Nano-engineered Magnetic Pinning Centers in High Temperature Superconducting Epitaxial Thin Films

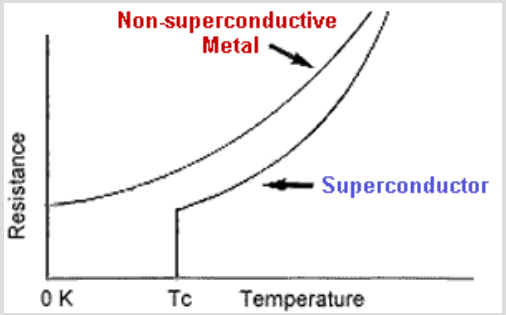
“MAGPIN”

Traian Petrișor Jr.

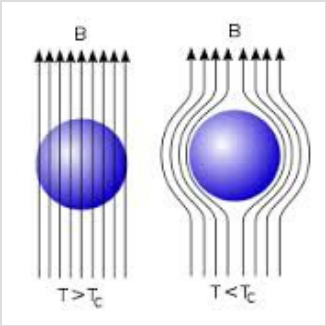
Technical University of Cluj-Napoca
Centre for Superconductivity, Spintronics and Surface Science (C4S)

Superconductivity

- Zero electrical resistivity below a critical temperature

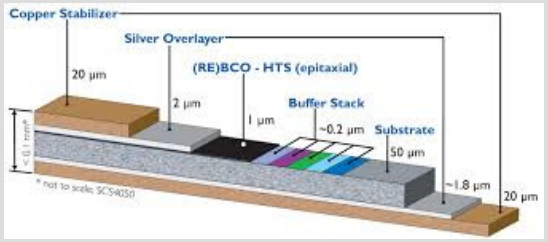


- Magnetic field expulsion (Meissner effect)

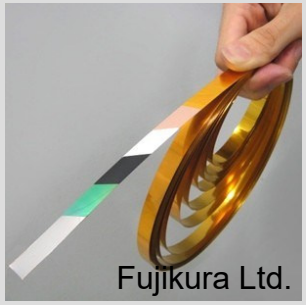


High temperature superconductivity, *e.g.* $YBa_2Cu_3O_7$ Tc = 92 K (-181 °C) (liquid nitrogen cooling, 77 K (-196 °C))

Applications: **Power cables (coated conductors)**, Generators, Motors, Energy storage



SuperPower Inc.

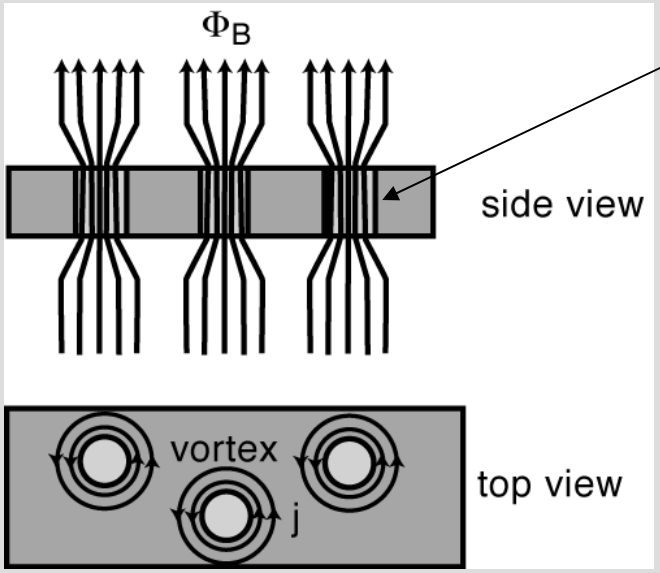


Fujikura Ltd.

