SAND2016-0622C

Giant magneto-resistance in epitaxial $ZnO:La_{0.7}Sr_{0.3}MnO_3$ nanocomposites

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Steve Lee

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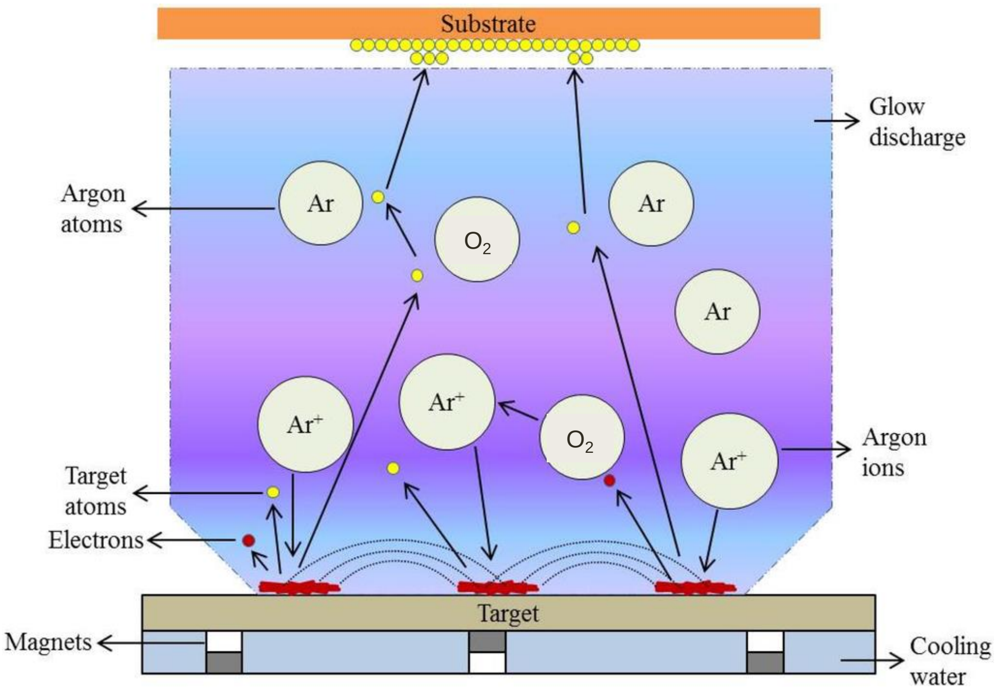
Outline

- Introduction
- Growth and Characterization
- Giant magneto-resistance

Sample growth

Jon Ihlefeld



rf magnetron sputtering

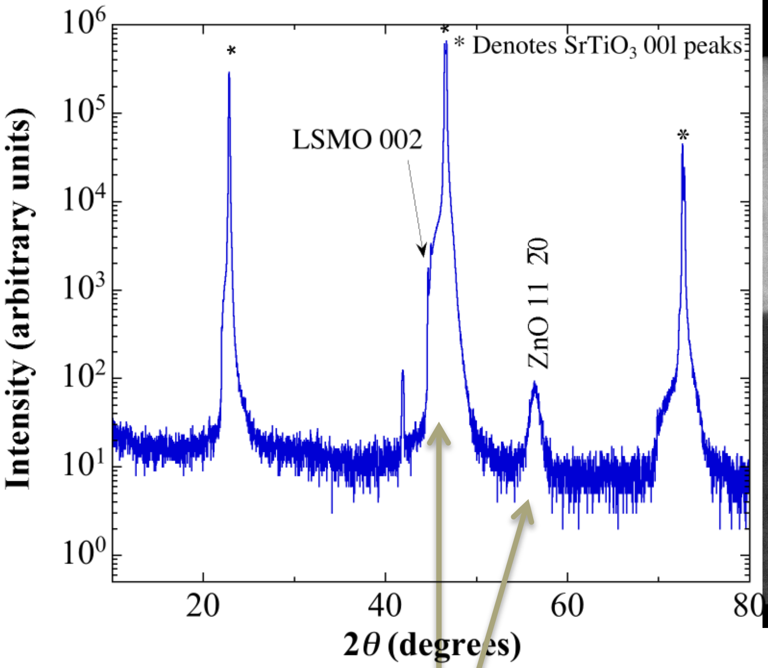
growth parameters:

