Romania

http://www.infim.ro

Materials Research at National Institute of Materials Physics

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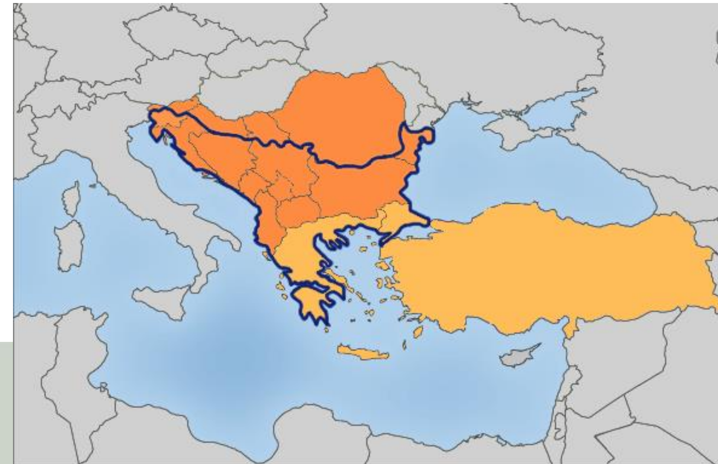
Romania: East of Europe, North of the Balkan Peninsula



Located: ~17 Km south from the Bucharest city center and ~150 Km from Dracula Castle

Magurele Science Hub

1. ‘Horia Hulubei’ National Institute for Physics and Nuclear Engineering (includes Extreme Light Infrastructure – Nuclear Physics)

2. National Institute for Laser, Plasma and Radiation Physics (includes Institute of Space Science)

3. National Institute for Earth Physics

4. National Institute for Optoelectronics – INOE 2000

History: **Institute of Physics of the Romanian Academy of Science 1949**

Labs:

10. Multifunctional Materials and Structures Laboratory

20. Laboratory of Magnetism and Superconductivity

30. Nanoscale Condensed Matter Laboratory

40. Optical Processes in Nanostructured Materials

50. Laboratory of Atomic Structures and Defects in Advanced Materials

60. Certified Laboratory for chemical analysis of advanced materials (XPS)*

***** - it is not an administrative entity***

Fields of interest:

1. Cond matter – phenomena and processes in nano-dimensional, surface and interface systems
2. Synthesis and characterization of nanomaterials and nanostructures
3. Functional materials and structures with technological impact

A: Fundamental studies cond. matter

1. Dimensional effects in nano-objects and cuantic layers
2. Surfaces and interfaces in structured materials
3. Electronic correlations and magnetic interactions
4. Computational modeling and simulation of the dynamics microstructures
5. Interaction between matter and radiation at micro and nano scales

B: Multifunctional nanostructures and materials

1 – Materials for energy (generation, transport, conversion, storage)

2 – Materials for applications from the high tech industry (materials for high frequency electronics MW, THz, materials for optoelectronics, transparent electronics, materials for non-volatile memories, sensors for automatization and control)

3 – Materials for applications in biomedicine and environment protection (biocompatible and biofunctional materials, bio and chemical sensors and foto-catalysts)

Laboratory of Magnetism and Superconductivity

Processing:
- -arc and induction furnaces
- -melt spinning,
- -r.f. sputtering, PLD
- - Planetary mills
- -spark plasma sintering
- -microwave sintering
- -hot press sintering
- -high temp furnaces
- -rolling/drawing machines
- -high purity glove box

Characterization:
- -SQUID magnetometry,
- -PPMS including transport and magneto-conduction, VSM
- -Nuclear gamma resonance (Mossbauer)
- -DSC, heat capacity and flash calorimetry
- -Gas reaction controller with gas absorption/desorption

Nanostructures responding to *magnetic* excitations.
Fundamentals and applications.

1. *Magnetic nanostructures for permanent magnets*
   - Exchange-spring magnets (nano-composites and multilayers).
   - Nanostructures with shape anisotropy
   - Molecular magnets, spin frustrated systems

2. *Magneto-functional nanostructures*
   - Magneto-conductive nanostructures (spin valves, exchange bias bilayers, surface and interface spin configurations in thin films and multilayers
   - magneto-elastic, magneto-caloric, shape memory alloys
   - Multi-functional nanostructures (heterogenous structures interfacing at least one magneto-functional material)

3. *Nanoparticles dispersed in various media*
   - Magnetic nanoentities dispersed in metallic/semiconducting/polimeric matrices. Functionalized nanoparticles., biomagnetic.
   - Magnetic nanofluids

Superconducting structures.
Fundamentals and applications.

1. *MgB2 based nanocomposites*
   - Spark Plasma Sintering and Microwave Sintering
   - Additions, substitutions, nanocomposites *(pinning engineering)*
   - Characterization, pining and vortex dynamics models
   - Application of X-ray tomography for 3D visualization of MgB2 (collaboration with INFLPR)
   - Bulk magnets, storage, concentrators and other devices
   - Wires and tapes
   - Irradiation and ion inplantation
   - Biomedical properties and applications of MgB2

2. *HTS based structures*
   - Nano-dots and nano-objects for pinning in HTS and other purposes *(pinning engineering)*
   - Composite heterostructures: growth principles, pinning fundamentals, vortex dynamics
   - Whiskers growth, characterization and application

3. *Novel and exotic superconductor; search for new superconductors, 2DEG superconducting interfaces*
   - Li2(Pd,Pt)3B: synthesis and physics
   - Fe-Se-Te and other Fe-based superconductors: vortex dynamics
   - oxide superconducting interfaces

4. *Nb-based superconductors: vortex dynamics*

Synthesis and processing of materials can be defined as:

Materials + (fields or particles) =

new materials and/or new properties and/or new functionality

‘Fields’ or particles: electrical, magnetic, thermal, optical, …..

The key question

How to introduce (pump) in a controlled manner energy into a material for its modification?