American Superconductor Inc.

dmcdi
Departamentul pentru Managementul Cercetării, Dezvoltării şi Inovării

- Maximum current density carried by a superconductor (type II) is limited by the motion of ***vortices***

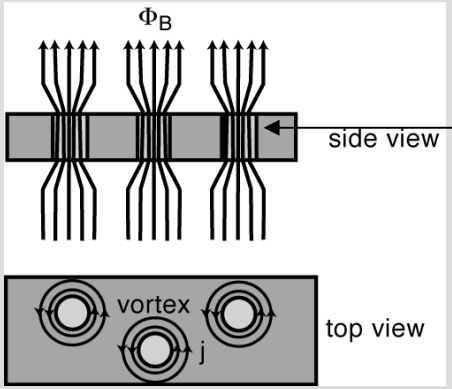


Vortex → Normal core
Vortex → Magnetic moment

Improve the current transport capabilities of a superconductor

Stop vortex motion

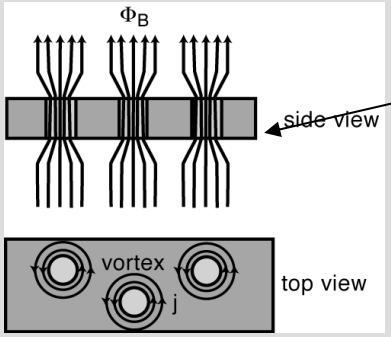
Stop vortex motion



Vortex

- Normal (not superconducting) core
- Magnetic moment

Stop vortex motion (vortex pinning)

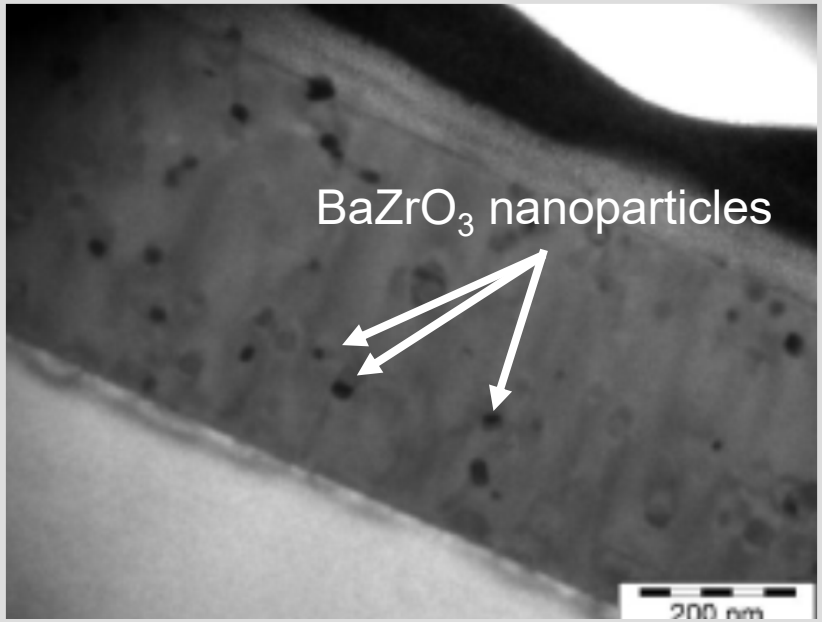


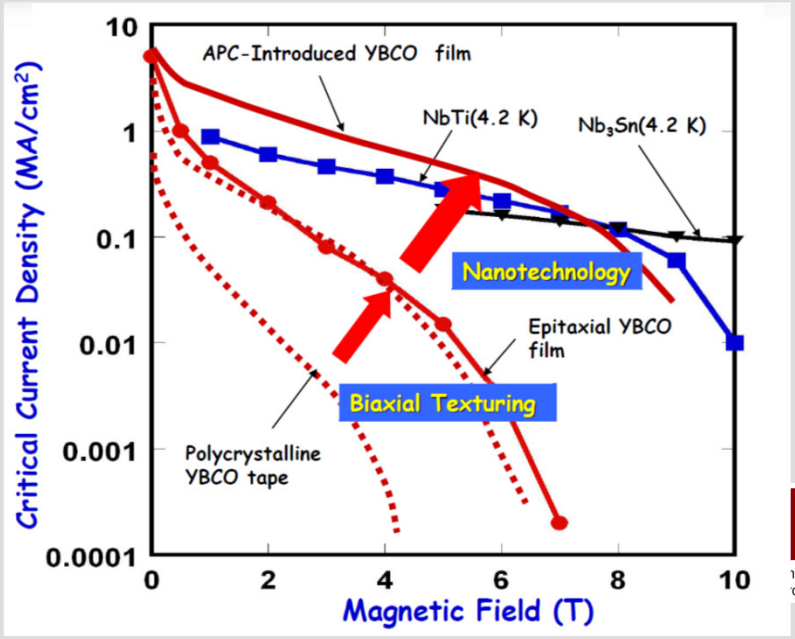
Vortex → Normal (not superconducting) core (~4 nm) ✓