30W, 20 mTorr

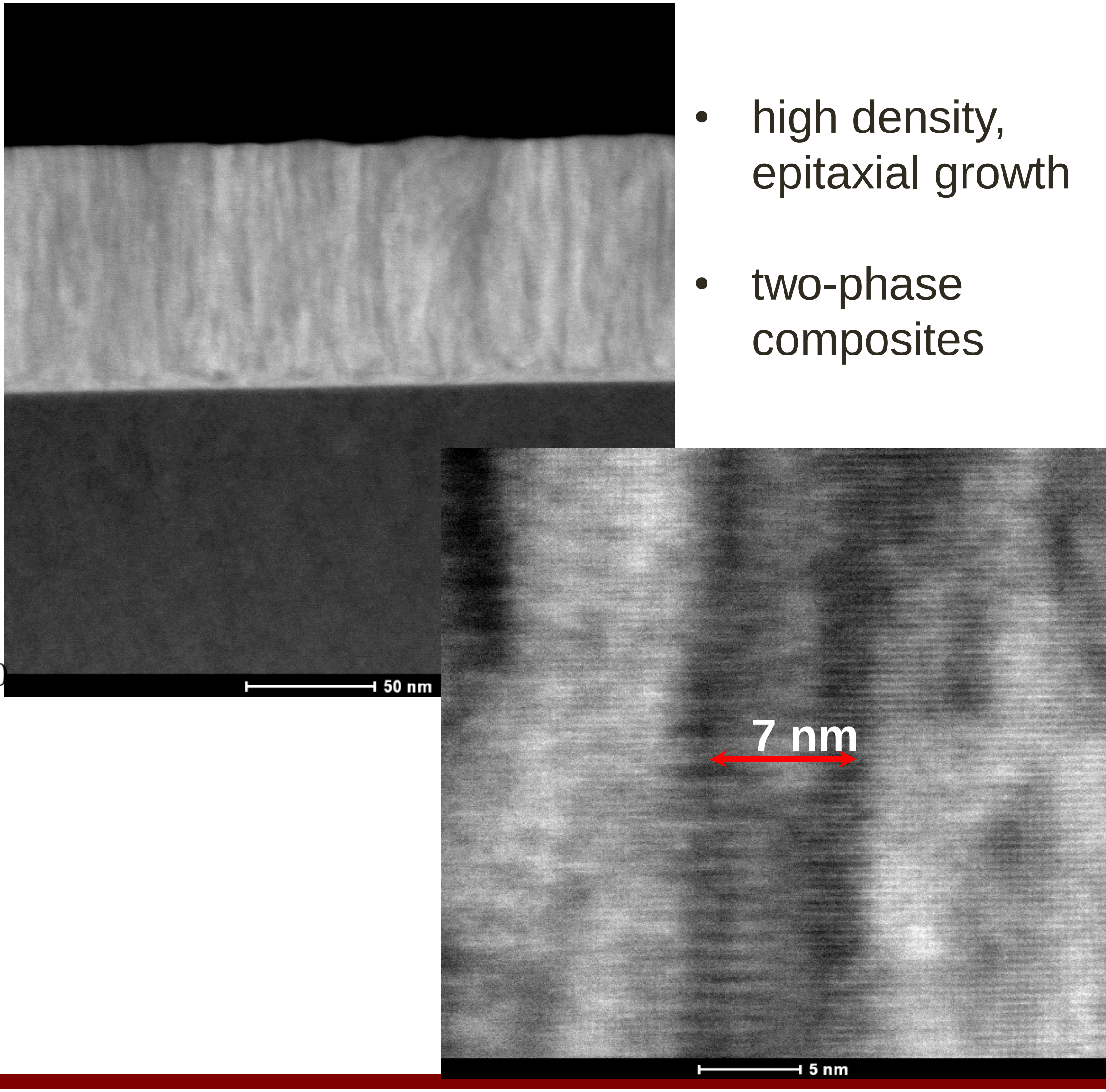
5:1 for Ar:O_2

Substrate Temp: 700 or 750 °C

XRD and TEM characterizations



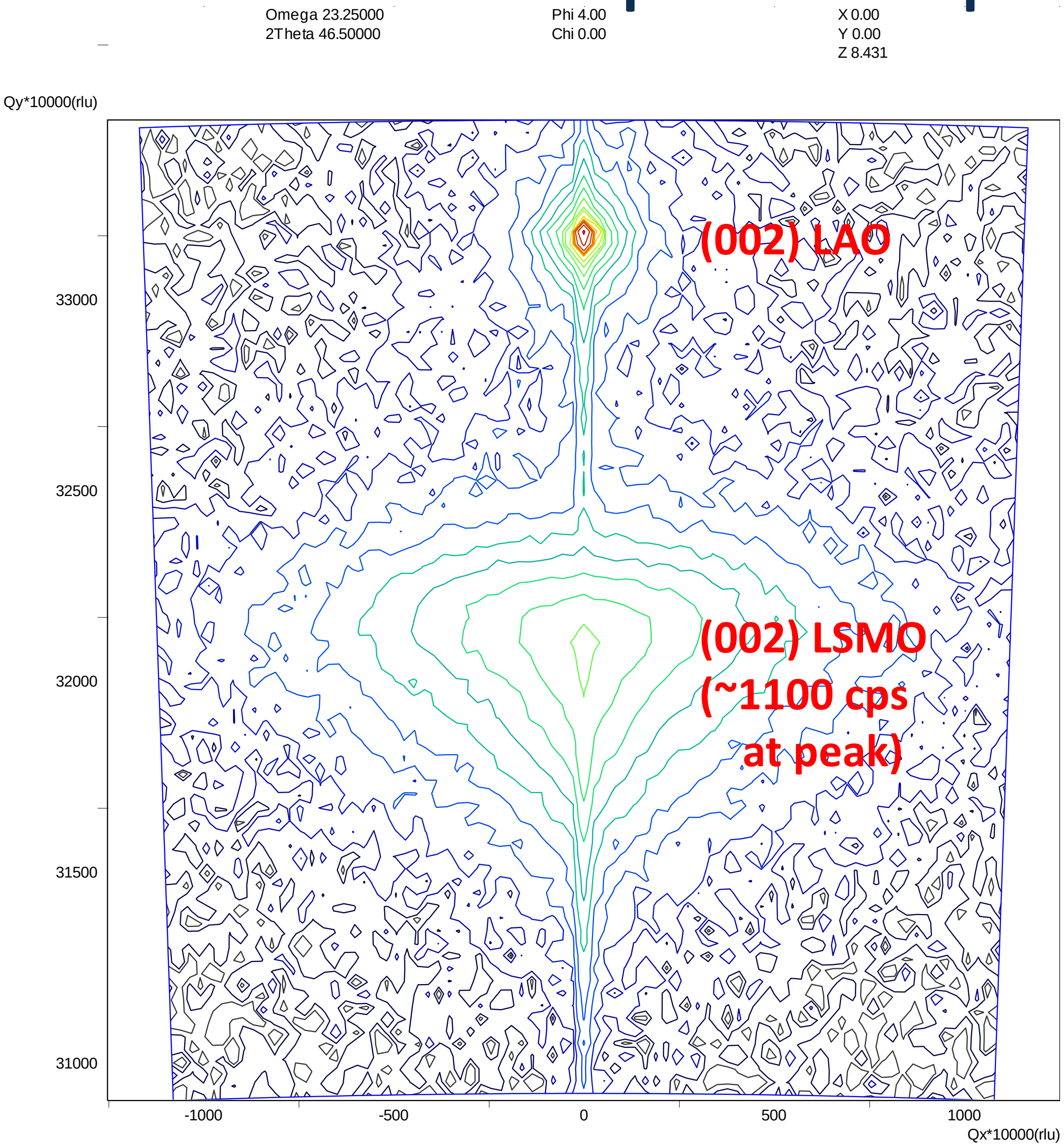
distinct LSMO and ZnO peaks



- high density, epitaxial growth
- two-phase composites

XRD reciprocal-space analysis

Steve Lee



Sample 021815A
LSMO/ZnO on LAO

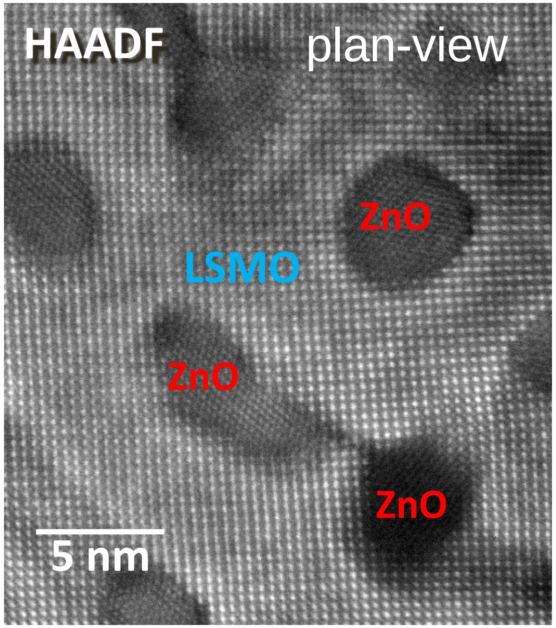
(002) LAO:
2theta=47.985°
Q_y=3.3171 (1/Å)

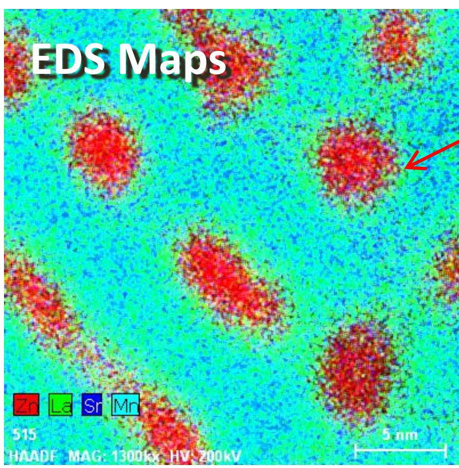
(002) LSMO:
2theta=46.368°
Q_y=3.2099 (1/Å)

The broad LSMO peak shape reflects the presence of both misfit dislocations and the quasi-periodic columnar holes in the epilayer (filled with ZnO) .

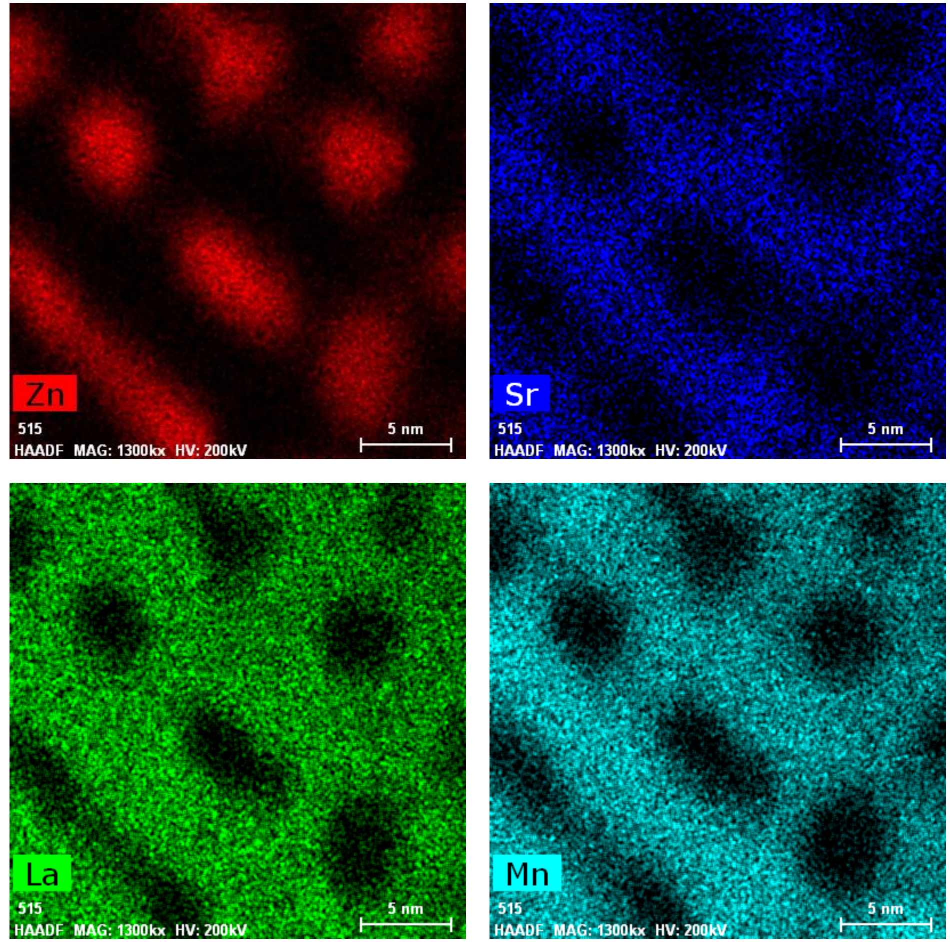
Plan-view TEM and EDS mapping

Ping Lu





A core-shell structure around ZnO, correspondin g to a (La, Mn) –rich, and Sr-deficient layer