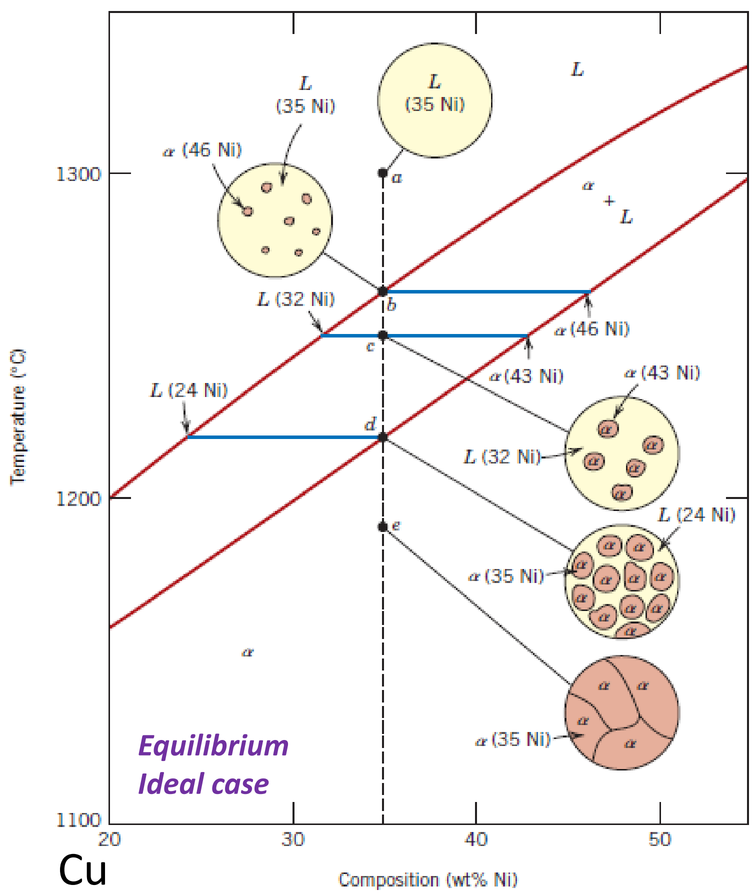
- Energy order of magnitude depending on purpose?
- Volume and time scale (equilibrium, non equilibrium) ?
- Energy pumping pattern (e.g. pulsed: on/off) ?
- Material / structure to be modified and its relationship to the field/particle ?

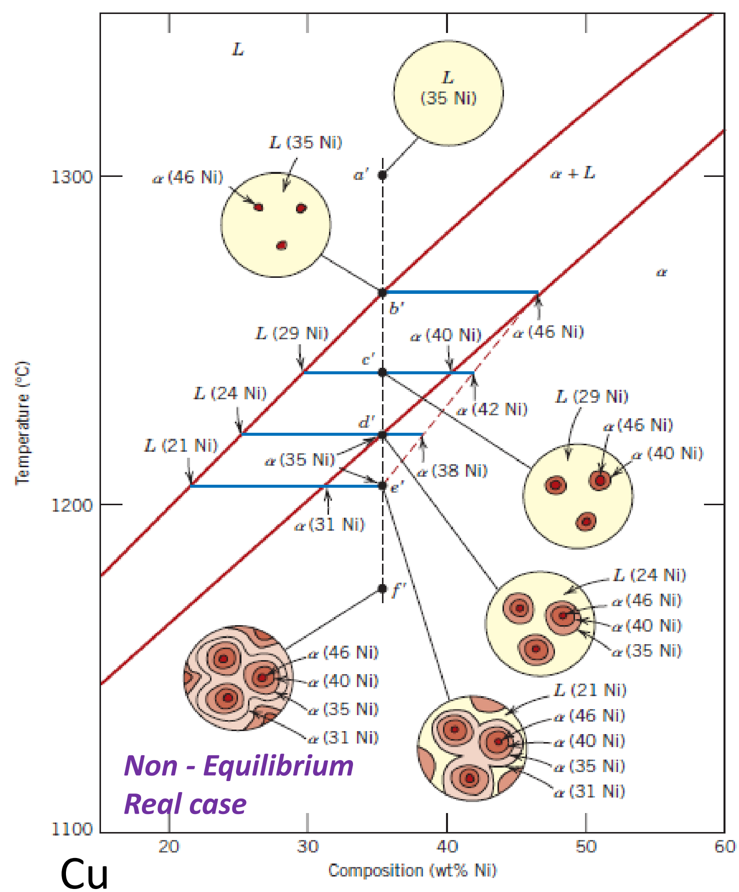
Unconventional and far from equilibrium novel technologies