Vortex → Magnetic moment

Normal core pinning

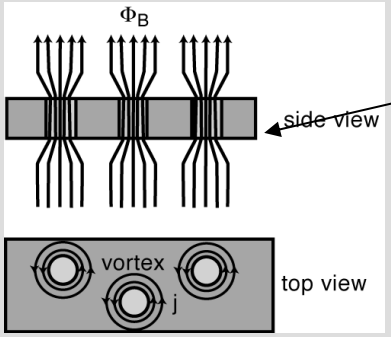
- introduction of non-superconducting (*e.g.* $BaZrO_3$) nanoparticles
- achieved and used at an industrial level





dmcdi

Stop vortex motion (vortex pinning)



Vortex
- Normal (not superconducting) core ✓
- Magnetic moment ✗

Magnetic pinning

- magnetic pinning force using magnetic nanoparticles
- has been proposed, some results, not yet a scalable solution

Objectives of the present project: Explore alternative, scalable routes for producing effective magnetic vortex pinning in superconducting thin films

UNIVERSITATEA TEHNICĂ CLUJ-NAPOCA

dmcdi
Departamentul pentru Managementul Cercetării, Dezvoltării și Inovării

“PRO INVENT” RESEARCH CONFERENCE–24.03.2016

<u>Objectives of the present project</u>: Explore alternative, scalable routes for producing effective magnetic vortex pinning in superconducting thin films

<u>Specific objectives:</u>

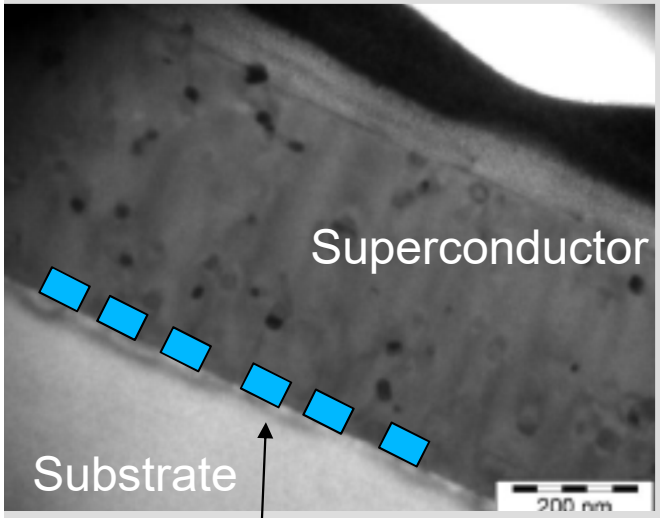
1. *Surface decoration of the substrate with magnetic nanostructures using polymer assisted deposition (PAD).*
2. *Magnetic nanostructure decoration of the YBCO films surface by diblock copolymer self-assembly methods.*
3. *Synthesis and characterization of YBCO- core-shell magnetic nanoparticle nanocomposite films grown by CSD using a colloidal coating solution.*

UNIVERSITATEA TEHNICĂ CLUJ-NAPOCA

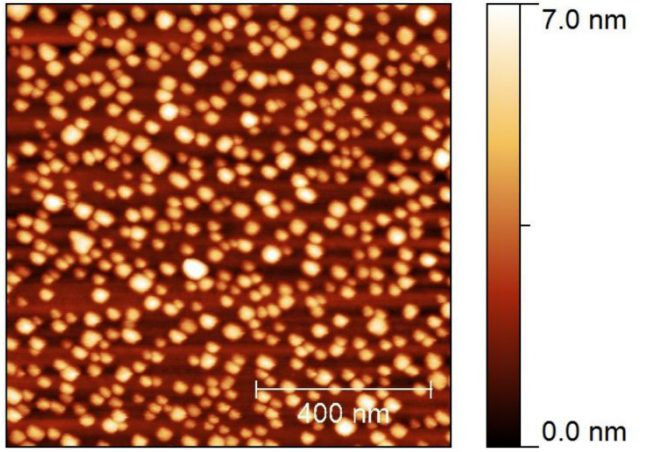
dmcdi
Departamentul pentru Managementul Cercetării, Dezvoltării și Inovării