Zn-red
La-green
Sr-blue
Mn-cyan

Substrates: STO($SrTiO_3$) *vs* LAO($LaAlO_3$)

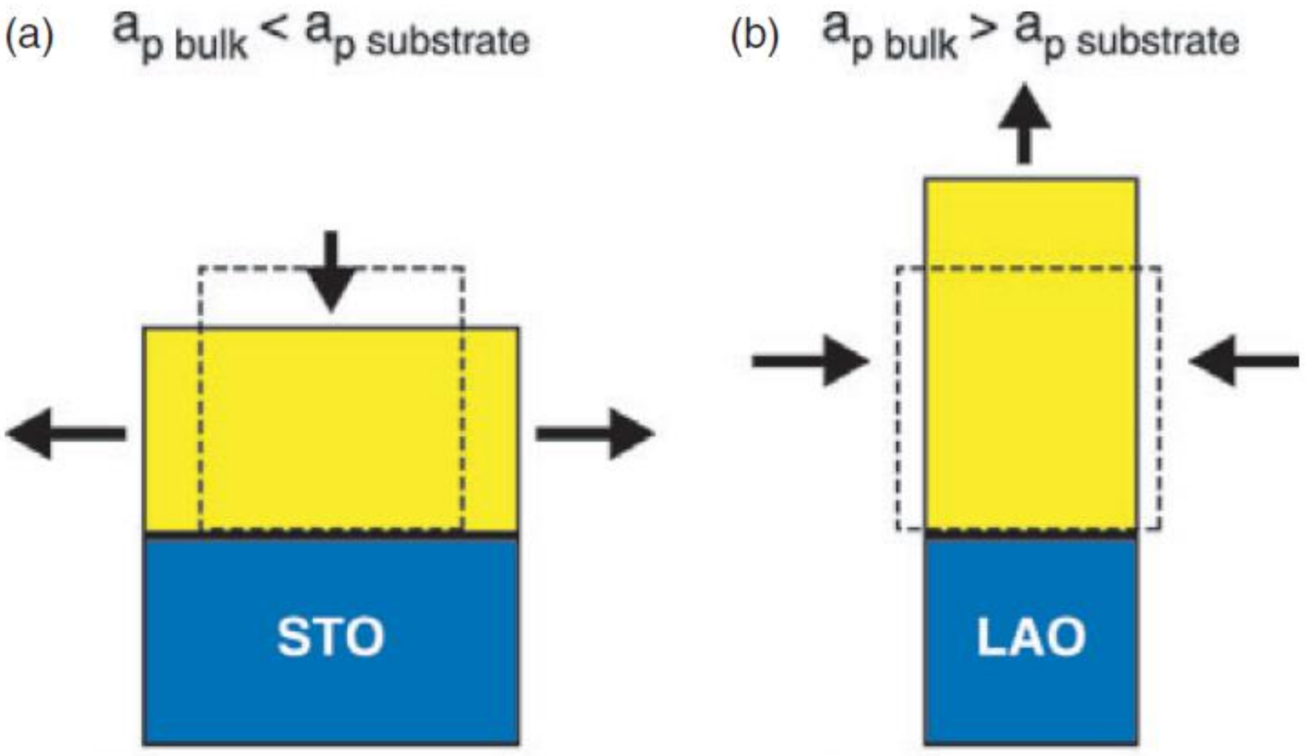
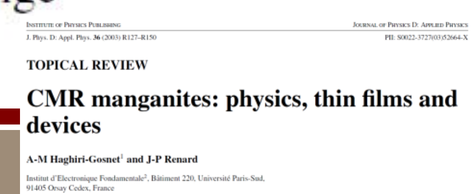


Figure 12. Schematic drafts of the lattice cell distortion in a strained epitaxial film (*a*) under tension or (*b*) compression. Note the change in the out-plane parameter corresponding to each stress sate.



INSTITUTE OF PHYSICS PUBLISHING — JOURNAL OF PHYSICS D: APPLIED PHYSICS
J. Phys. D: Appl. Phys. **36** (2003) R127–R150 — PII: S0022-3727(03)52664-X

TOPICAL REVIEW

CMR manganites: physics, thin films and devices

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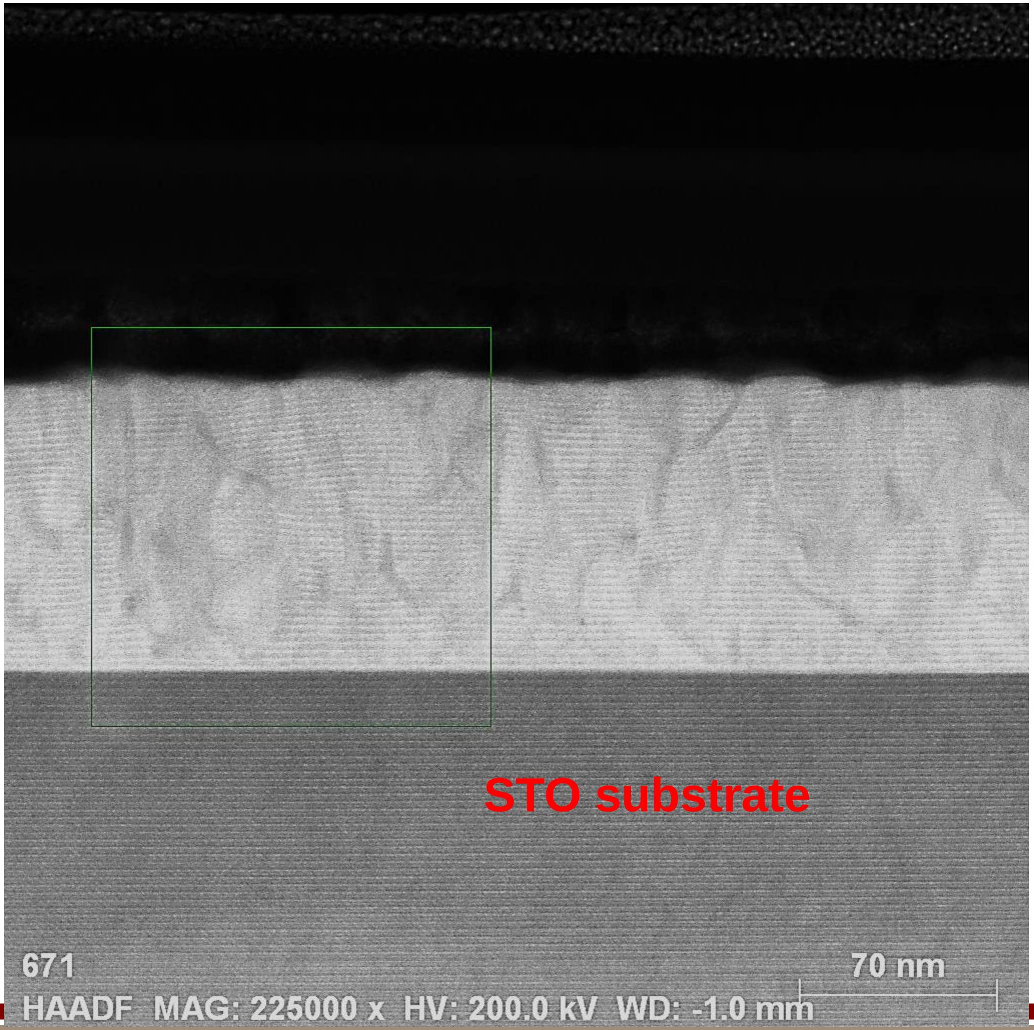
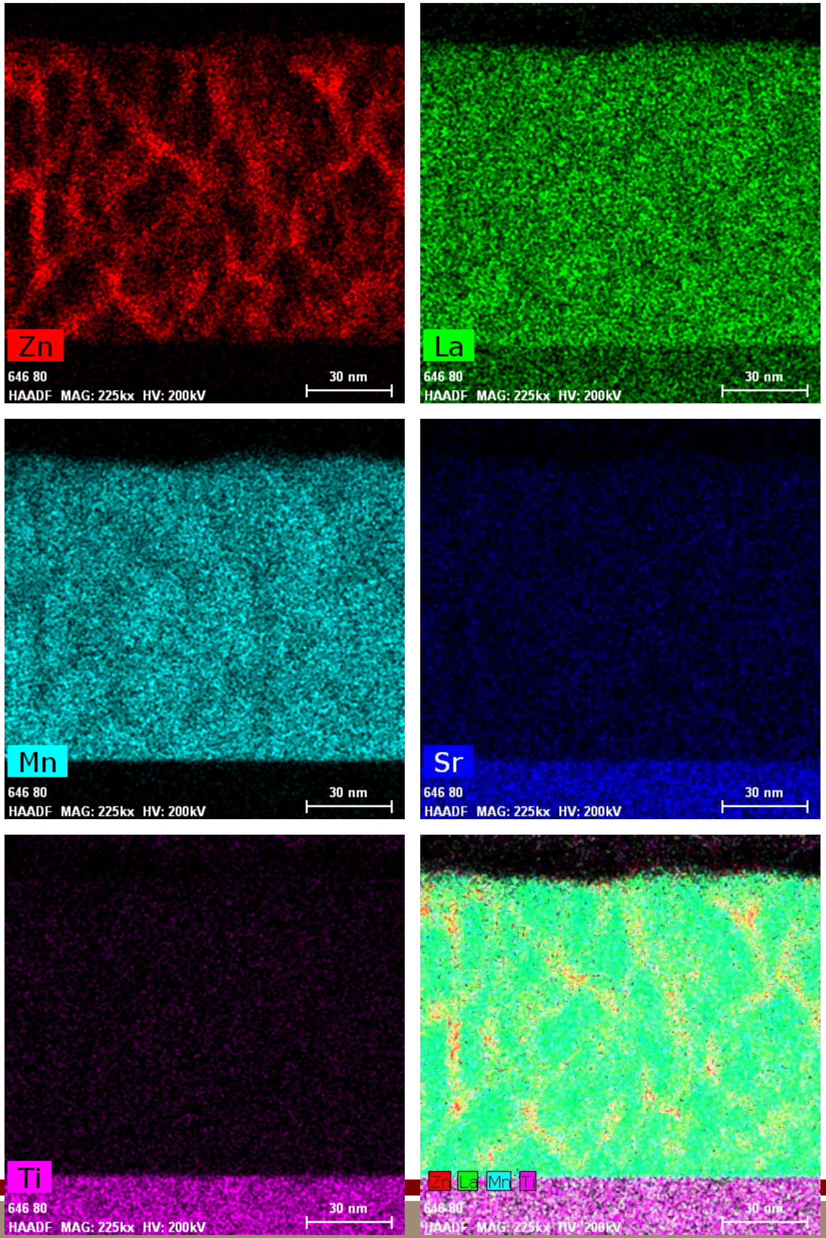
Substrate matters