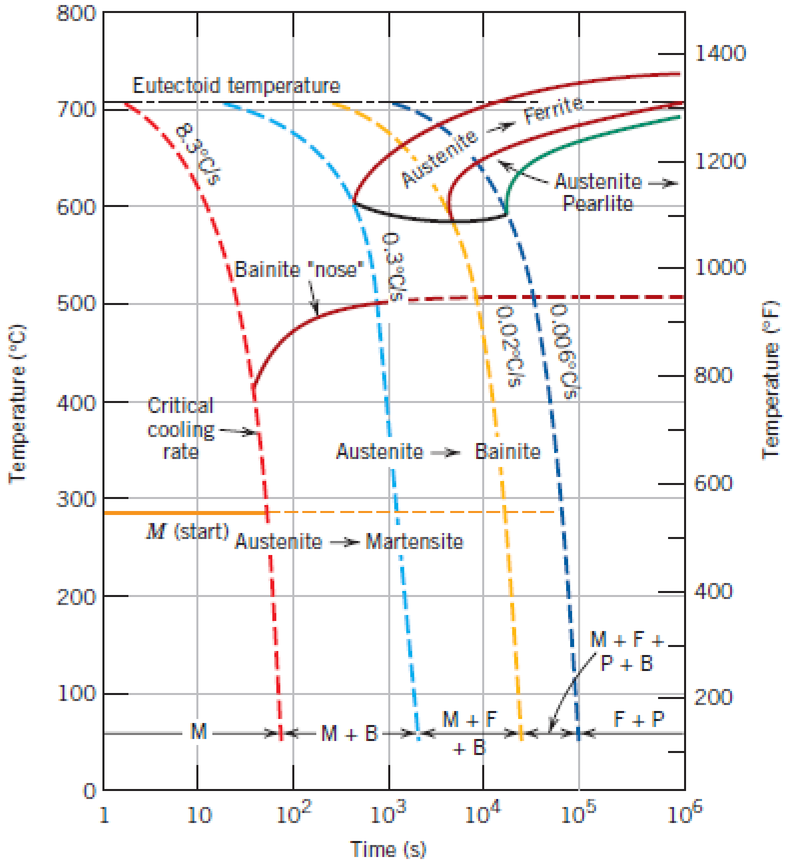
X-ray based technologies

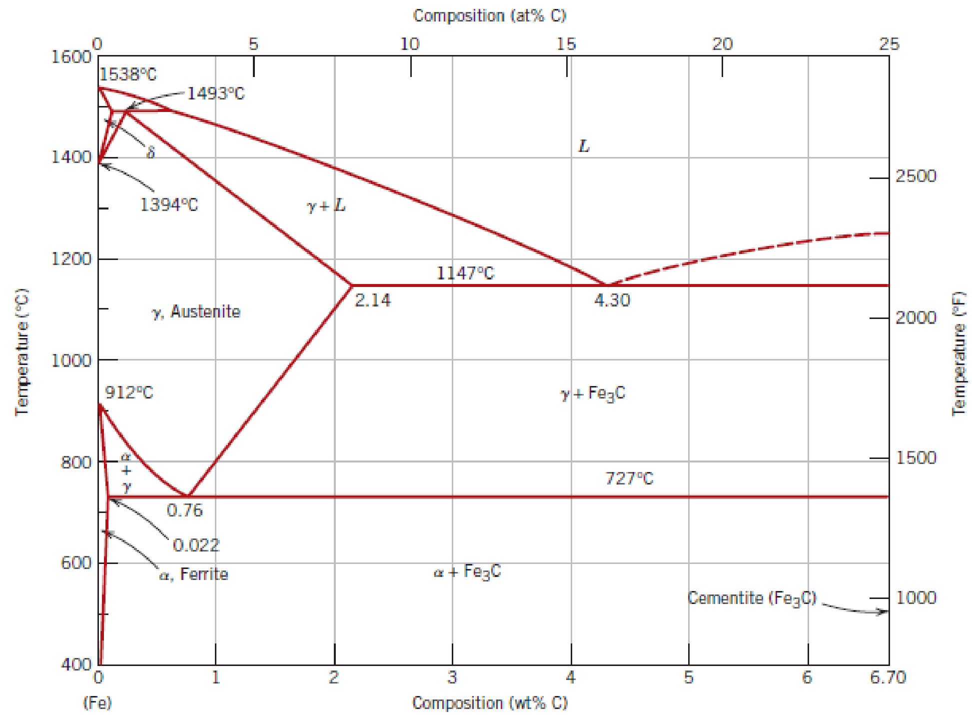
Solid solution

WD Calister Jr and DG Rethwisch, Materials Science and Eng, An Introduction, Wiley, 8th Edition









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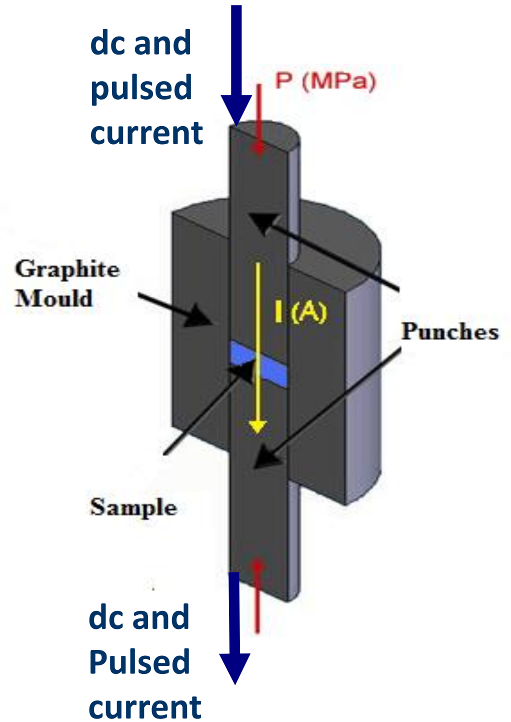
Spark Plasma Sintering (SPS)



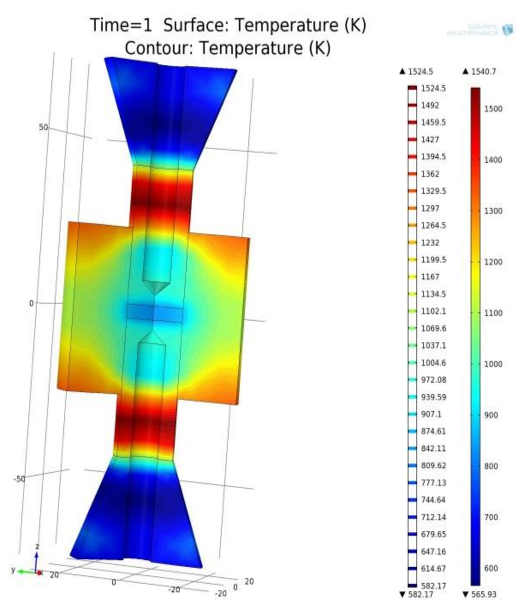
Thermal and non-thermal (debatable) particular features

– rapid heating, cooling (resistive heating)
- activated diffusion (electrodifussion?) leading to 'boundary cleaning'
- Discharges and occurence of plasma states (?): modified boundaries
-hot spots, heating from inside to outside as for MW heating (?)
-moderate or high pressures can be applied

Consequences:

-preserves nano-size,
-high density bulks (especially important for difficult to sinter materials)
-short processing times,
-technique far from equilibrium possibly introducing defects
- Metastable, new or difficult-to-synthesize phases are obtained

Temp distribution at 867 deg. C (Cu)

