



Flux Pinning Enhancements of YBCO with Nanosize Magnetic Additions



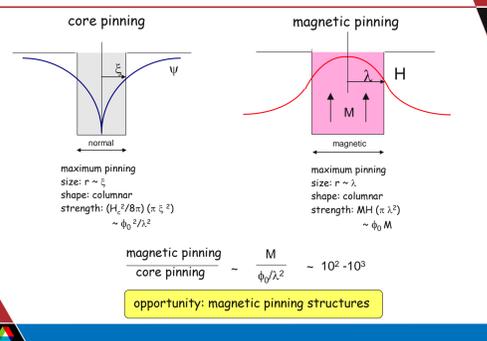
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Introduction

Magnetic pinning is suggested to be very effective, however has never been successfully applied to YBCO, to our knowledge. Herein, we test (M/YBCO)_N multilayer structures with M = magnetic phase, to determine if magnetic pinning in YBCO can be achieved. Multilayer structures have advantages to reduce chemical reactions which otherwise can lower T_c (Haugan et al, IEEE Trans. Appl. Supercond. 2007).

Core and Magnetic Pinning



G. Crabtree, DOE Basic Sciences Workshop, 2006

Issues to Incorporate Magnetic Nanoparticles into YBCO

- Hard or soft magnet phase, crystal epitaxy, particle orientation, magnetic domain size, chemical reactivity, operation temperature, oxides necessary for YBCO, feasibility (?)

	σ_s (emu/g) @ 298K	σ_s (emu/g) @ 77K	M_o (emu/cm ³) @ 273K	T _c K
La_{0.67}Ca_{0.33}MnO₃	7	90	113 @100K	240
SrRuO₃	3.5 μ_B	20		160
Y₃Fe₅O₁₂	25		75	560
BaFe₁₂O₁₉	75			723
Fe	197		1740	1043

Table I. Crystal properties of M phases studied, and lattice mismatch to 123. The lattice parameters of epitaxy are $\tilde{a} = (a,b)_{\text{epi}}$, $\tilde{a}^{**} = a/2$, $\tilde{a}^* = a/\sqrt{2}$, $\tilde{c}^{***} = c/3$; $\tilde{c}^{****} = c/6$.

Material	Lattice Type	Lattice Parameters (nm)	Lattice Parameter of Epitaxy (nm)	Ab-in Plane Lattice Mismatch to 123 a (%)	Lattice Mismatch along c to 123 (%)
YBa ₂ Cu ₃ O _{7-x}	Orthorhombic	a = 0.3825 b = 0.3886 c = 1.166	$\tilde{a} = 0.3855$		
La _{0.67} Ca _{0.33} MnO ₃	Orthorhombic	a = 0.5457 b = 0.5451 c = 0.7708	$\tilde{a}^* = 0.3857$	+0.04	-0.8
CeO ₂	Cubic	a = 0.54115	$\tilde{a}^* = 0.3827$	-0.75	-1.5
SrRuO ₃	Pseudo-Cubic	a = 0.393	$\tilde{c}^{**} = 0.3854$	+1.95	+1.1
Y ₃ Fe ₅ O ₁₂	Cubic	a = 1.2376	$\tilde{a}^{***} = 0.41253$	+7.0	+6.1
BaFe ₁₂ O ₁₉	Hexagonal	a = 0.58945 c = 2.3215	$\tilde{a}^* = 0.41680$ $\tilde{c}^{****} = 0.3869$	+8.1	-0.05
BaZrO ₃	Cubic	a = 0.41898	$\tilde{a}^* = 0.41898$	+8.7	+7.8
MgO	Cubic	a = 0.4203	$\tilde{a}^* = 0.4203$	+9.0	+8.1

** Epitaxy of Y₂BaCuO₇ onto 123 is b-axis oriented⁶, so the lattice misfit is calculated for both a* and c*.

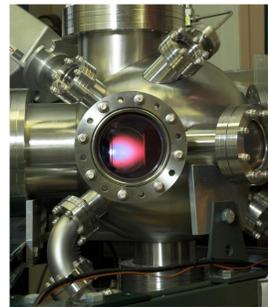
Experimental

PLD Deposition

- (M/YBCO)_N multilayer films by deposition of alternate targets
- O₂ pressure = 300 mTorr
- Substrate temperature = 790°C-800°C
- Deposition rate ~ 15 nm/min
- Interval of ~ 12 sec between YBCO and pinning layers
- Laser Hz = 4