EDS mapping:

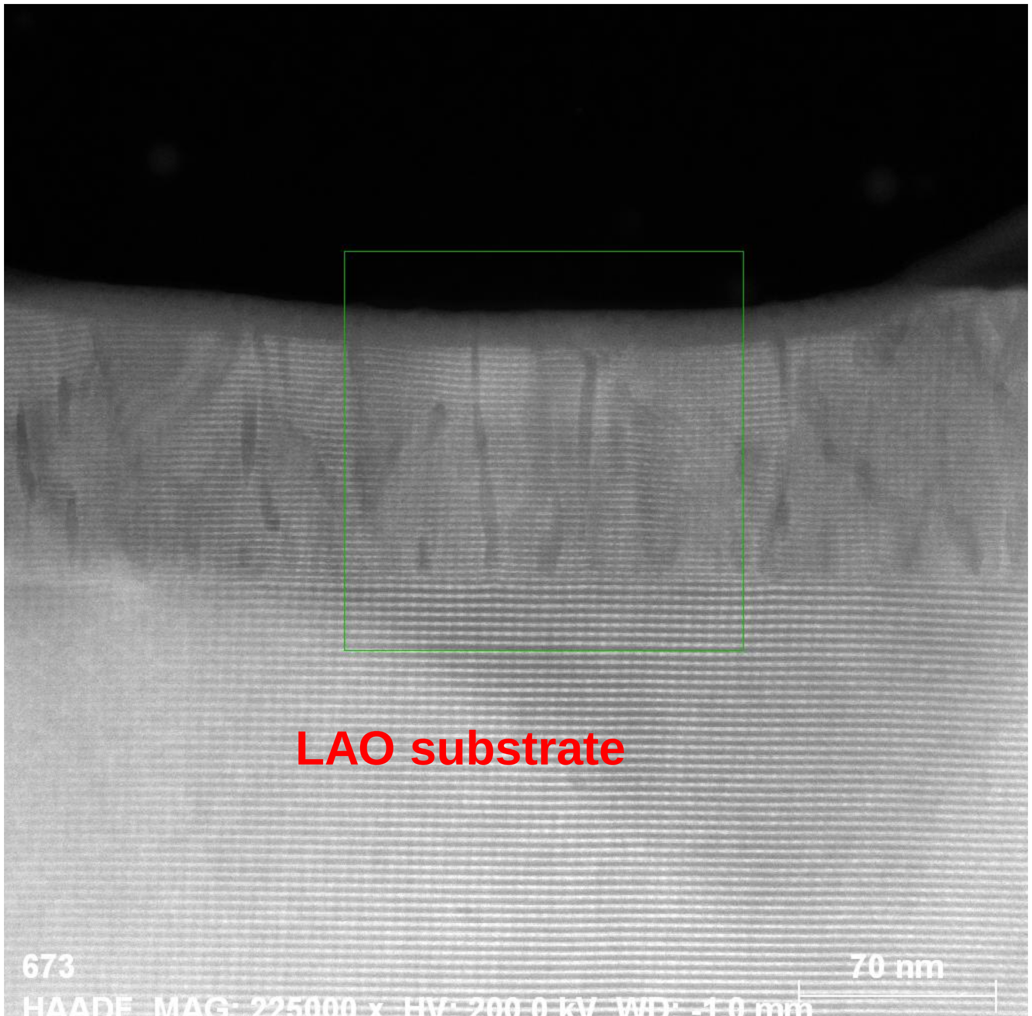
Sample C: 750C, STO substrate

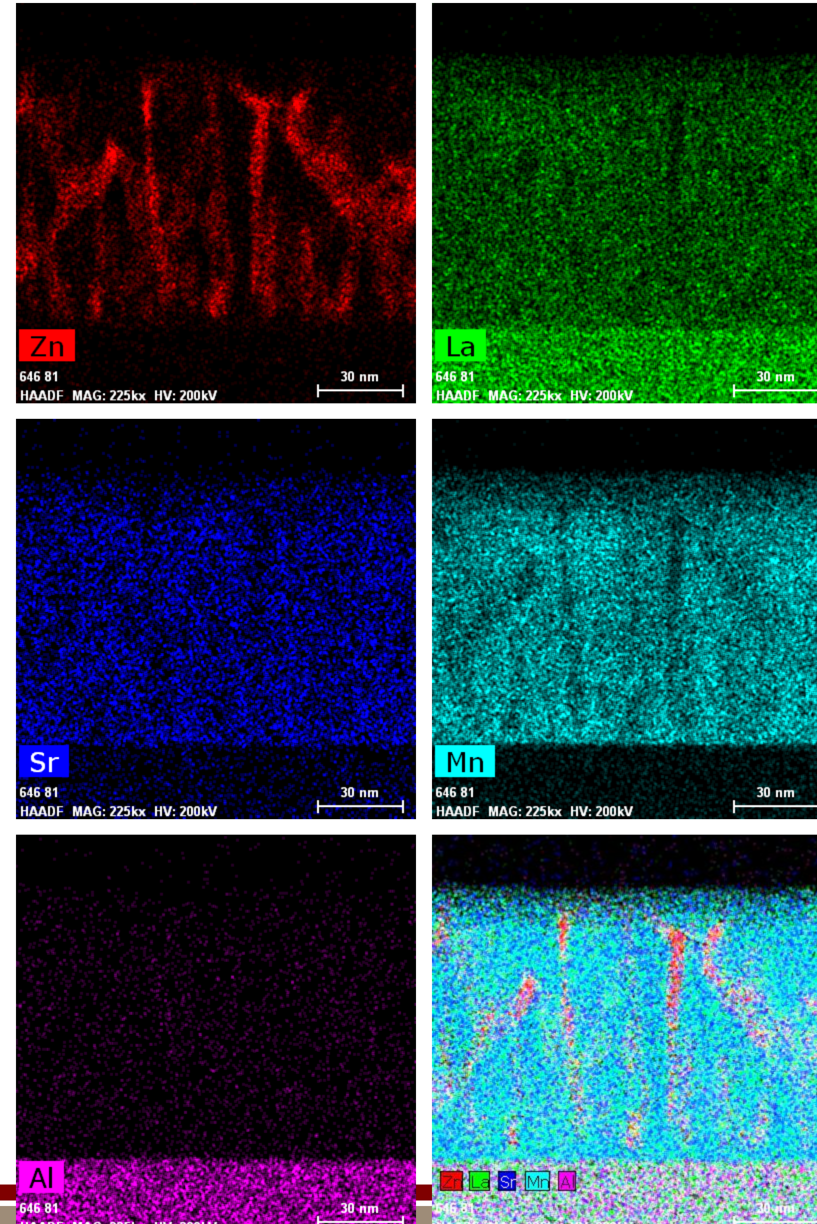




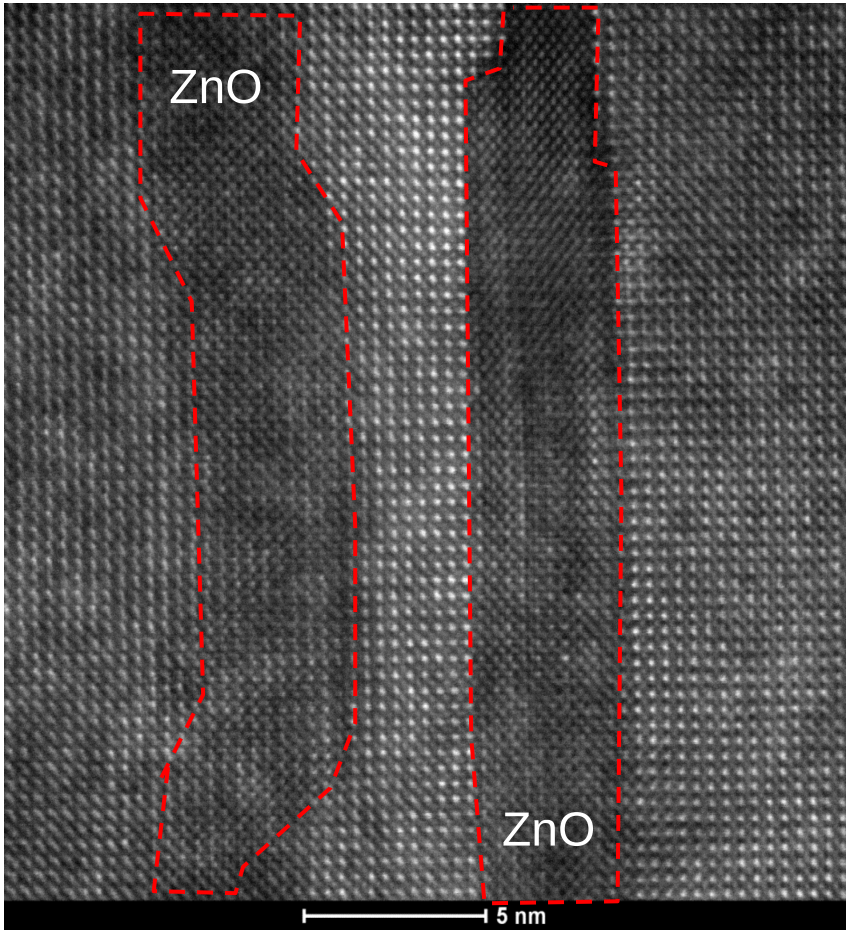
EDS mapping:

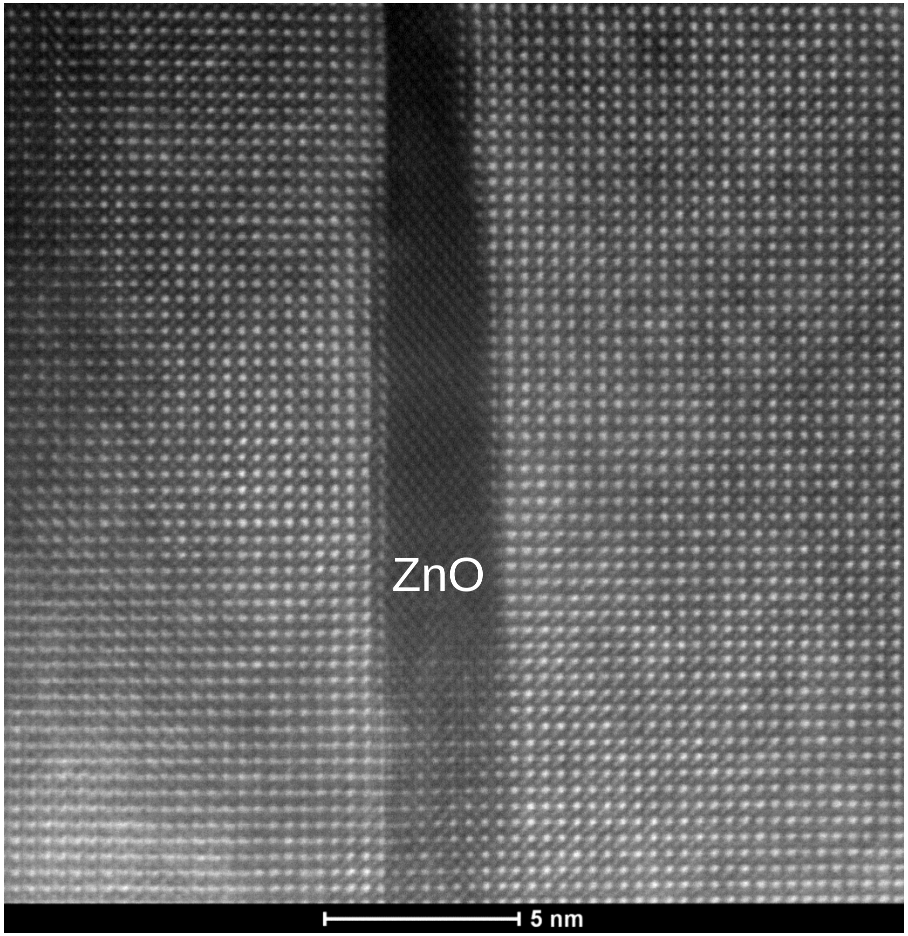
Sample D: 750C, LAO substrate



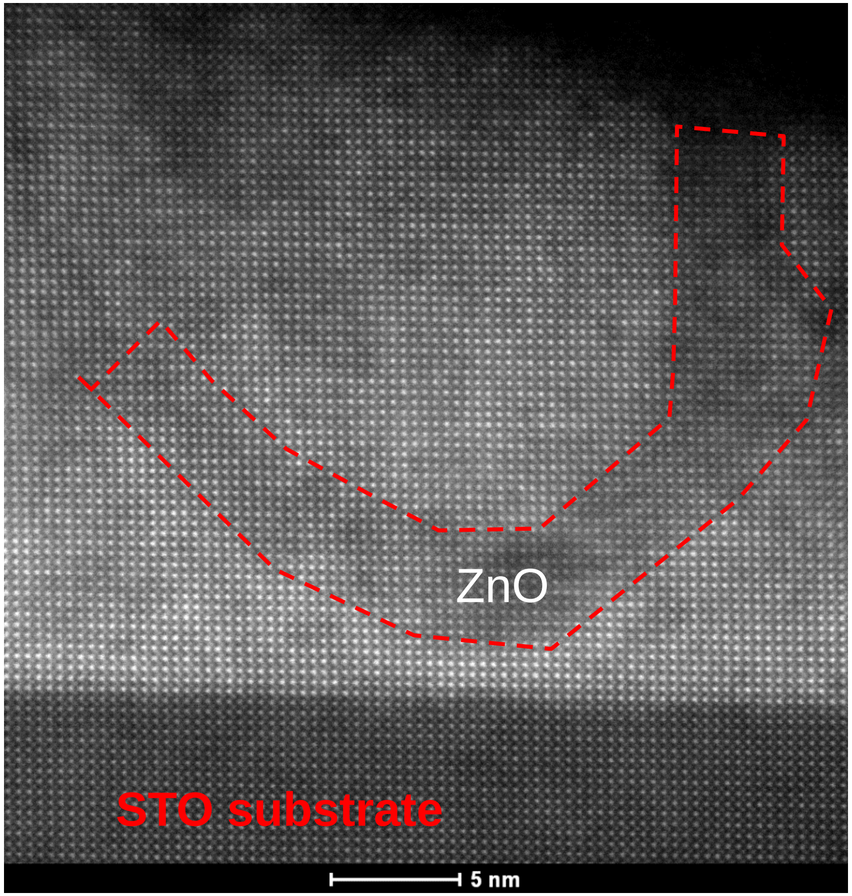


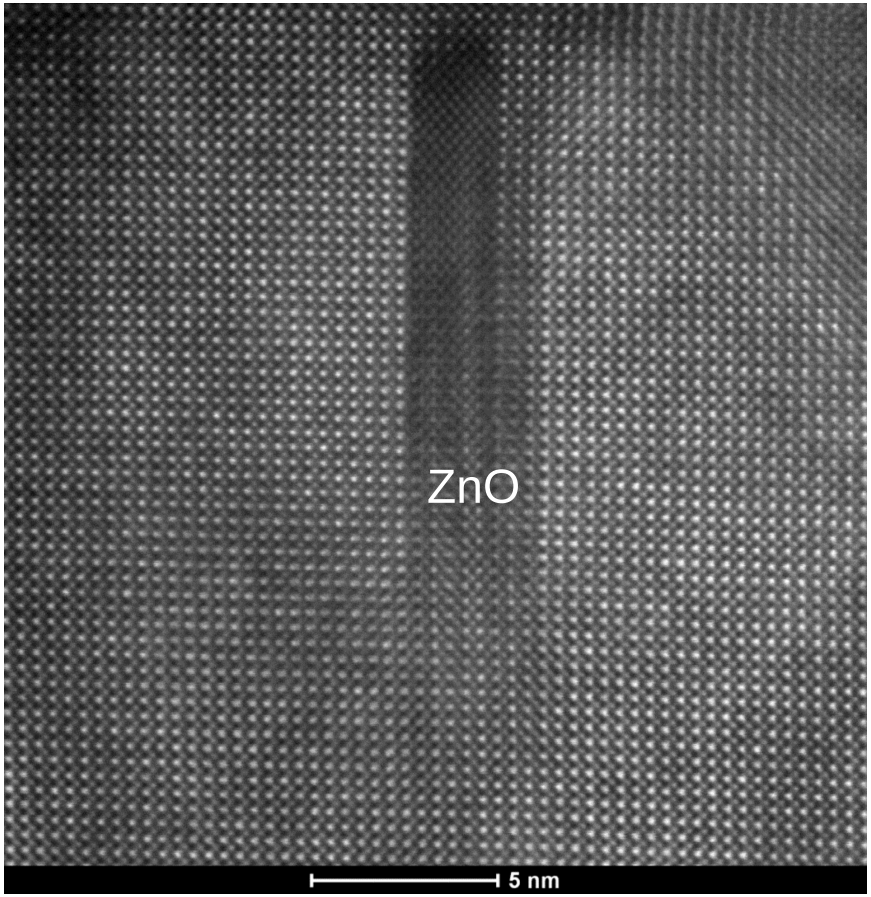
Sample D: 750C, LAO substrate





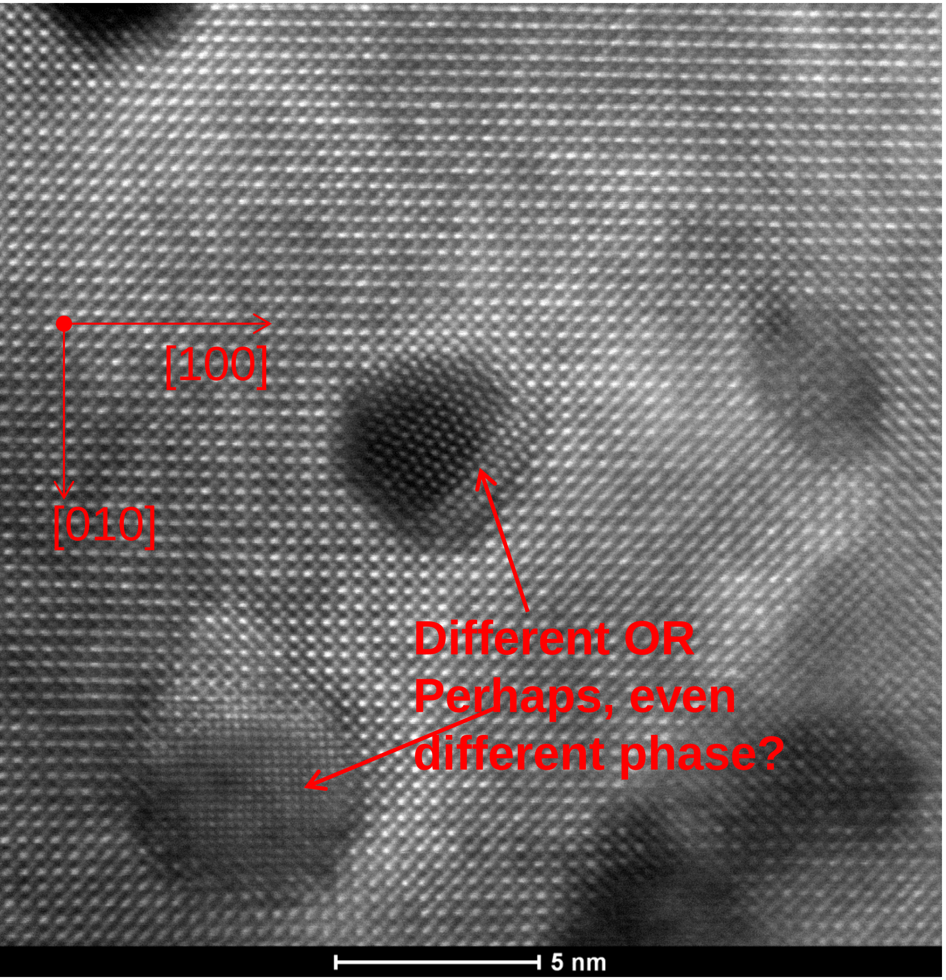
Sample A: 700C, STO substrate

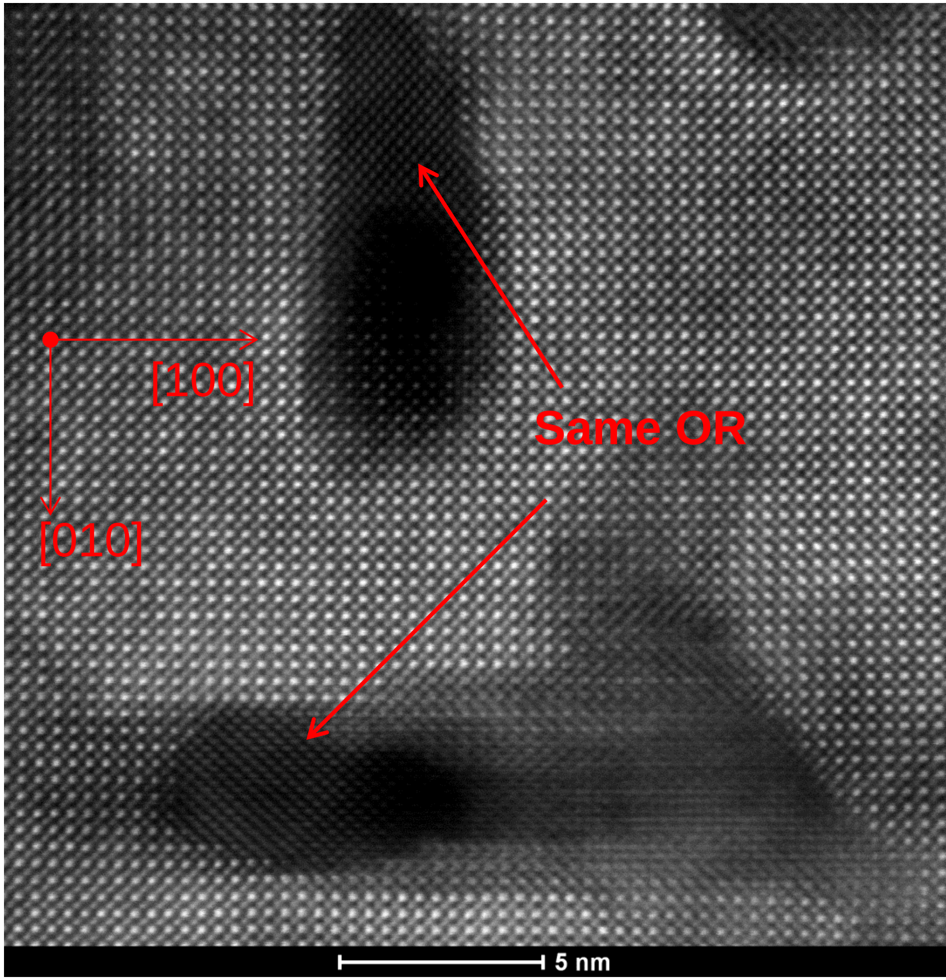