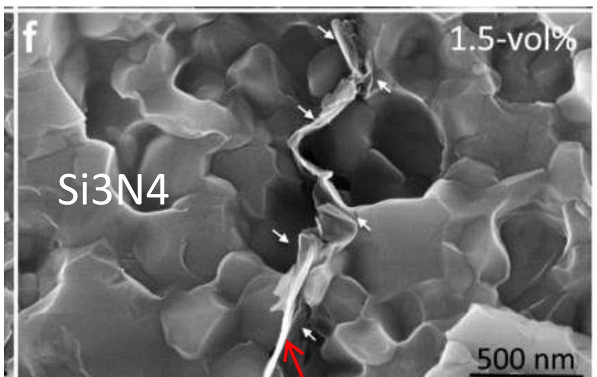


FCT-5, Germany

Literature

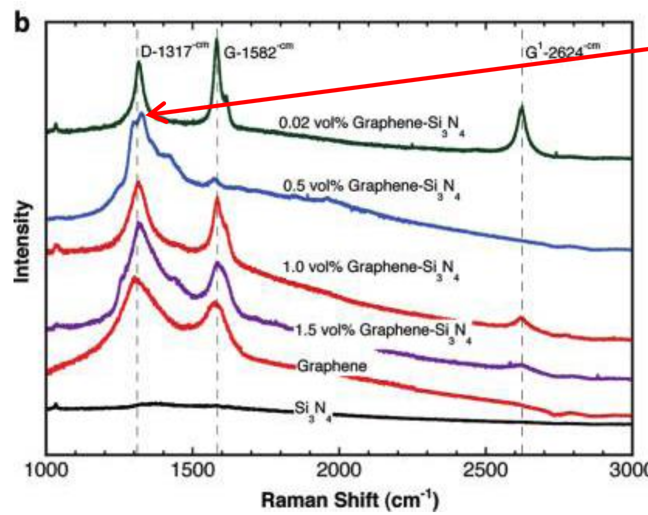
-SPS can result in formation of phases not available in normal conditions!

Diamond !!?



graphene

SPS

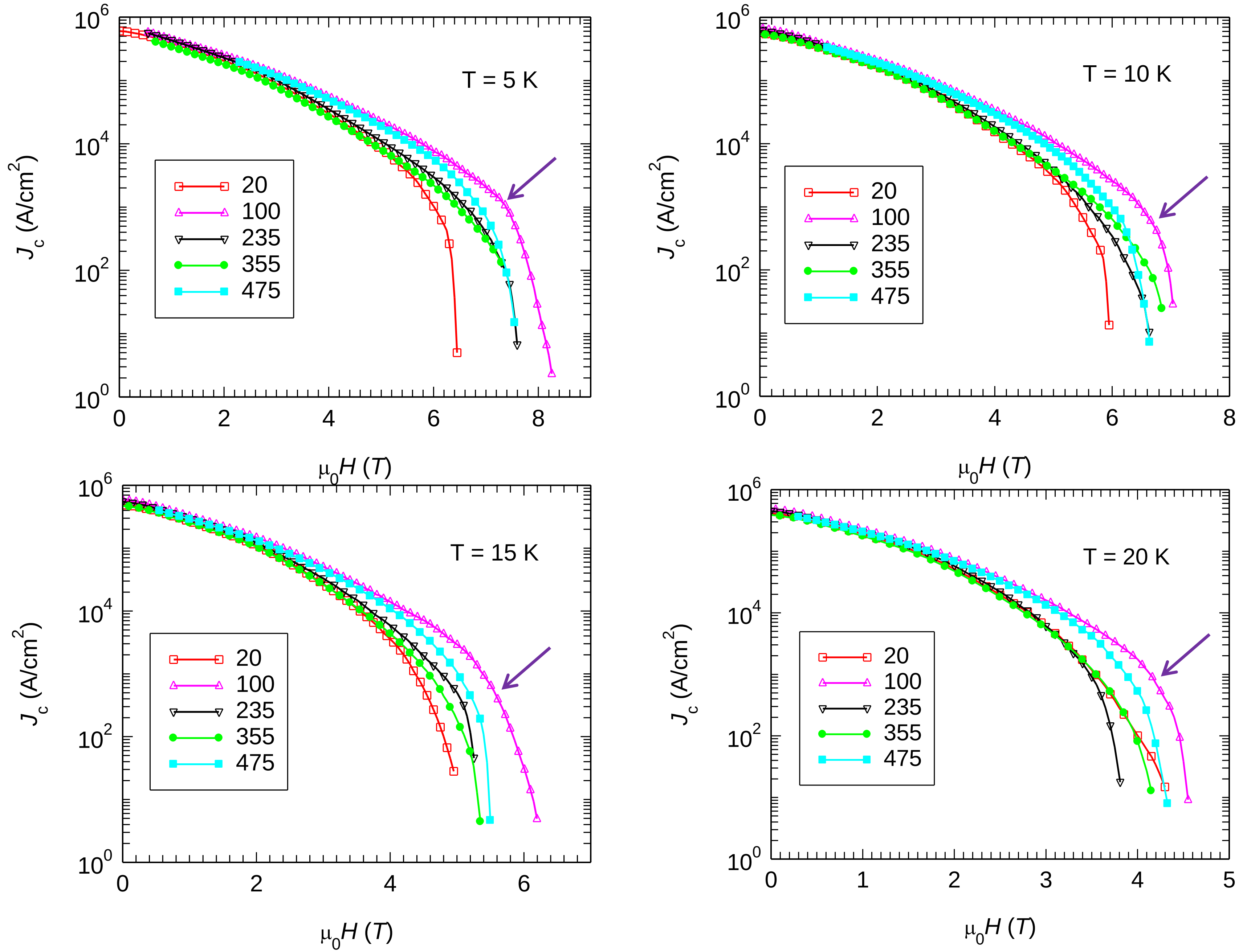


ACS Nano 5 3182 2011

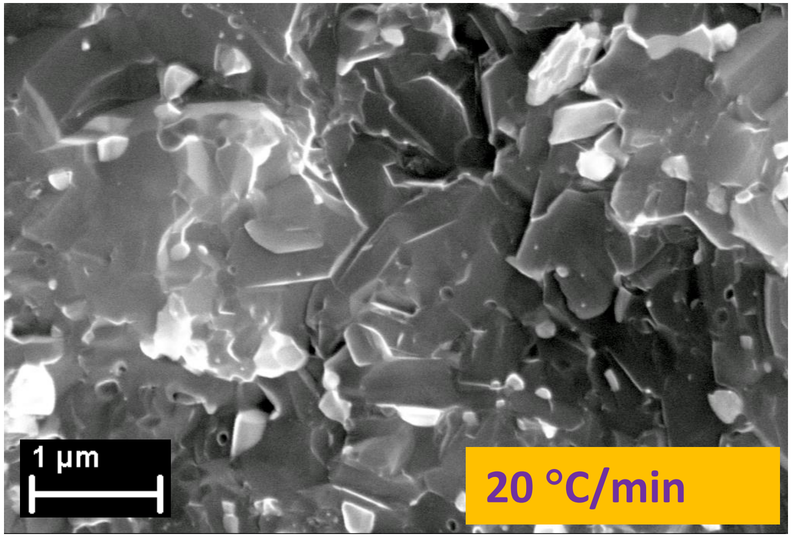
Samples (we use MgB2 commercial powder)
Heating rate