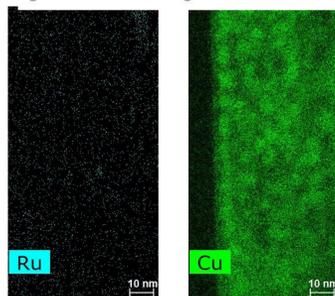
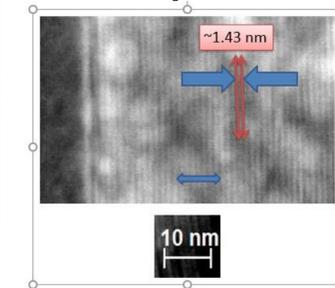
J_c measurements

- VSM magnetization ramp rate = 9,000 (A/m*s)
- J_{cm} = 15 ΔM/Vol,
- transport currents
- J_{ct} by 1 mv/cm criteria.

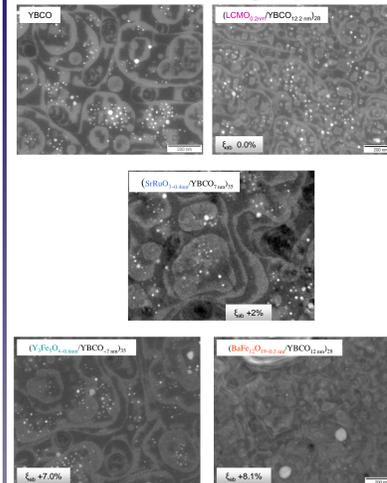


Haugan et al., IEEE Trans. Appl. Super. 17(2), 3724 (2007)

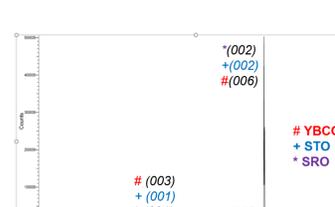
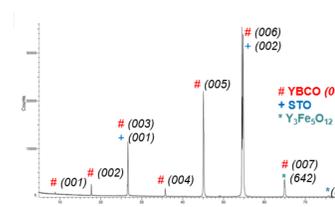
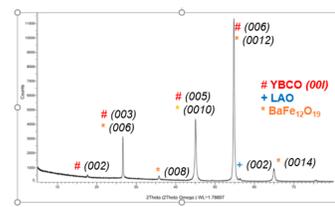
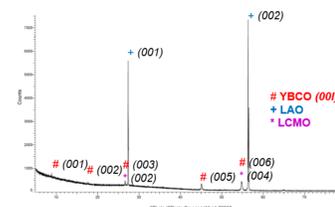
TEM SrRuO₃/YBCO



SEM Micrographs



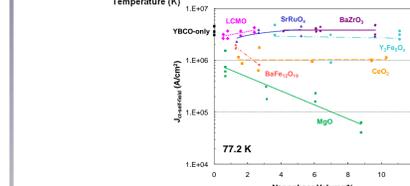
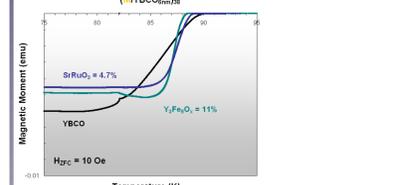
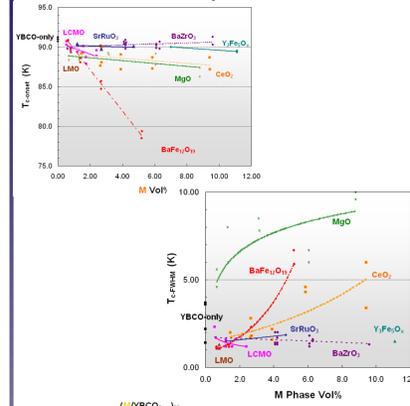
XRD