Sample A: LSMO:ZnO/STO, 700C

Sample D: LSMO:ZnO/LAO , 750C

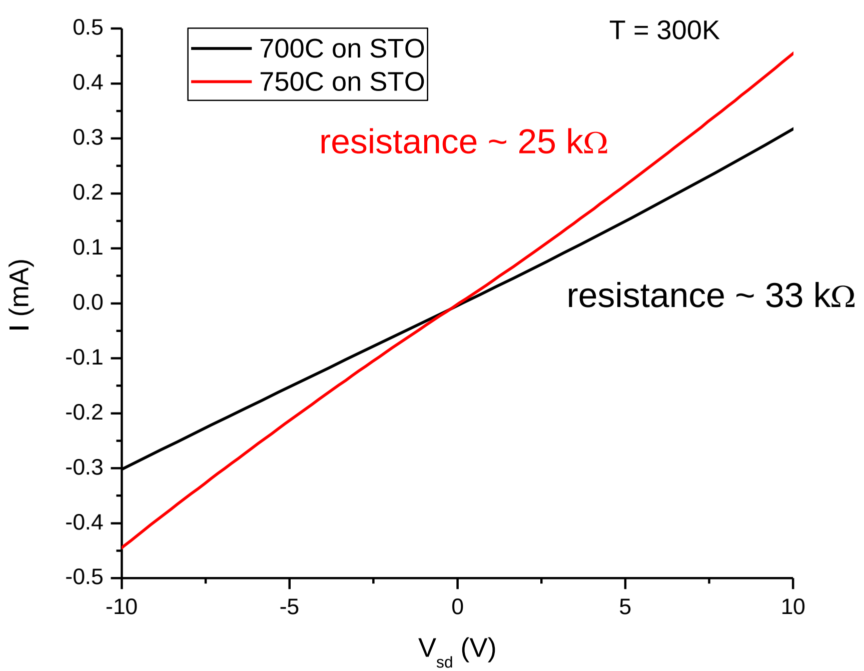


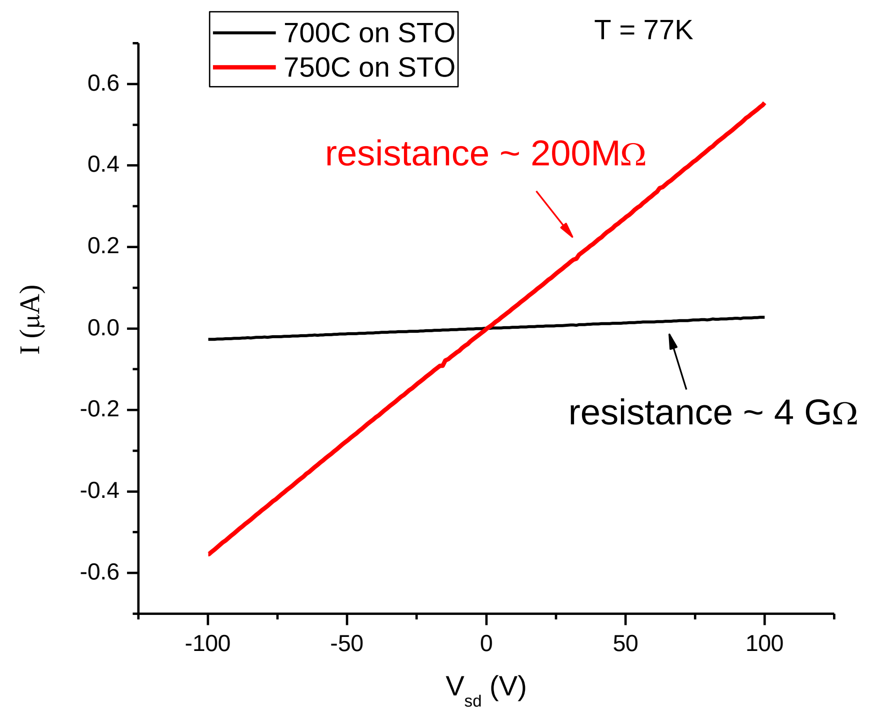


The pillar orientation is different!
On STO, the pillars are in different orientation!
On LAO, same orientation (in different variant due to the symmetry).