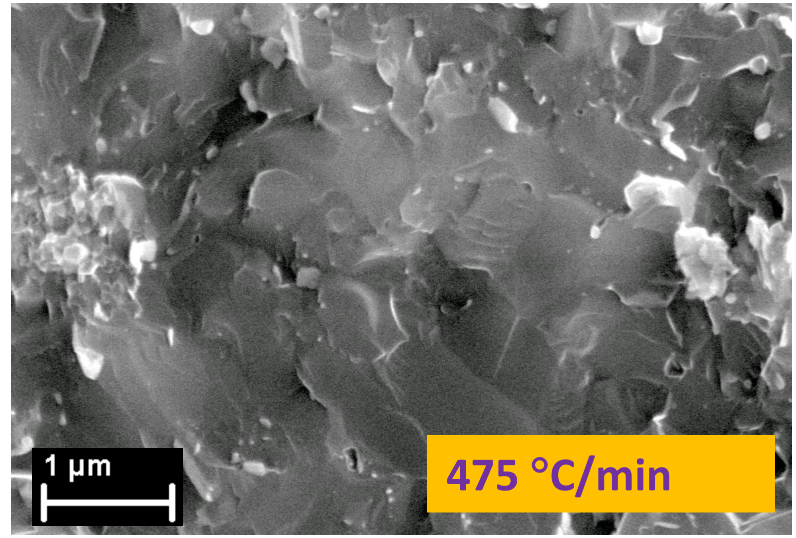
Sample	Heating rate (°C/min)	Apparent density ρa^{SPS}/ R^{SPS} [g/cm^3]/[%]	Lattice parameter for MgB_2		Average crystallite size of			Content wt [%]	
			a [Å]	c [Å]	MgB_2 [nm]	MgO [nm]	MgB_4 [nm]	MgO	MgB_4
pw	Powder MgB_2	-	3.0866	3.5226	75 ±7	-	-	-	-
'20'	20	2.64/99.3	3.0811	3.5249	175 ±41	77 ±1	70 ±20	8.1	13.6
'100'	100	2.54/95.1	3.0824	3.5270	143 ±38	100 ±12	77 ±25	8.1	11.6
'235'	235	2.64/99.0	3.0819	3.5264	177 ±57	84 ±10	74 ±17	8.1	13.6
'355'	355	2.65/99.5	3.0819	3.5253	190 ±60	78 ±3	71 ±22	7.1	11.1
'475'	475	2.64/99.0	3.0823	3.5260	121 ±25	70 ±5	68 ±18	6.9	11.0

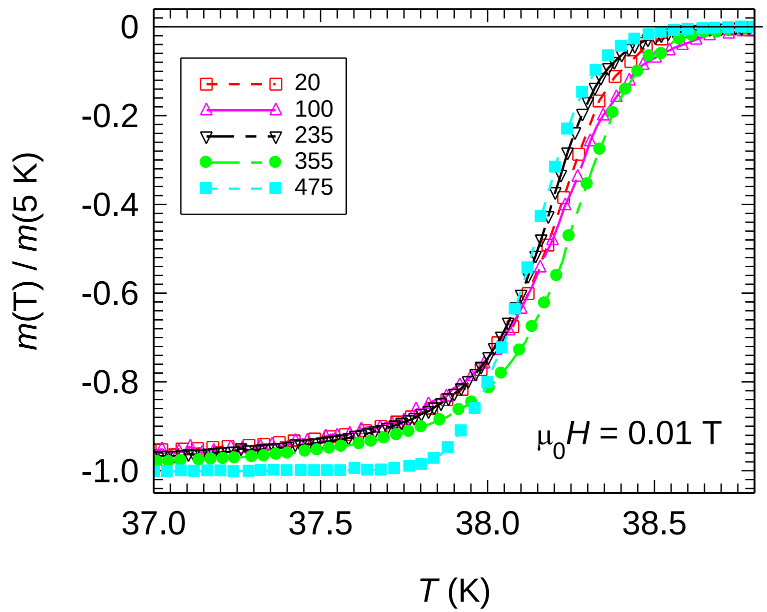
*Crystallite size is shown for a comparative analysis, considering that Williamson-Hall method is not reliable above 100-150 nm.



T = 5 K
T = 10 K
T = 15 K
T = 20 K
20
100
235
355
475
J_c (A/cm^2)
μ_0H (T)







