LCMO
From thin films to nanowires

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Groupmeeting 08-09-05

Outline

✓ Introduction

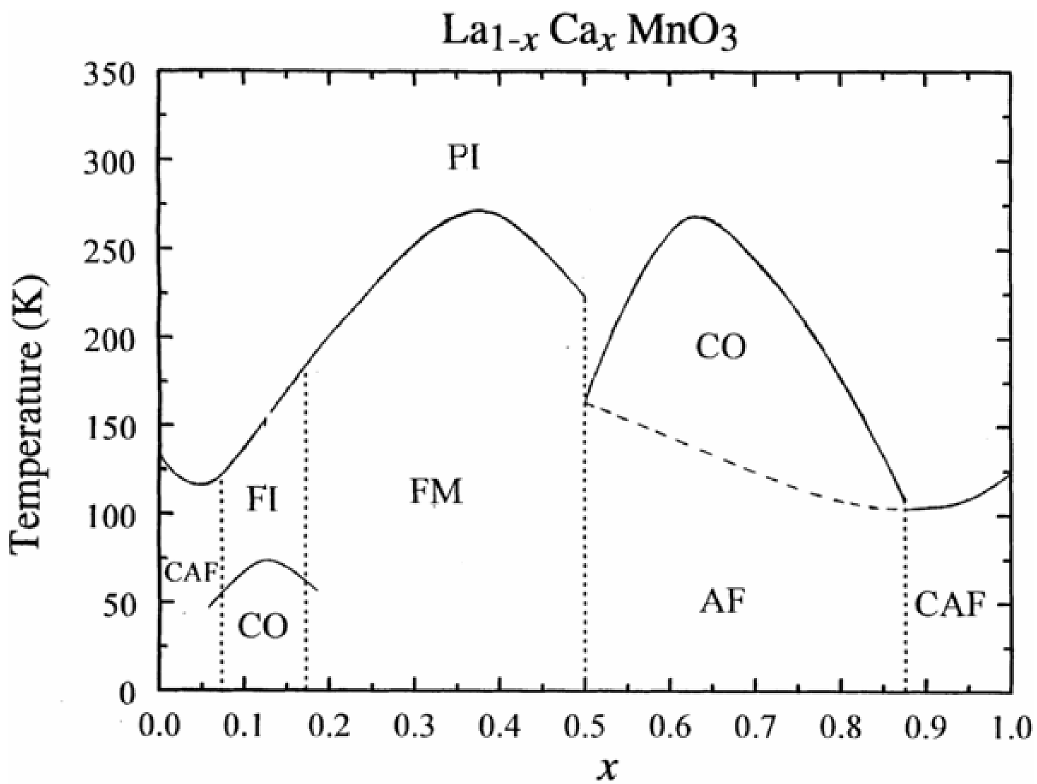
- Complex phase diagram
- Double exchange
- Magnetoresistance

✓ Miscut substrates

✓ Growing LCMO nanowires

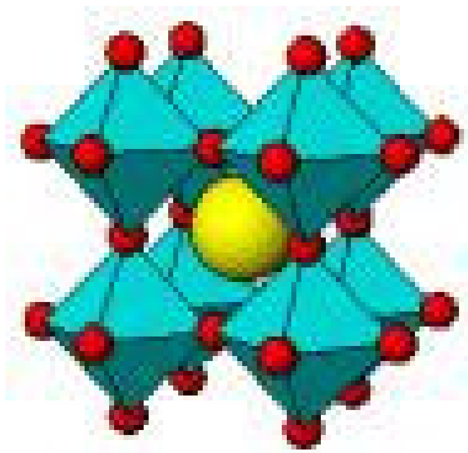
- Sol-gel process with alumina templates
- Pt as contact material

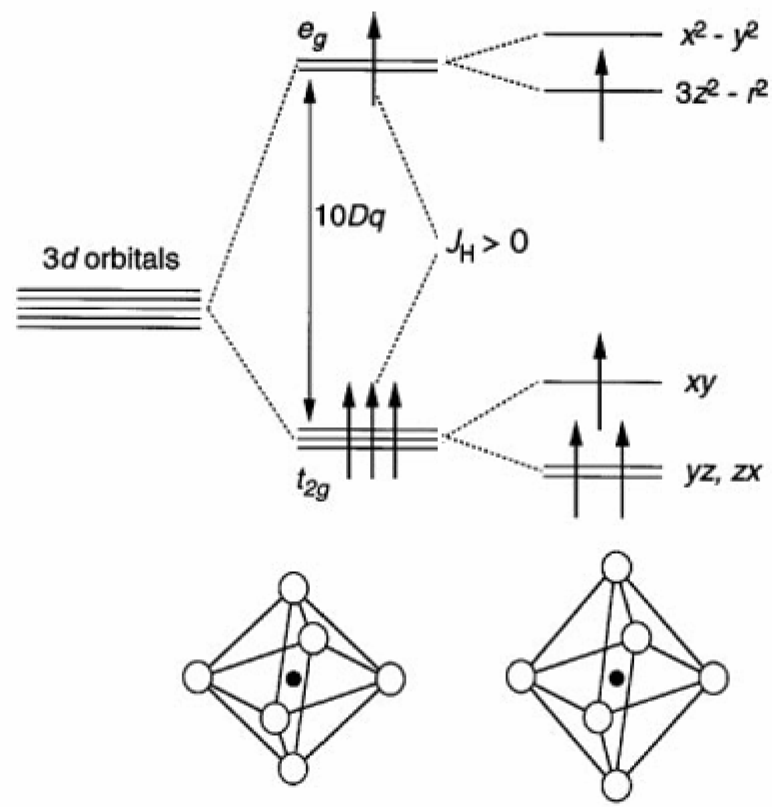
LCMO



$La_{0.7}Ca_{0.3}MnO_3$: - CMR effect
- 100% polarized ferromagnet
- metal-insulator transition

Perovskite lattice

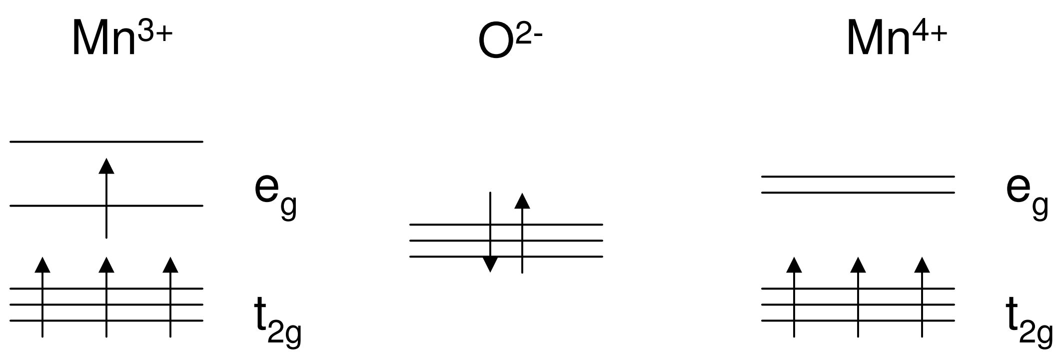




t_{2g}: localized core electrons

e_g: delocalized electron

Double exchange



Hopping mediates the onset of the ferromagnetic state

Double exchange

Hopping rate determined by:

Transfer integral

$$\tilde{t} = t\cos(\Delta\theta_s / 2)$$

$\Delta\theta_s$: difference in spin angle between the Mn ions

One electron bandwidth

$$W \propto \frac{\cos^2(\theta)}{l_{Mn-O}^{3.5}}$$

θ: Mn-O-Mn bond angle, $l_{Mn\text{-}O}$: Mn-O bond length

Jahn Teller distortions

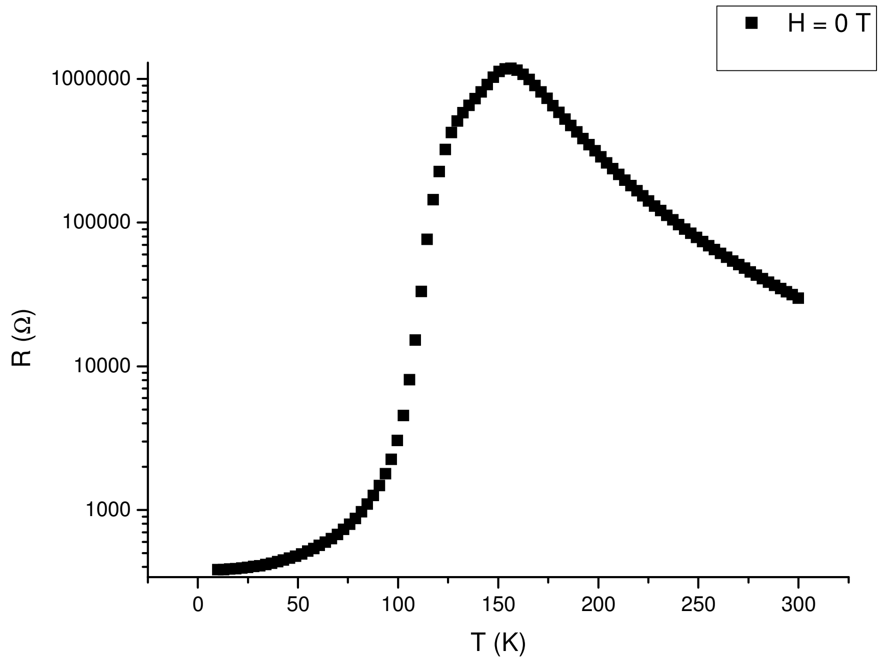
DE model does not explain the localization above T_C

Strong electron-lattice coupling can cause localization

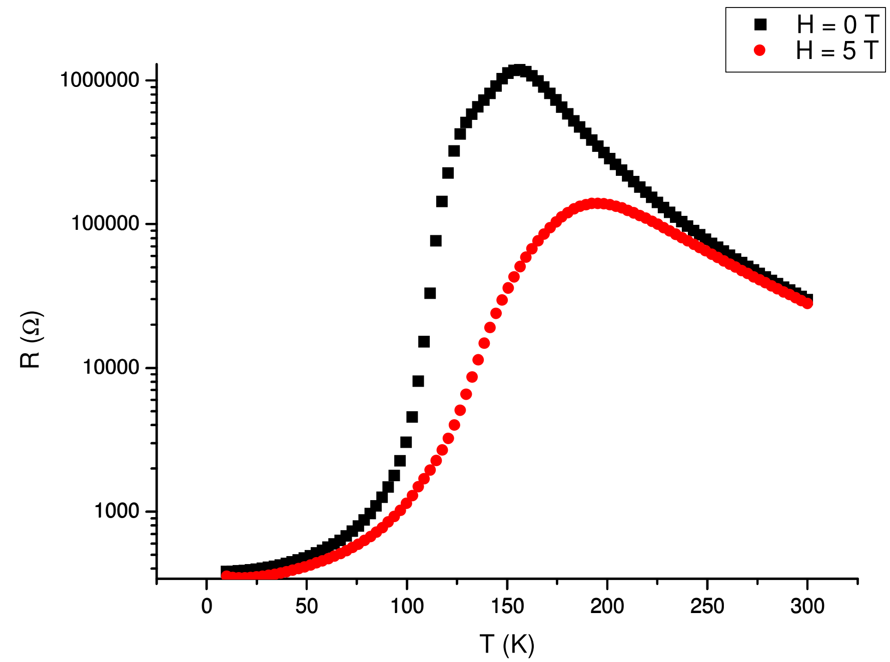
Competition between polaron formation and delocalization due to hybridization which can be described by the ratio,

$$\lambda = \frac{E_{latt}}{t_{eff}}$$

t_{eff}: ‘bare’electron kinetic energy,
E_{latt}: energy gained by e-ph coupling without hybridization

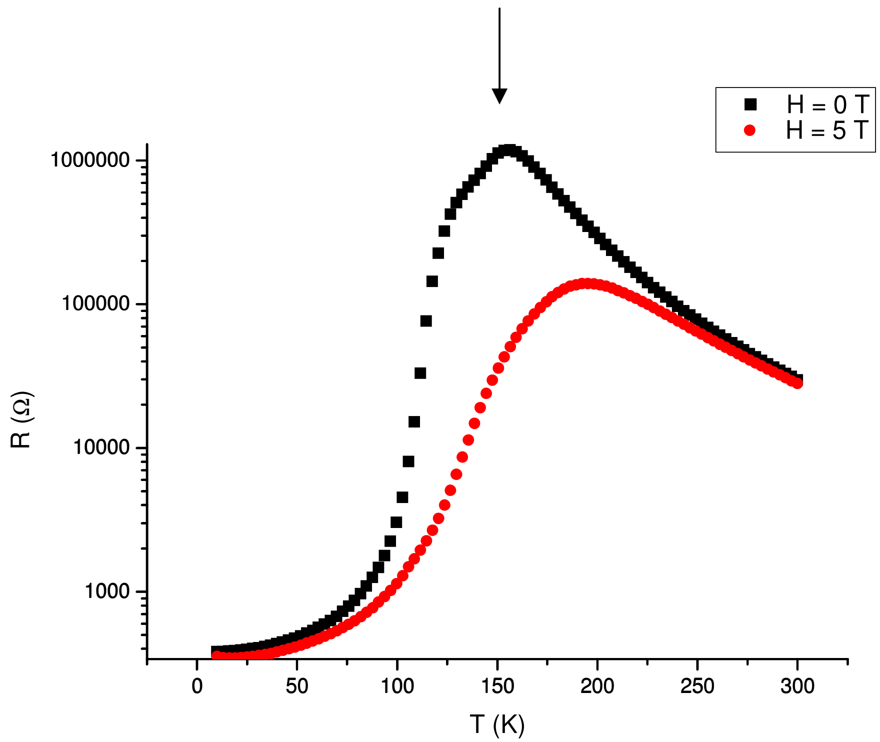


Above T_C : activated polaron hopping
Below T_C : e_g electrons delocalize, onset of spin ordering