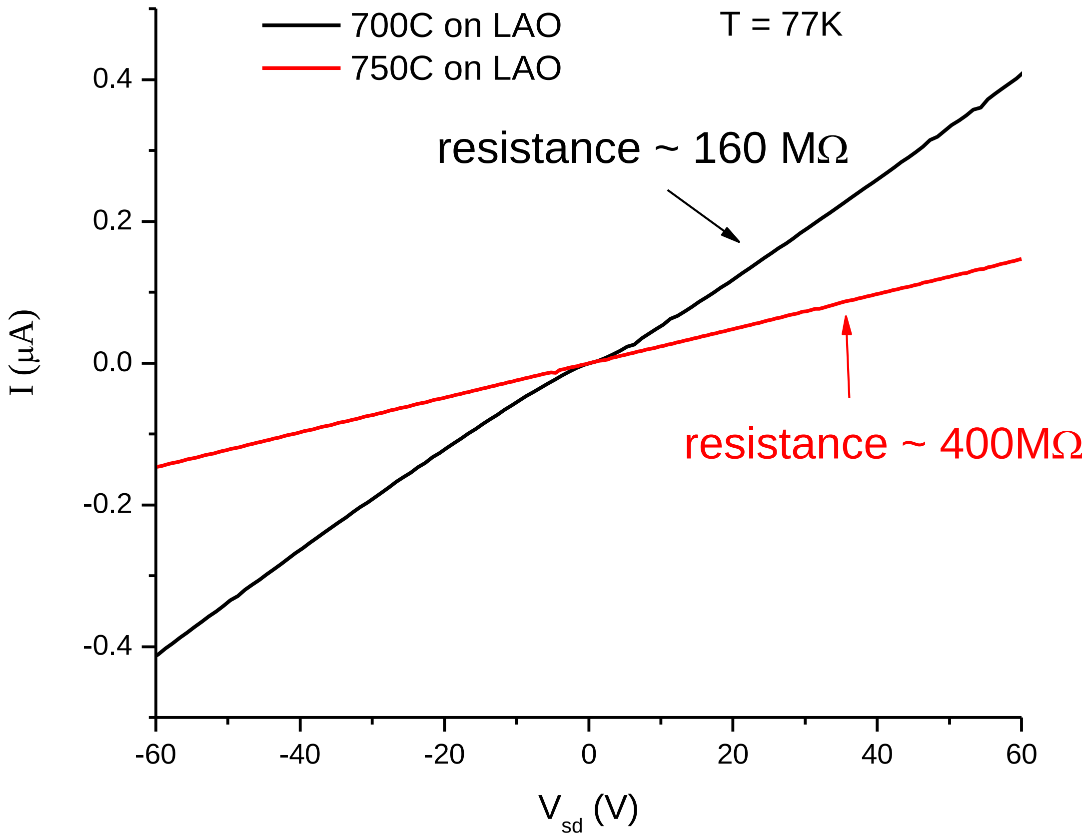
Transport characterizations

Wei Pan

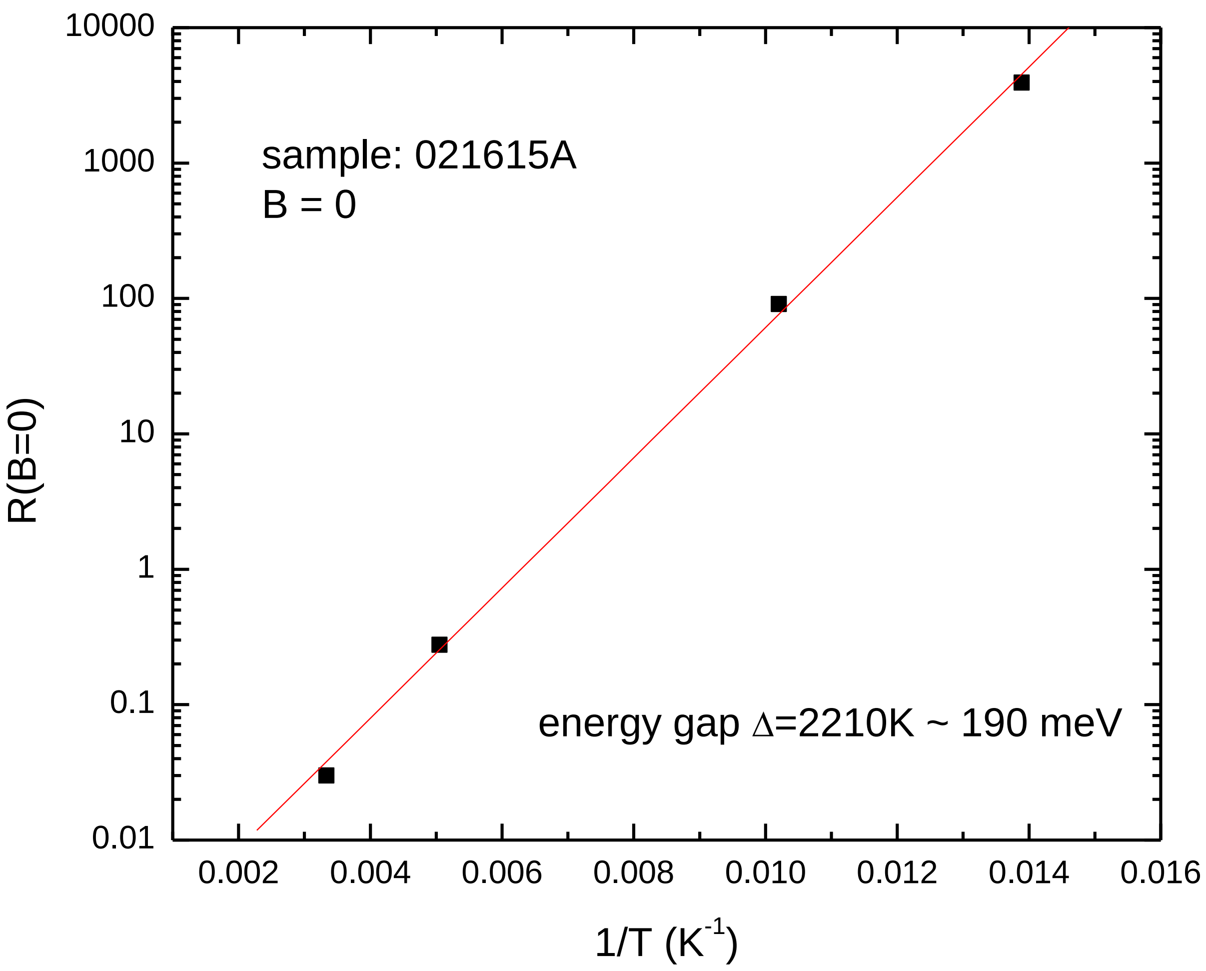




1) For LSMO:ZnO on STO substrate, resistance is lower at high growth temperature.
2) At room temperature, resistance at two growth temperatures differs by a