Physica C, 519, 184, 2015

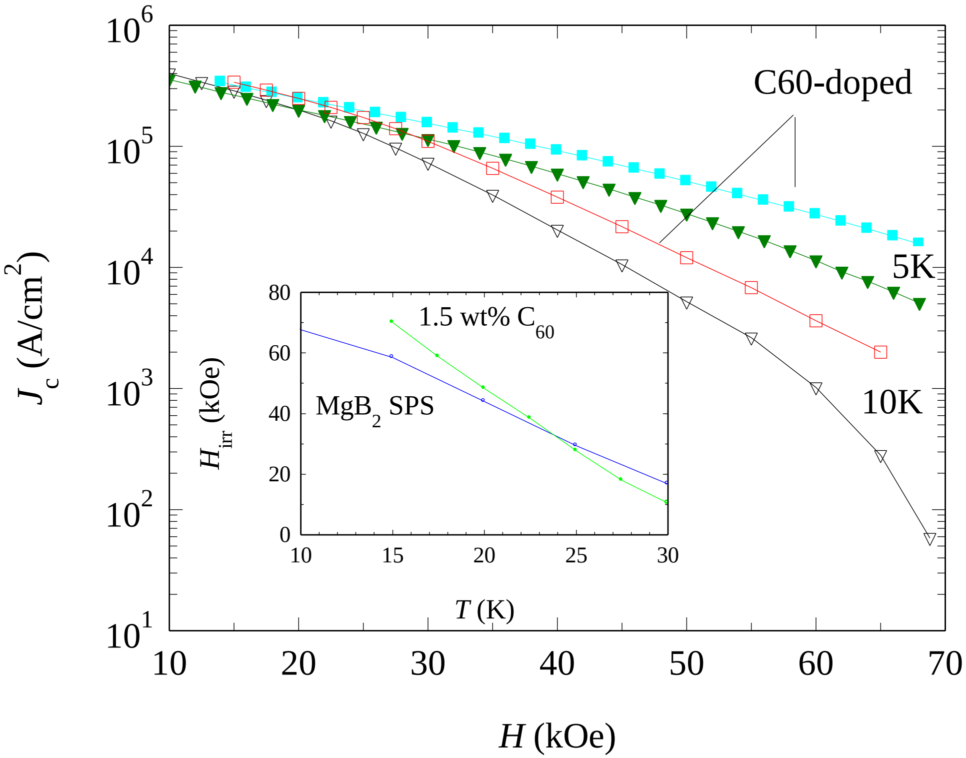
There is an optimum heating rate of ~100 °C/min to maximize J_{c0}, H_{irr}, (J_{c0} x H_{irr}), and to partially avoid formation of undesirable flux jumps at low temperatures.

MgB_2 by SPS for different on / off pulsed pattern of the current (work in progress)

MgB$_2$ added with C60 by SPS

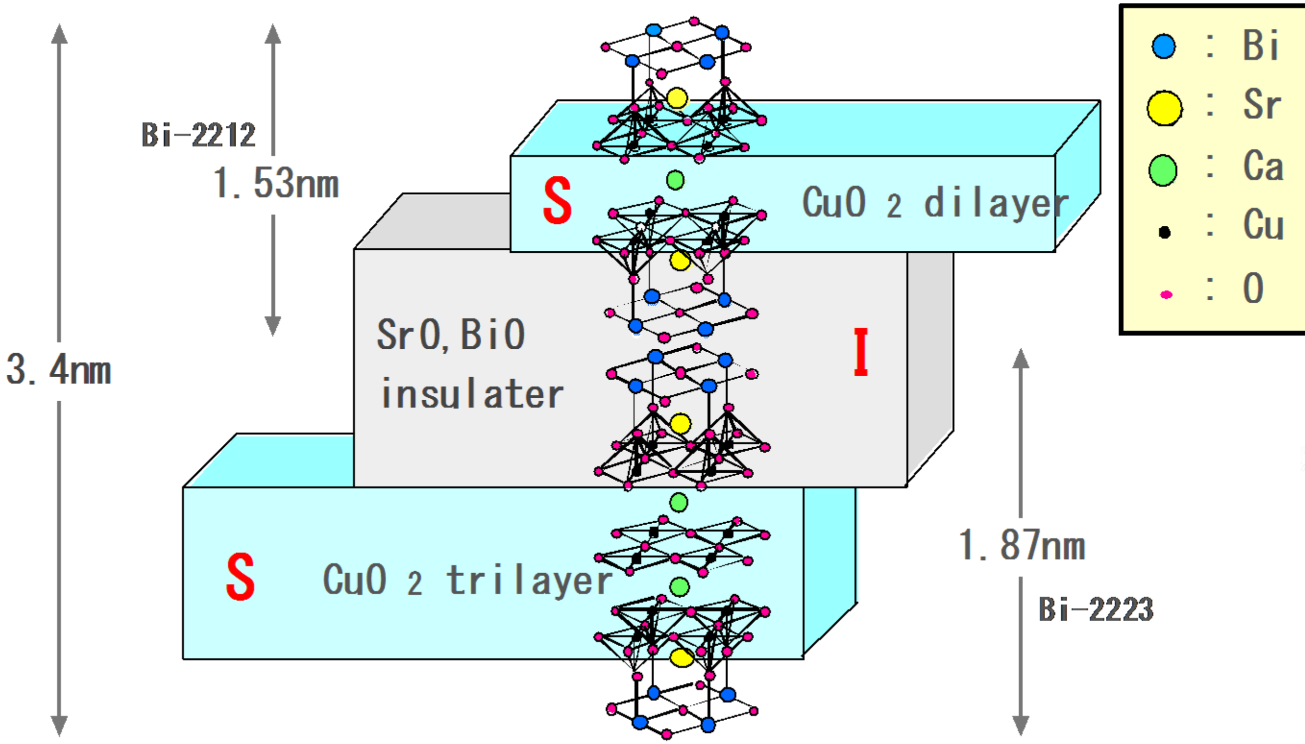
Use of graphene C60 was not successful to produce substitution effects of C for B;

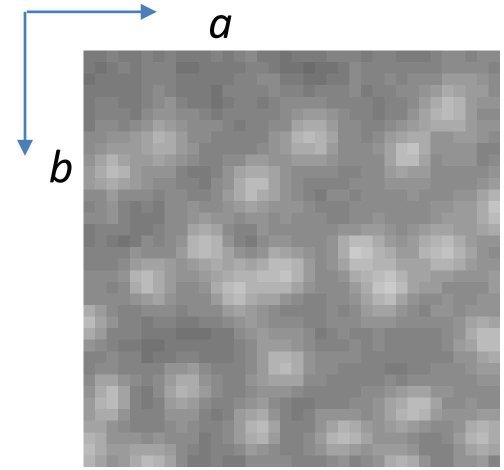
Jc was constant (Lim HJ et al, Phys C, 2008, 468 18)