“PRO INVENT” RESEARCH CONFERENCE–24.03.2016

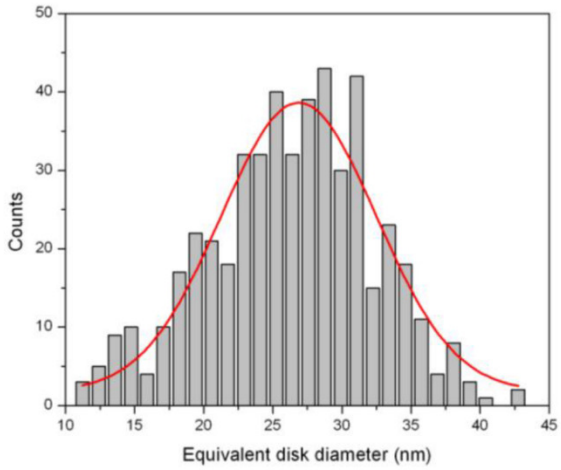
1. *Surface decoration of the substrate with magnetic nanostructures using polymer assisted deposition (PAD).*

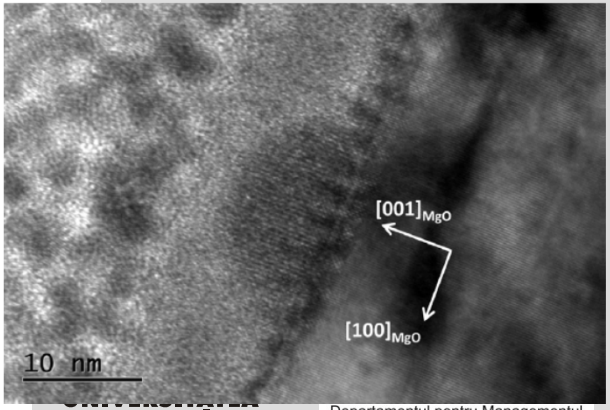


Magnetic nanoparticles



Surface decoration with $La_{0.66}Sr_{0.33}MnO_3$ nanoparticles



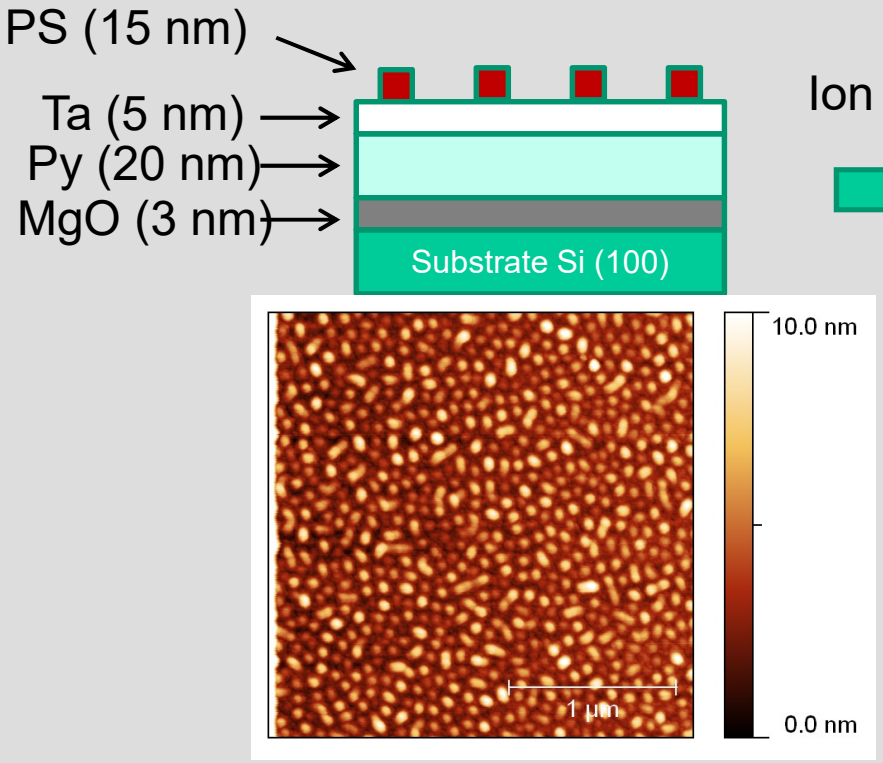


TEHNICĂ
CLUJ-NAPOCA

Departamentul pentru Managementul Cercetării, Dezvoltării şi Inovării

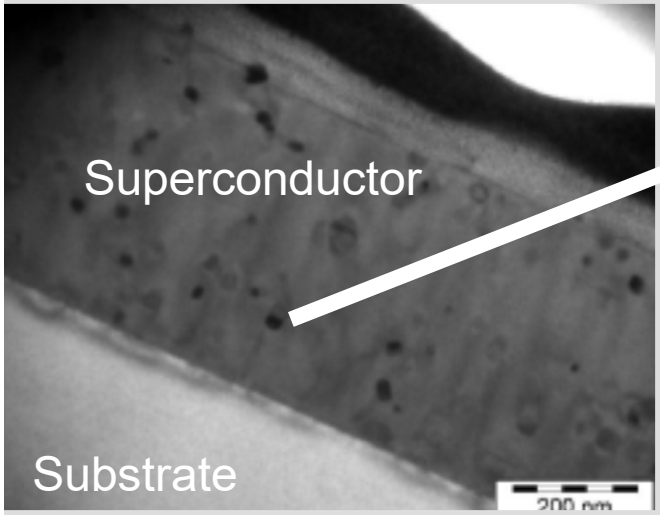
2. *Magnetic nanostructure decoration of the YBCO films surface by diblock copolymer self-assembly methods.*

Diblock copolymer etching mask – Permalloy nanostructure fabrication

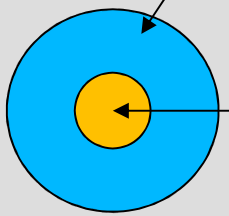


✓ **not all nanoparticles display a magnetic response**

3. *Synthesis and characterization of YBCO- core-shell magnetic nanoparticle nanocomposite films grown by CSD using a colloidal coating solution.*

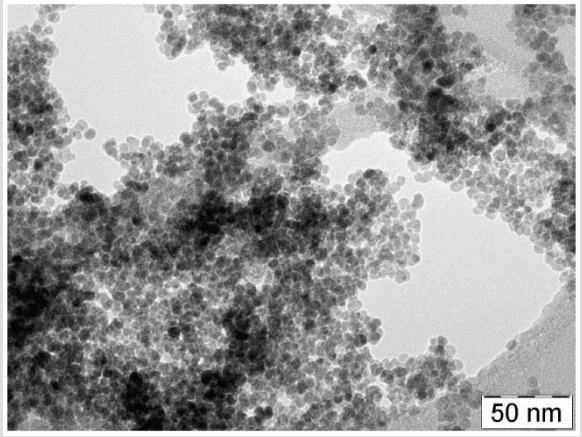


Insulating shell ($BaZrO_3$) (Normal core pinning)



Ferromagnetic core ($CoFe_2O_4$) (Magnetic pinning)

Ferromagnetic core ($CoFe_2O_4$) synthesis



- average particle diameter ~ 6 nm

UNIVERSITATEA TEHNICĂ CLUJ-NAPOCA

dmcdi