External field : different magnetic domains align reducing resistance, CMR effect

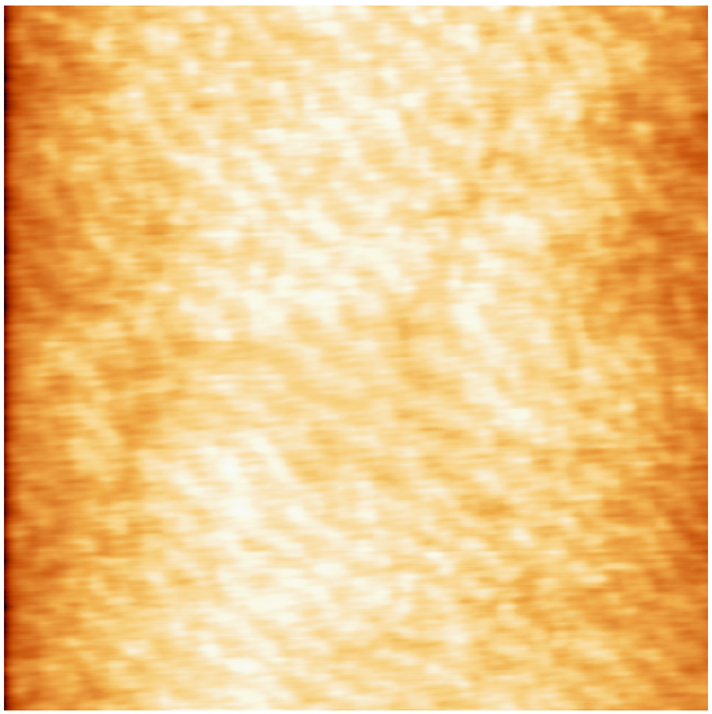
$T_C \approx 150$ K



Bulk : $T_C \approx 270$ K ➔ lattice mismatch with STO substrate causes strain which reduces T_C

Miscut substrates

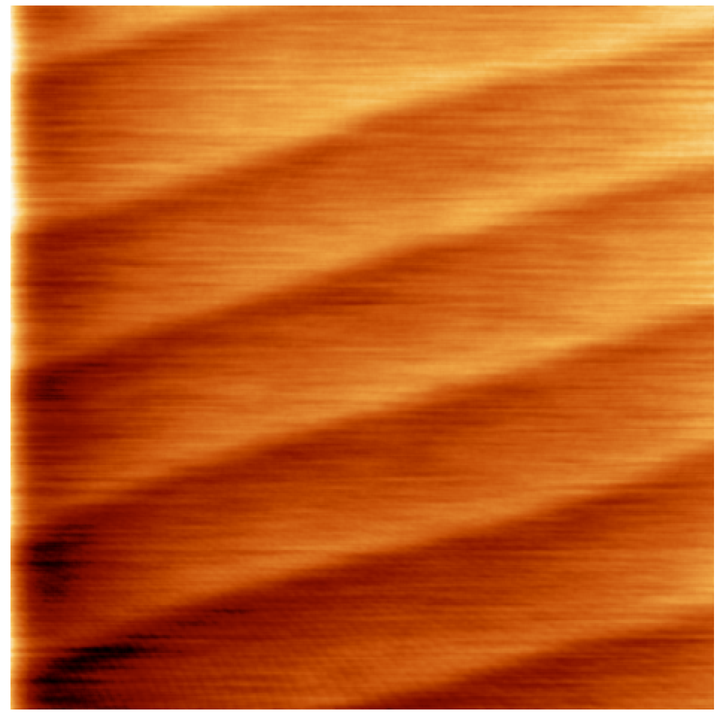
AFM picture of 0.2° miscut substrate



← 2.3 x 2.3 µm →

No visible steps

AFM picture of 0.18° miscut substrate terminate layer TiO_2

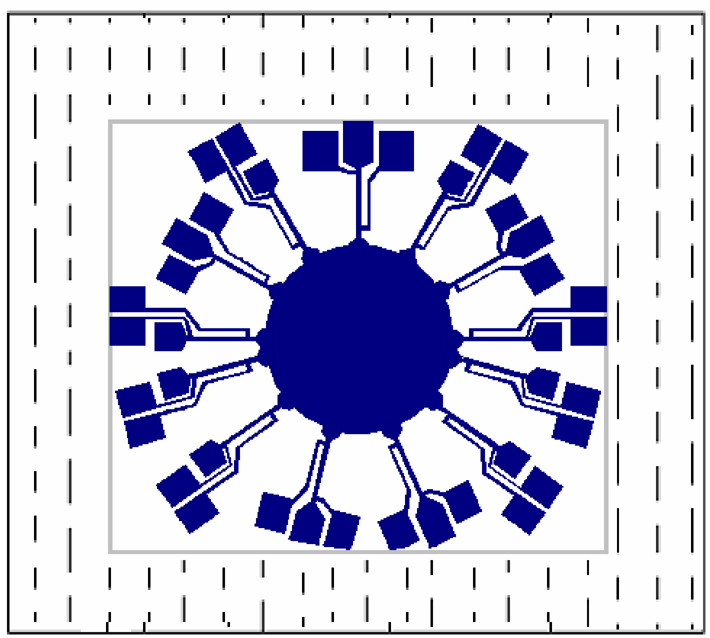


← 737 x 737 nm →

Clearly visible steps

Miscut substrates

Optical lithography



Structure sizes:

Diameter: ~ 5 mm

Contactpads: ~ 350 x 400 μm

Strips: w = ~ 40 μm
l = ~ 500 μm

T_C reduction:

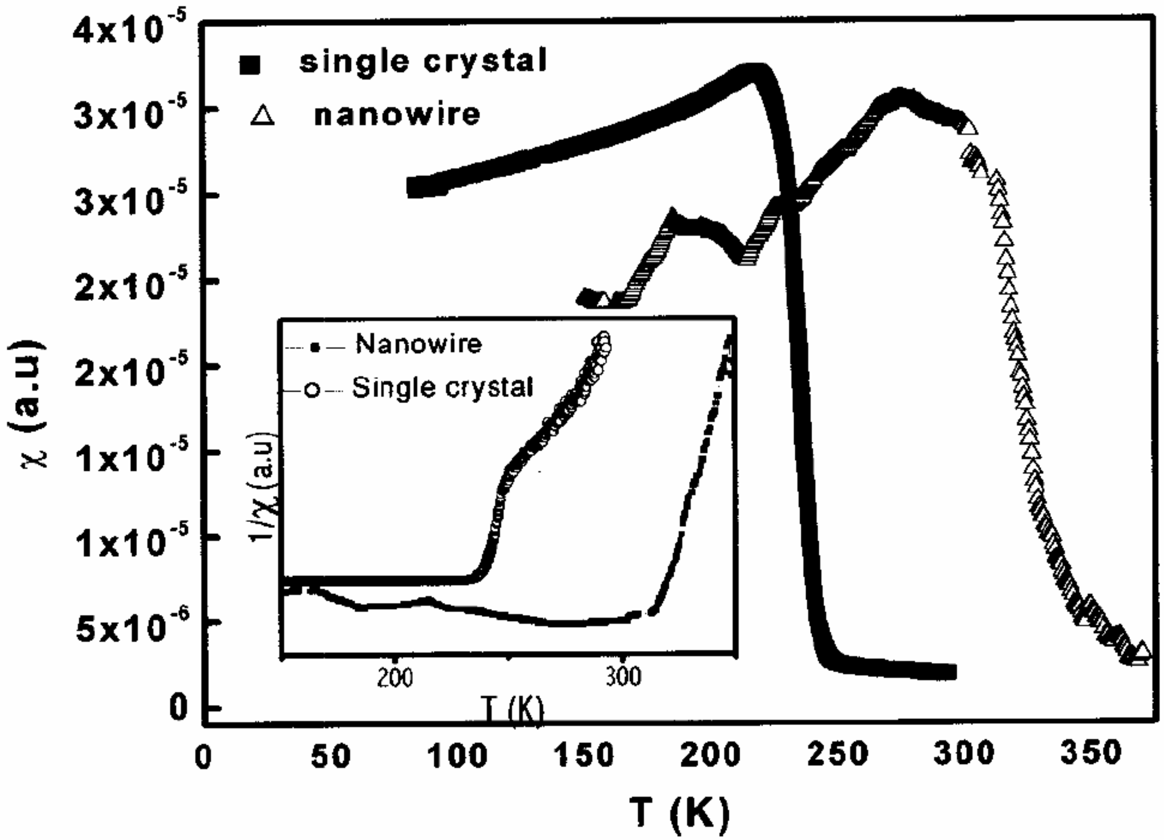
- ✓ Strain due to lattice mismatch with substrate
- ✓ Internal “chemical” pressure: decrease radius dopant ions

T_C enhancement:

- ✓ External pressure: oxygen ions more densely packed
- ✓ Reduction of sample size: nanopowders & nanowires