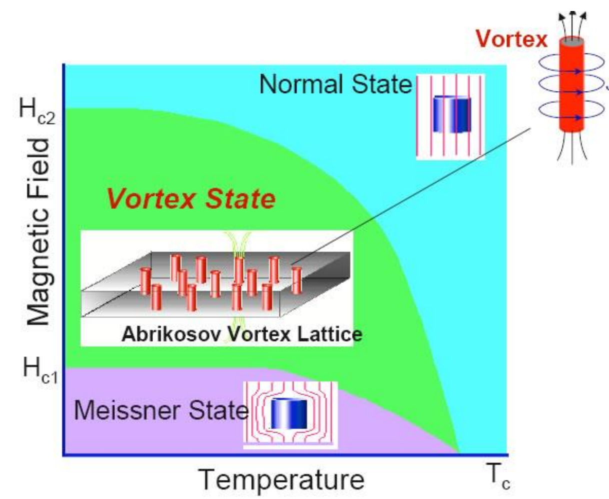


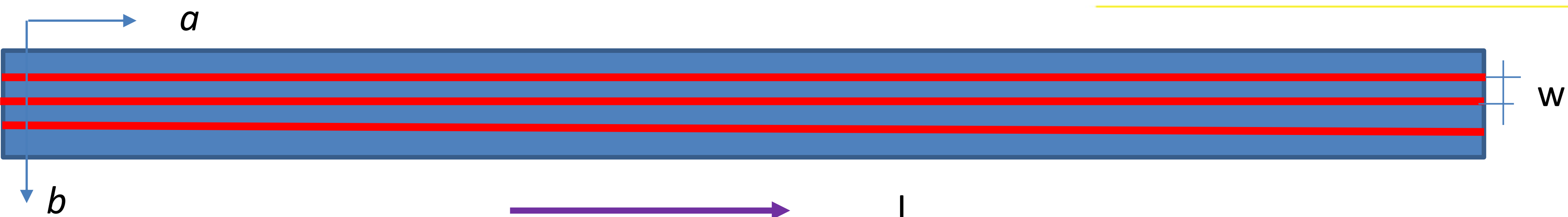
Supercond Sci Technol 23 (2010) 095002

ξ<w<λ









conductor

Diameter of nucleus D ≈ 1/H² (Derango, P. et al *Nature* 1991, *349*, 770)

Superconducting Bi-2212 whiskers

Orientation: **(H>0T)**
-Bi-2212 only *a*-axis ⊥H.

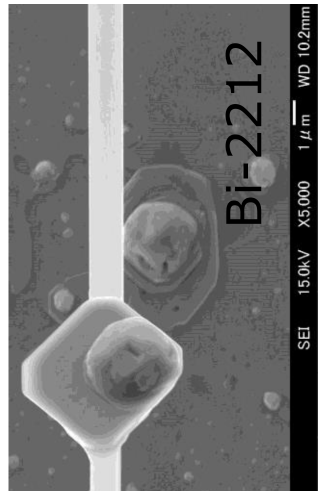
Size: **(H>0T)**
-aspect ratio (length/width) *is decreasing*.
-maximum length and thickness
-are *decreasing*
(*10 - 40 times lower than average at H=0T)*

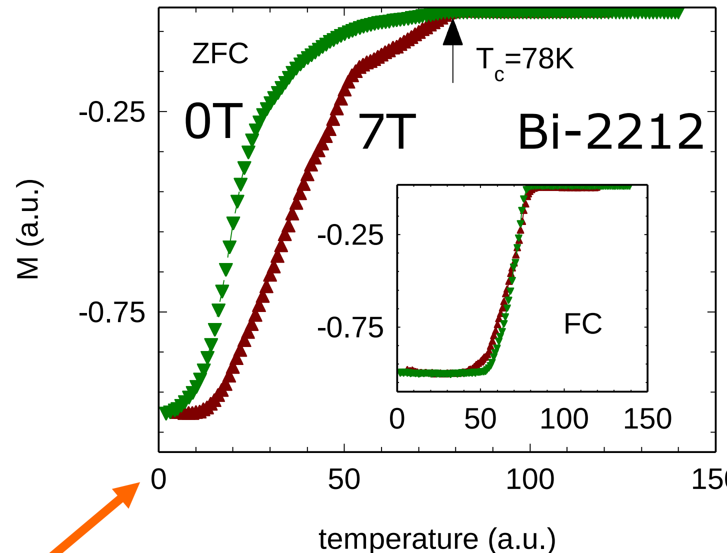
Output: **(H>0T)**
-is *lower*

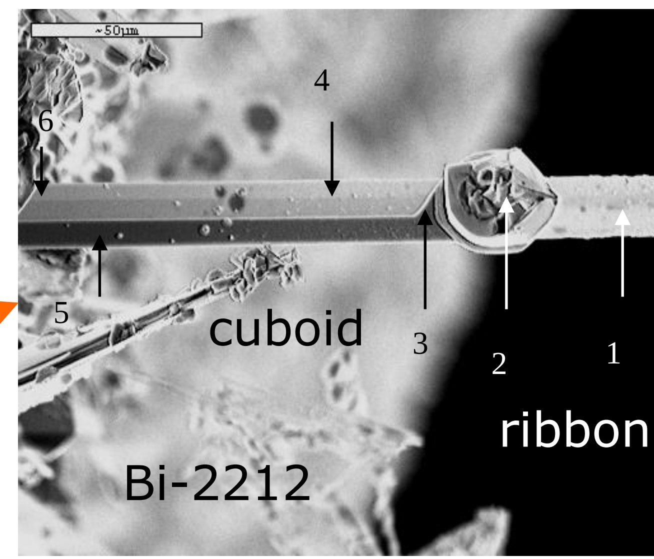
Defects: **(H>0T)**
- *less*: less stripes and layers

Crystal quality: **(H>0T)**
- *narrower* transition

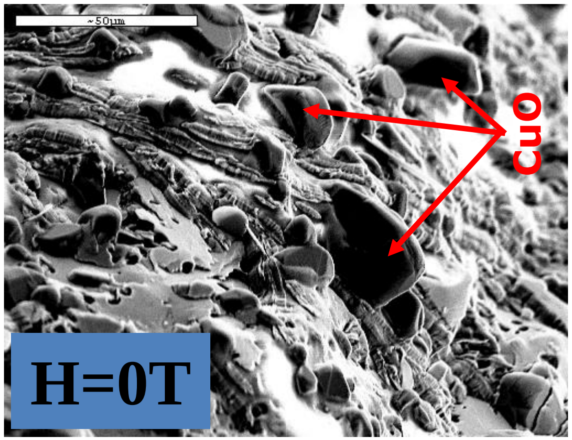
Morphology: **(H>0T)**
- *cuboid* is possible