Departamentul pentru Managementul Cercetării, Dezvoltării şi Inovării

Next steps:

- Optimization of magnetic nano-particle synthesis following the three proposed approaches;
- Integration of nano-particles in superconducting thin films;
- Evaluation of the vortex pinning efficacy of the elaborated systems;

The (extended) team:

Dr. Traian Petrisor Jr.

Dr. Mircea Nasui

Dr. Mihai Gabor

Dr. Amalia Mesaors

Dr. Bianca Mos

Rares Bortnic

UNIVERSITATEA TEHNICĂ CLUJ-NAPOCA

dmcdi
Departamentul pentru Managementul Cercetării, Dezvoltării şi Inovării

Thank you!

UNIVERSITATEA TEHNICĂ CLUJ-NAPOCA

dmcdi
Departamentul pentru Managementul Cercetării, Dezvoltării şi Inovării

Nanotechnology

"…manipulation of matter with at least one dimension sized from 1 to 100nm…"

National Nanotechnology Initiative

"…the particular technological goal of precisely manipulating atoms and molecules for fabrication of macroscale products…"

Wikipedia

Nanotechnology

"…manipulation of matter with at least one dimension sized from 1 to 100nm…"

National Nanotechnology Initiative

"…the particular technological goal of precisely manipulating atoms and molecules for fabrication of macroscale products…"

Wikipedia