LCMO nanowires

Shankar et al. Appl. Phys. Lett., Vol. 84, No. 6, 9 February 2004

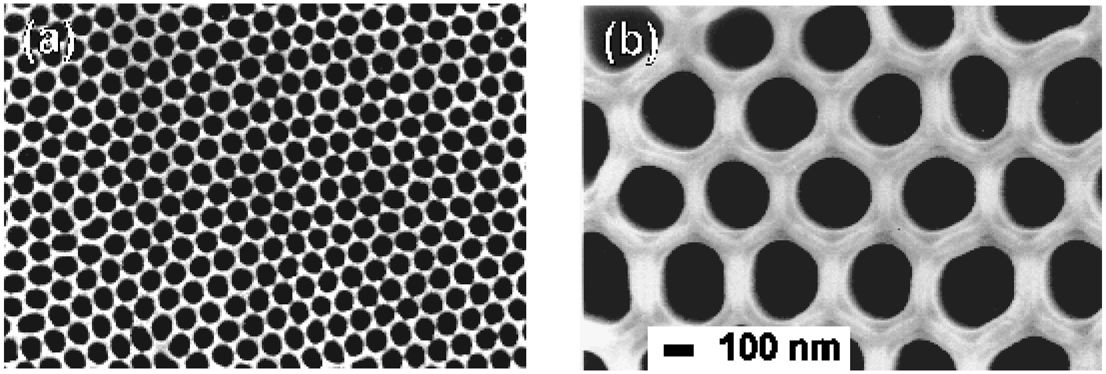


Nanowire: T_C is enhanced compared to bulk single crystal

LCMO nanowires

Growth process: Sol-gel

Polymer assisted nucleation of cation complex in pores of alumina templates



Sol: La_2O_3, $CaCO_3$, $Mn(NO_3)_2$ & ethylene glycol

LCMO nanowires

Shankar et al. nanotech., Vol. 15, 1312, 2004

Growth process: Sol-gel

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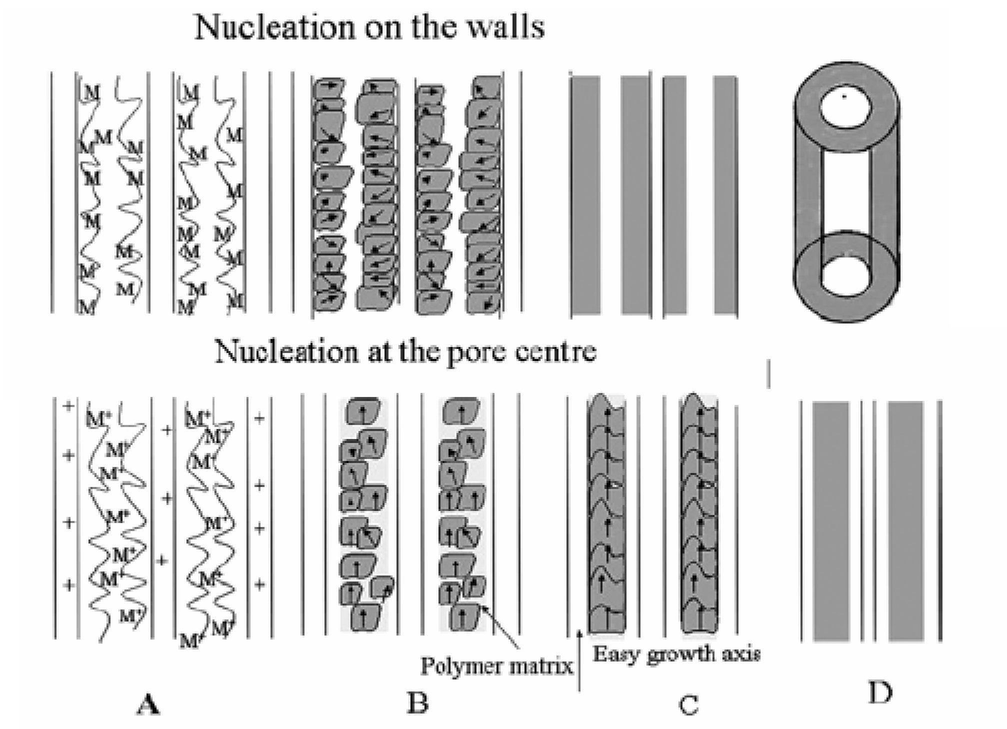
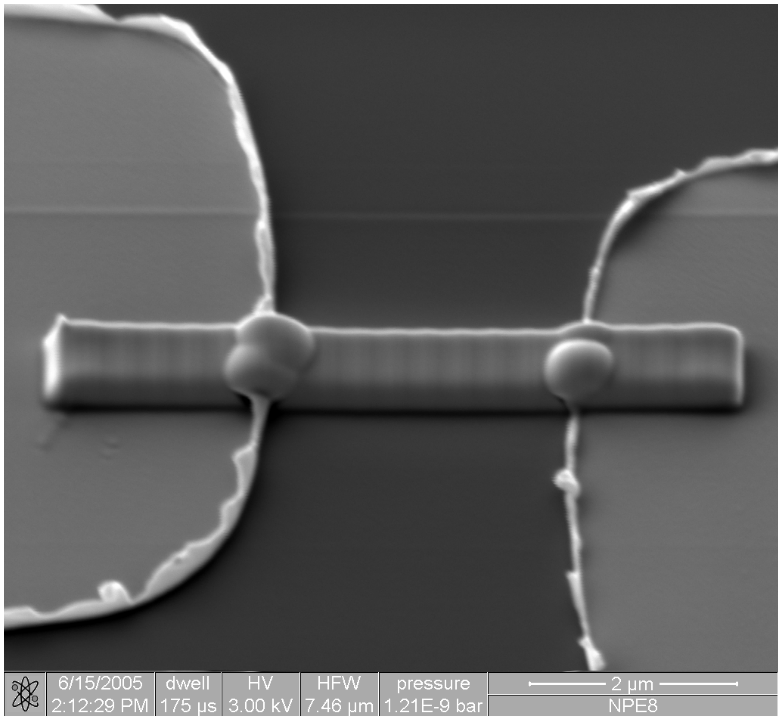
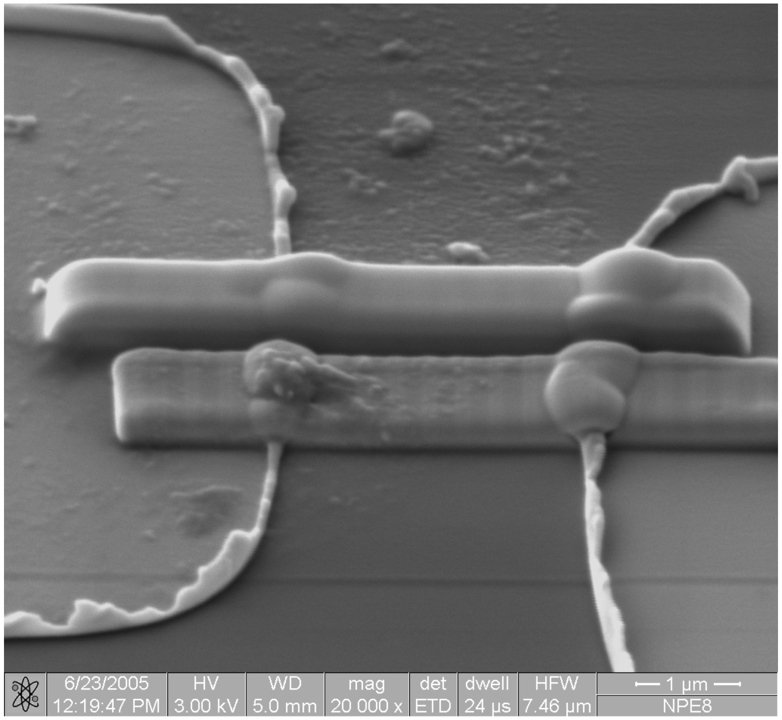