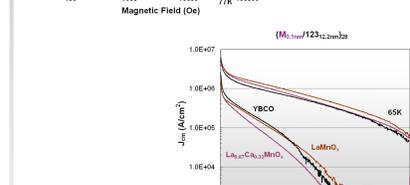
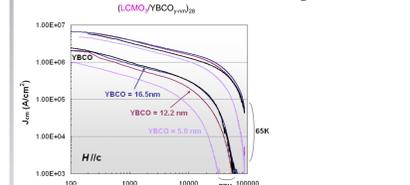
2Theta (Degrees) (XRD) (VLS) 19887

Results and Discussion

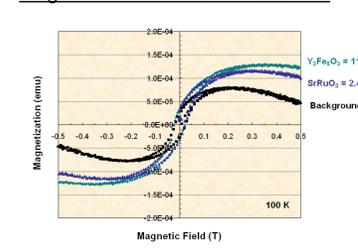
(M_x/123_{12nm})₂₈ Multilayer Films



Magnetic J_c

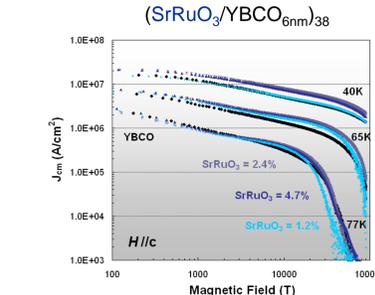
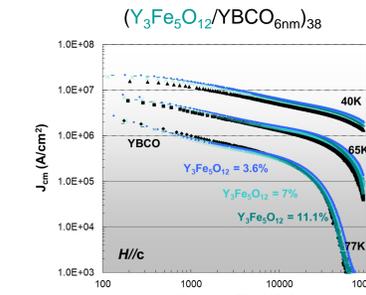
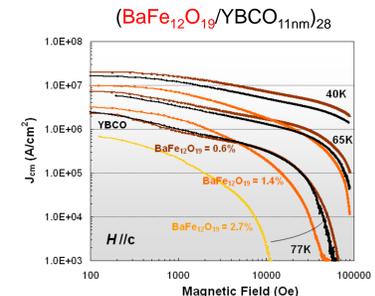
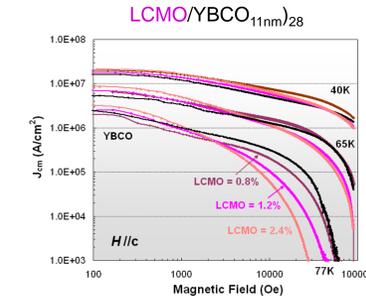


Magnetic Characterization @ 100K

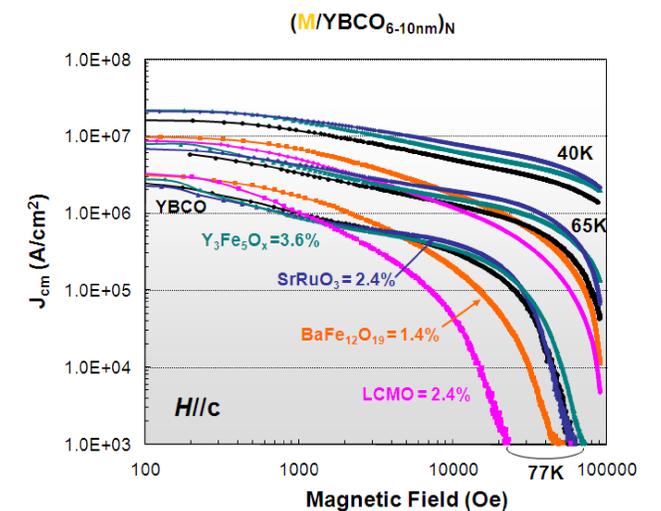


Courtesy: M. Sumpson, Ohio State Univ.

Magnetic J_{cm}



Summary



M Phase	M Phase Nano-Magnetic	H _{sat} (T)	T _c (K)	T _{c-FWHM} (K)	J _{cm} /J _c (YBCO) H < 0.5T 40-77K	J _{cm} /J _c (YBCO) H > 1T 40-77K
La_{0.67}Ca_{0.33}MnO₃			89.5	1.3	+ 50%	- 100x
BaFe₁₂O₁₉			85.5	2.5	+ 100%	- 10x
Y₃Fe₅O₁₂	Yes	0.3	90	~1.6	+ 25%	+35%
SrRuO₃	Yes	0.25	90	~1.8	+25%	+70%