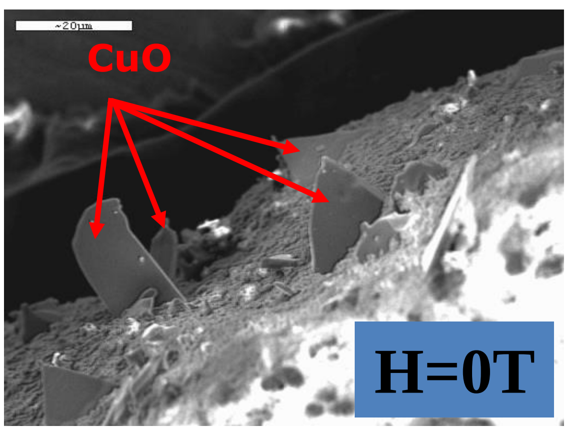




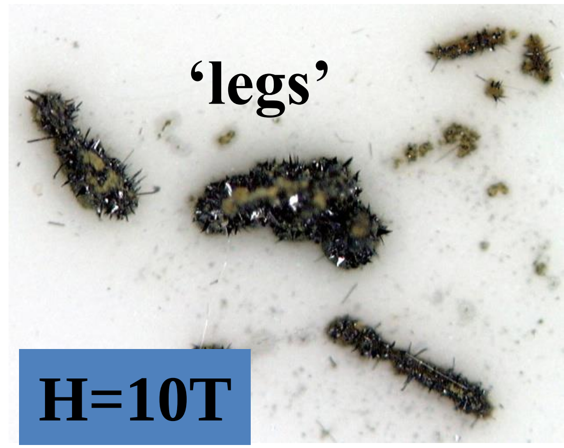


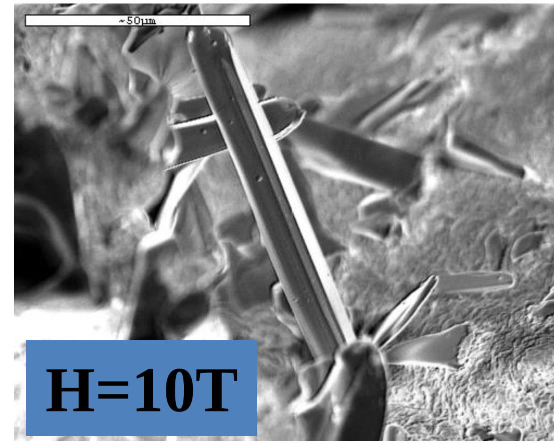
CuO whiskers

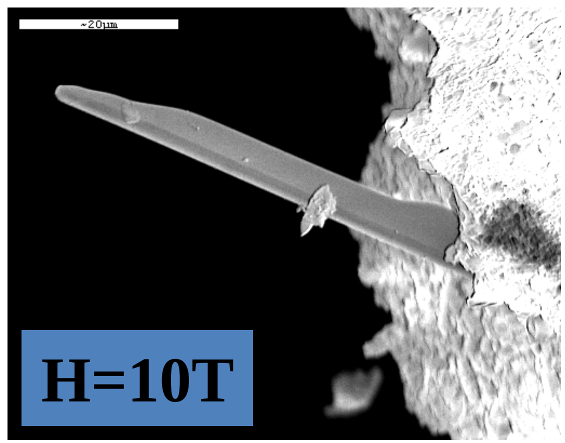


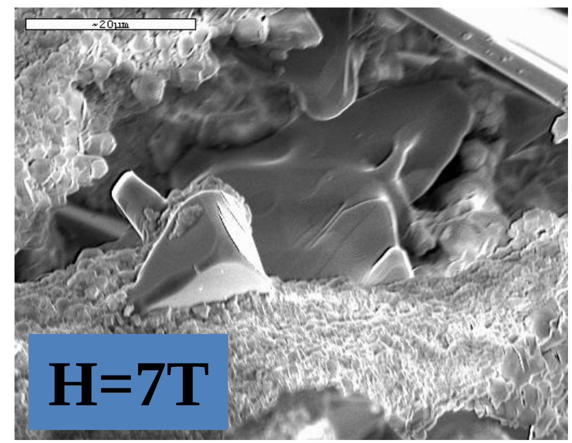


2D or 3D growth









1D growth under H

MoO3 whiskers
- gas sensing in breadth analysis
- pseudocapacitive materials with insertion/removal of Li

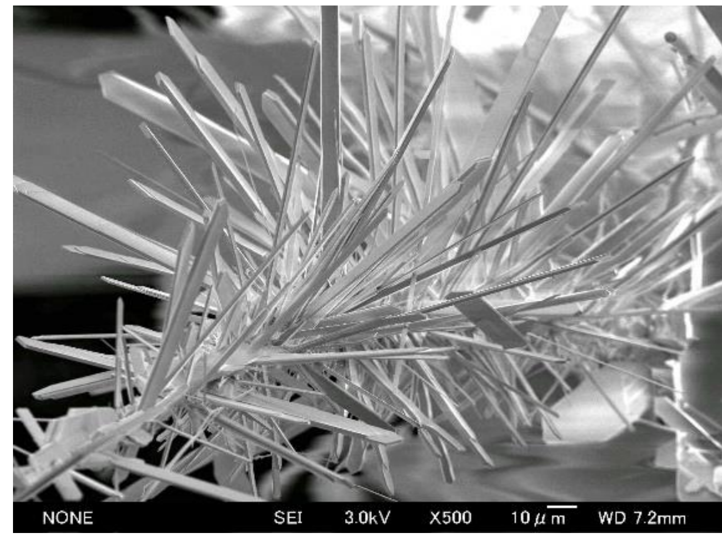
LaSrMnO3 – films by PLD -magnetic

ZnO (Mn) diluted magnetic films by sputtering

CeO2-Tb/Yb grown by PLD
for optical purposes and conversion in solar cells

(Sr, Ba)TiOx for MW and THz

Bi2(Sr, Ca)2Co2Ox thermoelectric whiskers



Thank you for your attention !!!!