Pt as a contact material

Contact geometry can be written with FEI nanosem



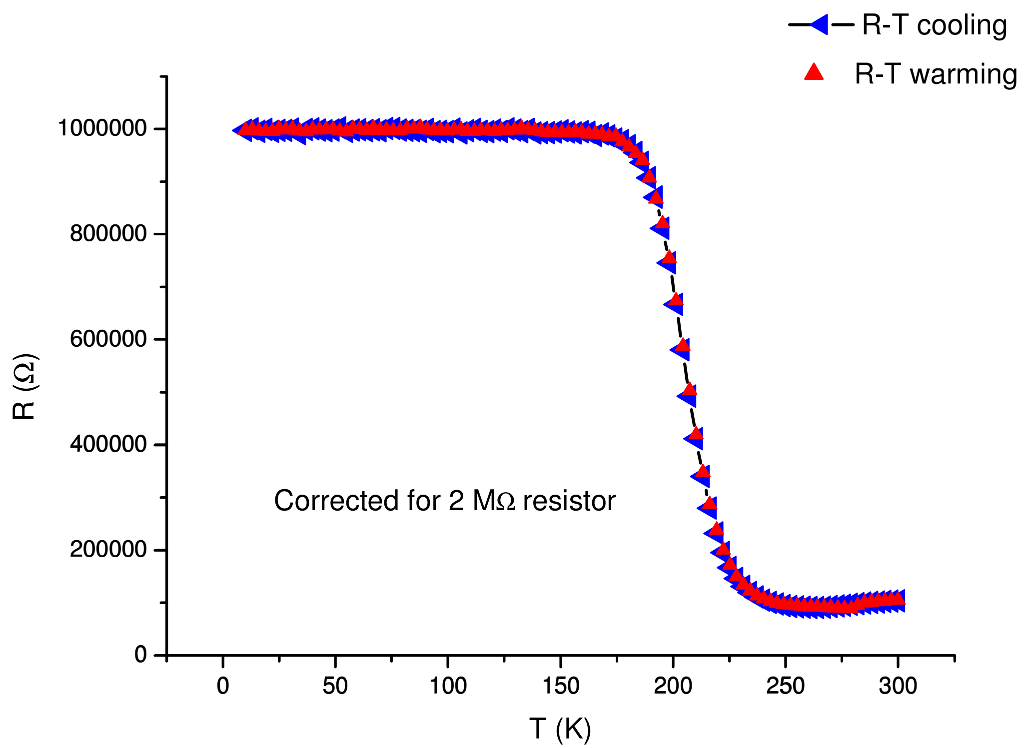


Pt strip: t = 500 nm

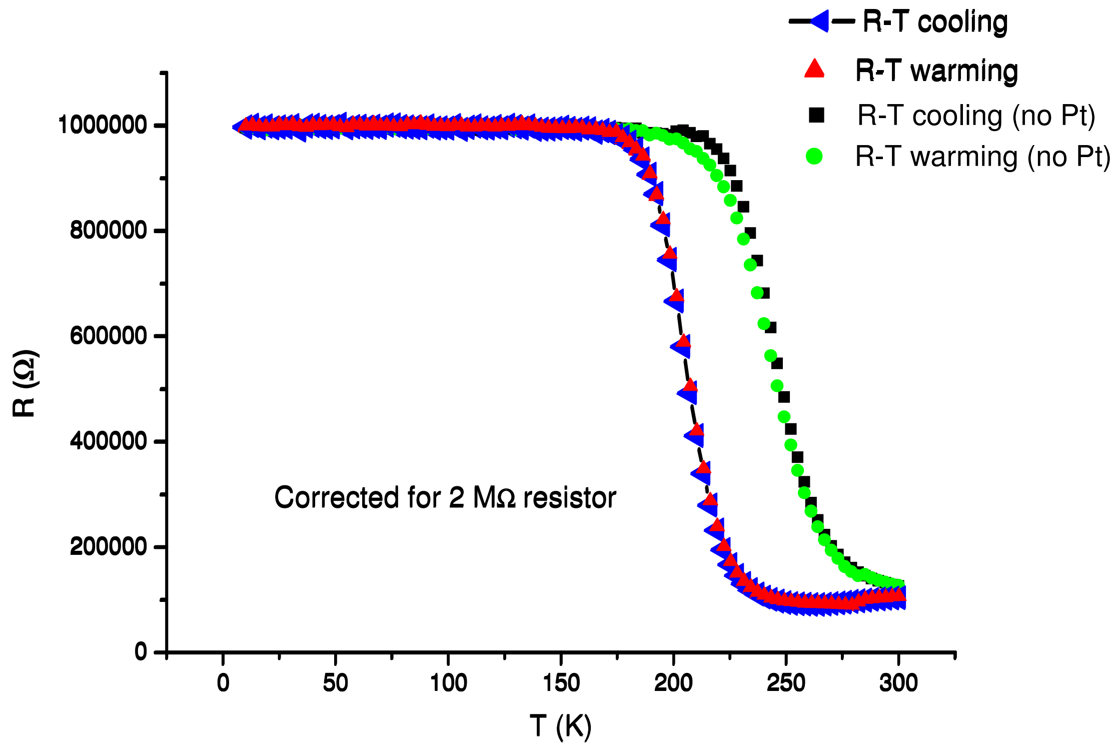
w = 800 nm

l = 6.5 µm

Pt as a contact material



Pt as a contact material



Measuring substrate instead of Pt strip

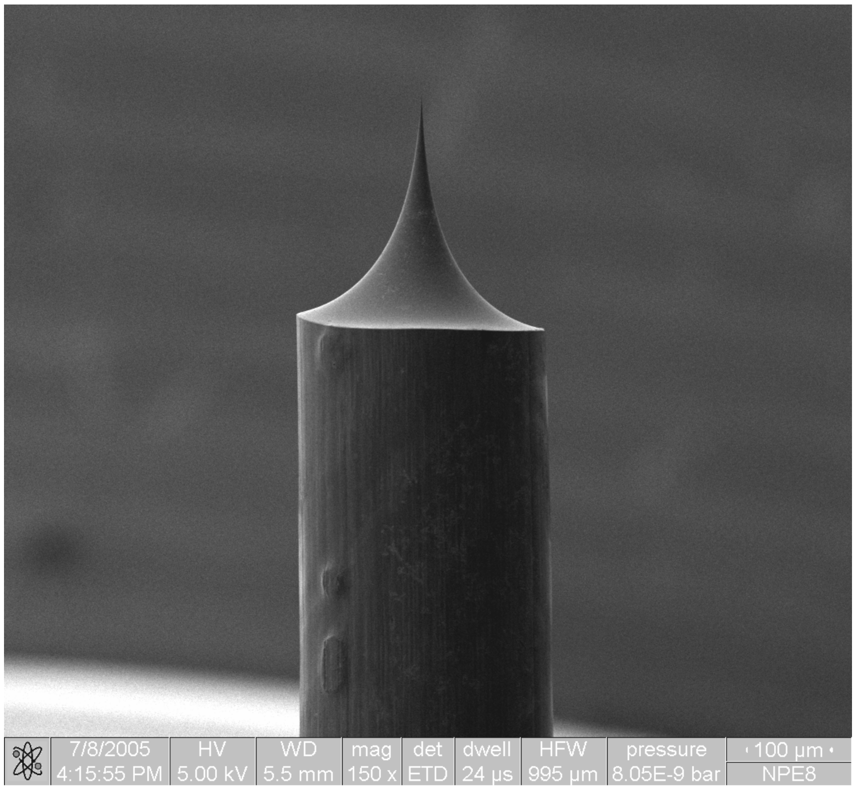
Bad interface?

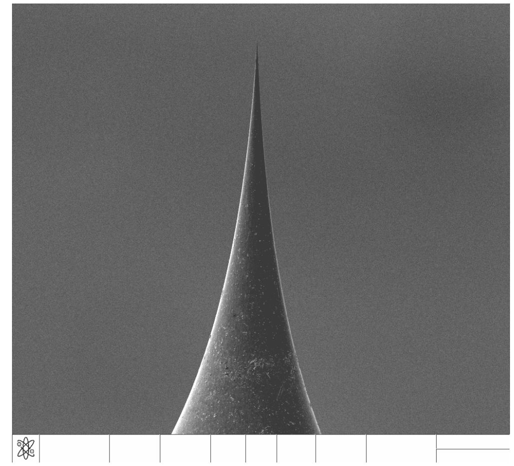
Future research

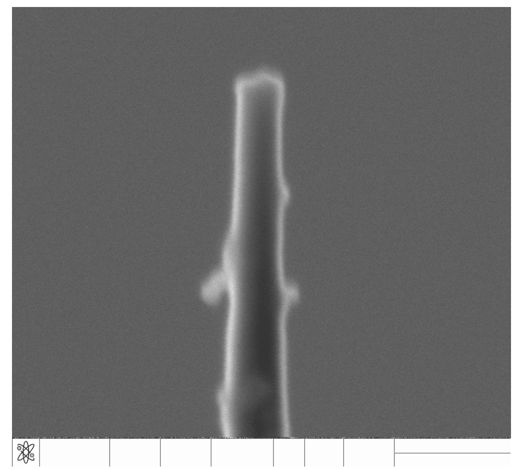
- ✓ Surface treatment for miscut substrates

- ✓ Measure the transport properties of LCMO strip for different angles relative to terraces

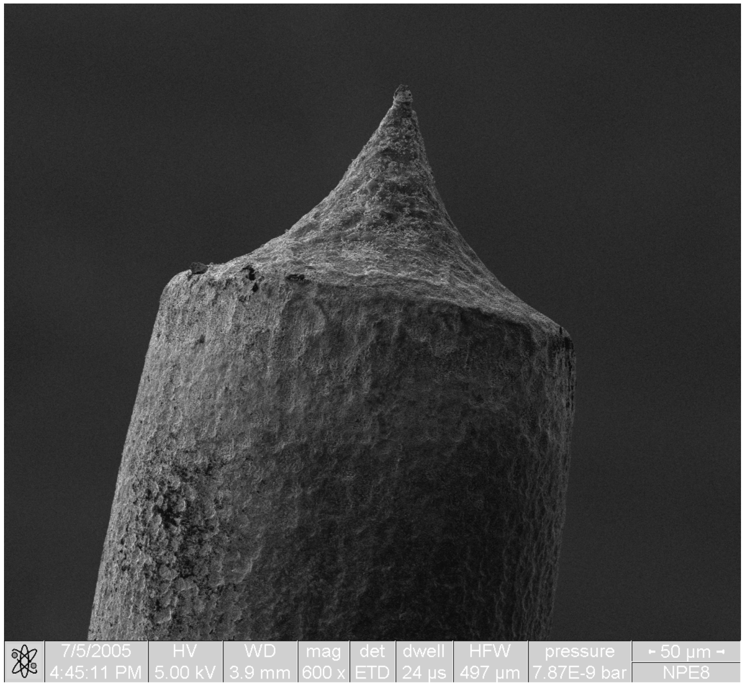
- ✓ Develop the sol-gel procedure for the growth of LCMO nanowires

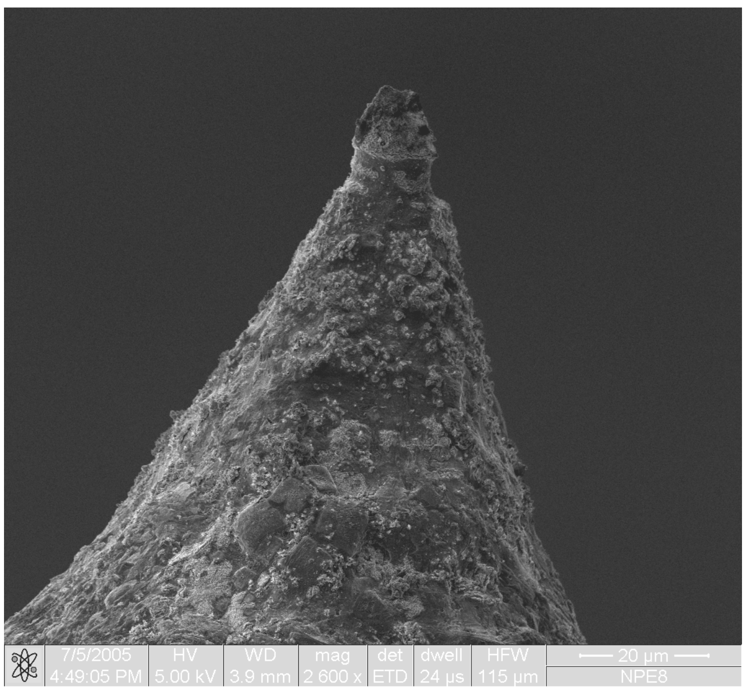


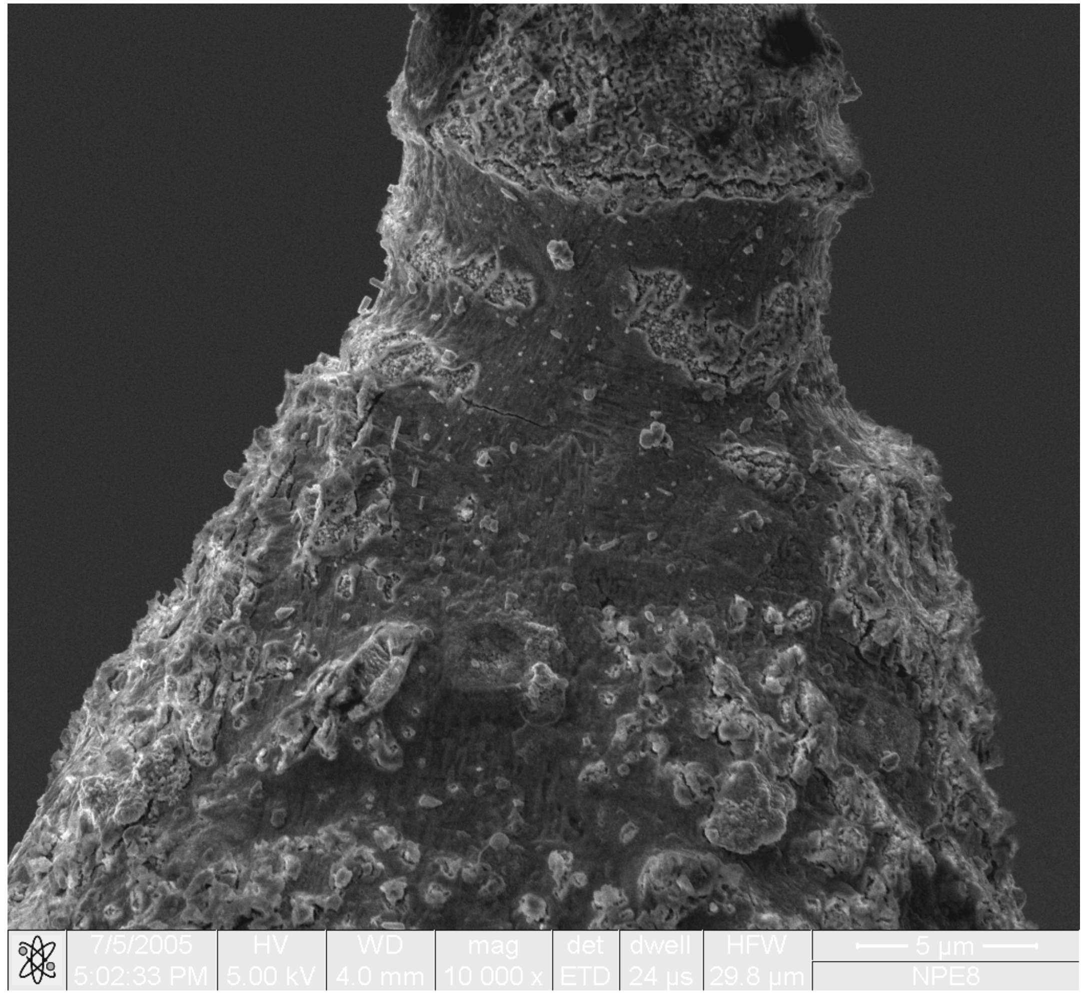




Tip radius of curvature ~ 136 nm
Needle has same tree like surface as the coated tip (LCMO) suggesting LCMO only grows near the tip.

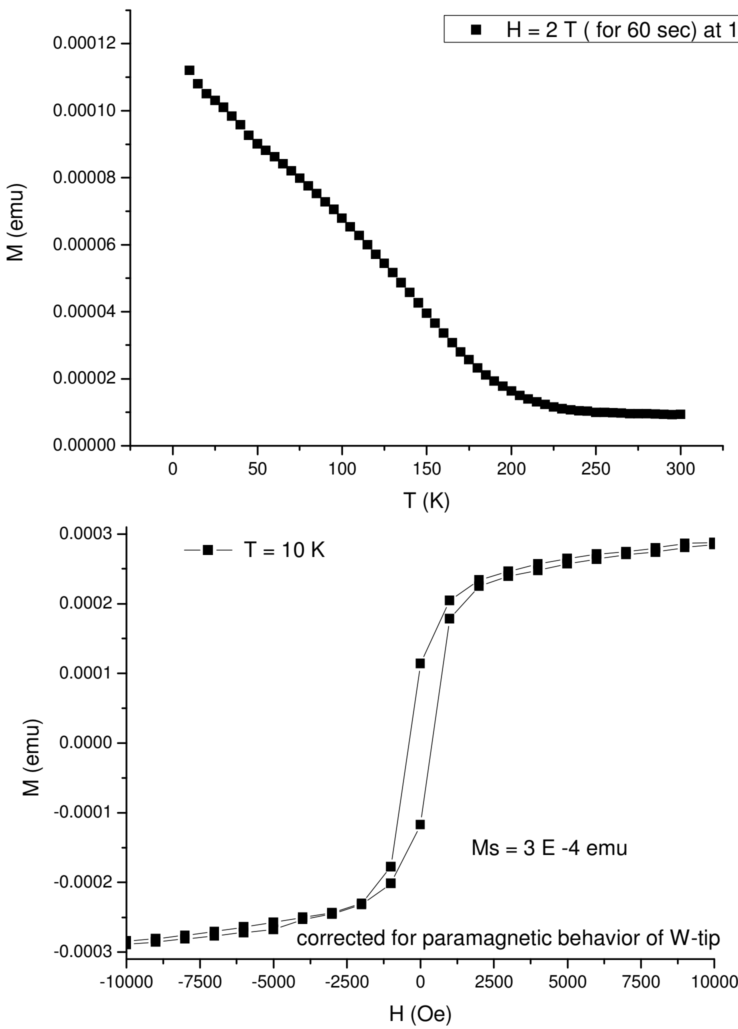




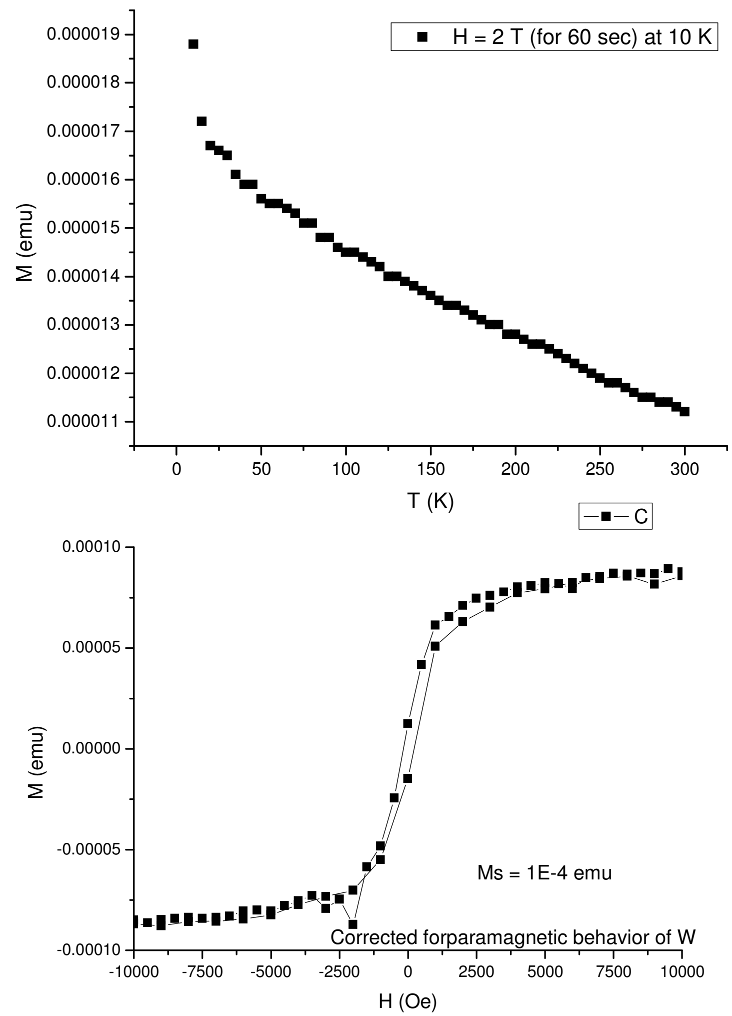


SEM imaging of LCMO ($La_{0.67}Ca_{0.33}MnO_3$) coated W-tip
During sputtering cooling water was leaking into the vacuum, probably causing corrosion.
Expected layer thickness 25-50 nm (sputter rate 50nm/hour)

From images:
tip radius of curvature ~ 6 um (before coating radius of curvature should be ~ 20 nm)
roughness order of magnitude ~ 1 um



W-tip coated with LCMO



Bare W-tip