factor of less than 2. at 77K, the ratio is 20.



1) For LSMO:ZnO on LAO substrate, resistance is lower at lower growth temperature.
2) At 77K, the ratio is 2.5.

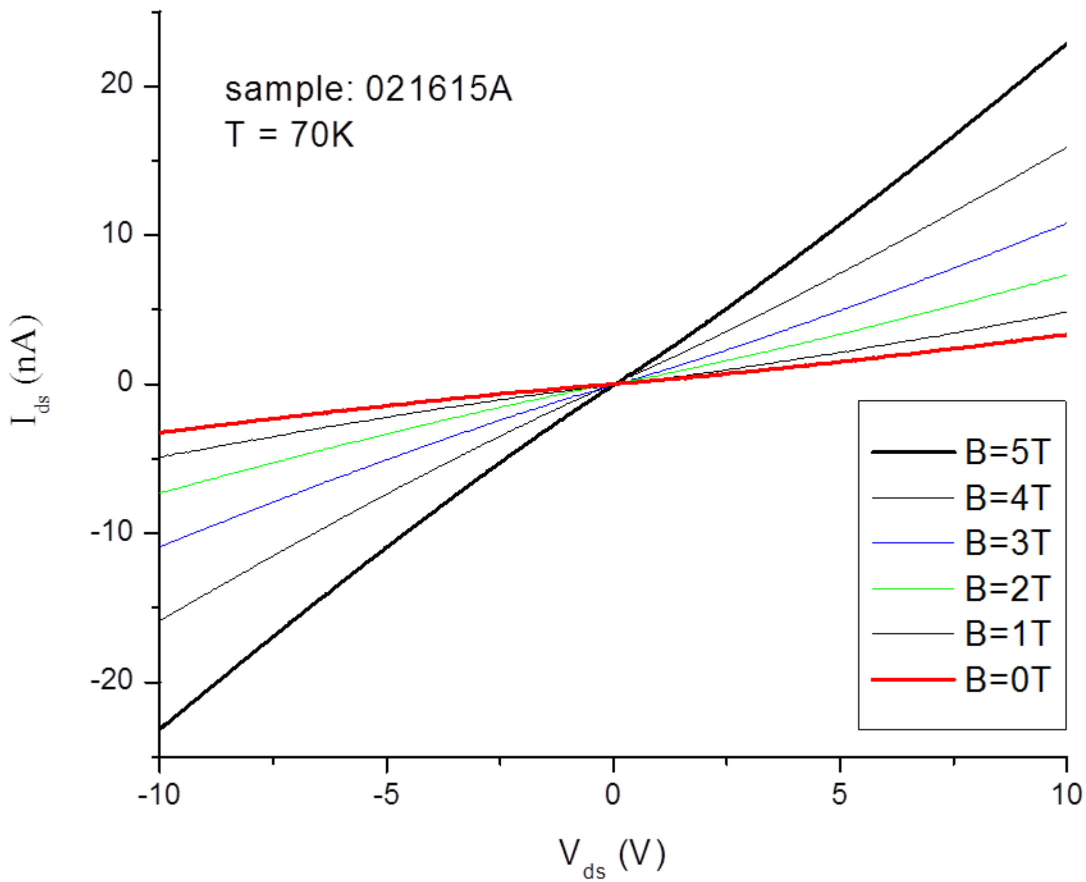


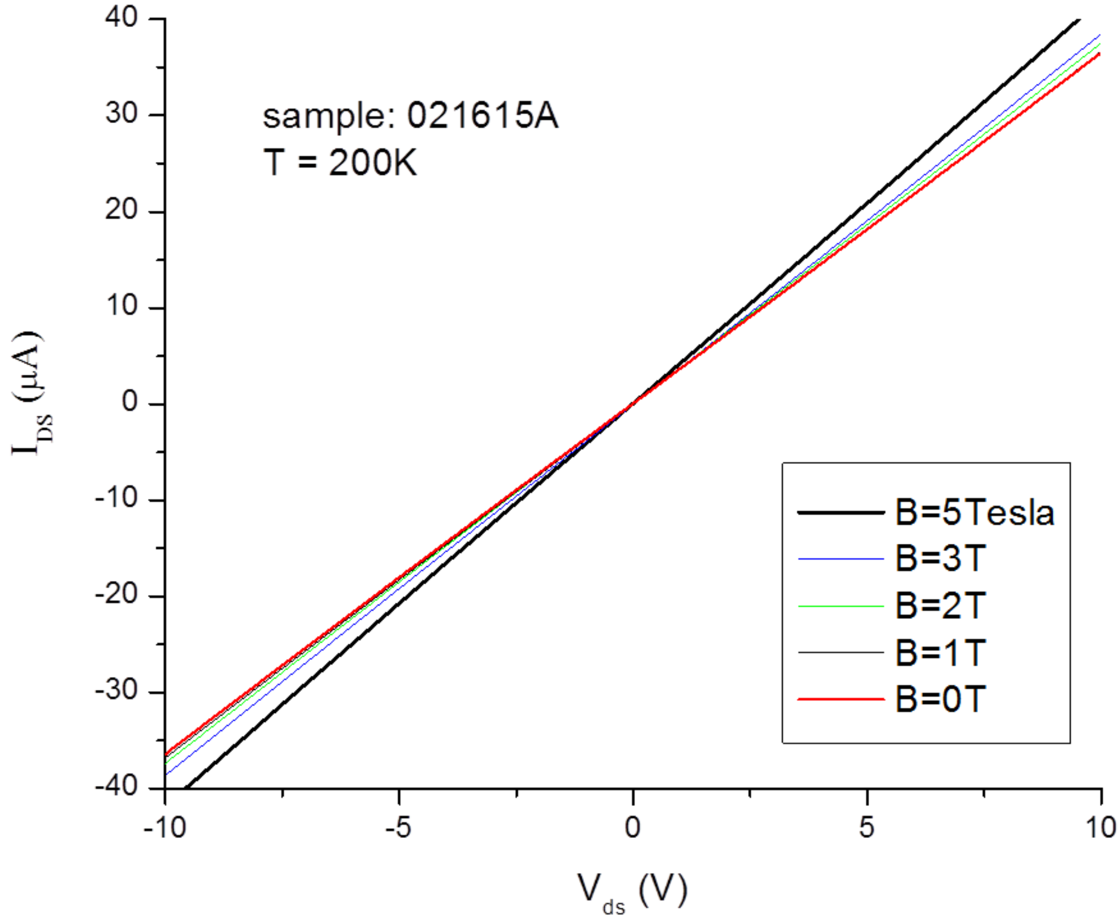
Resistance shows activated behavior

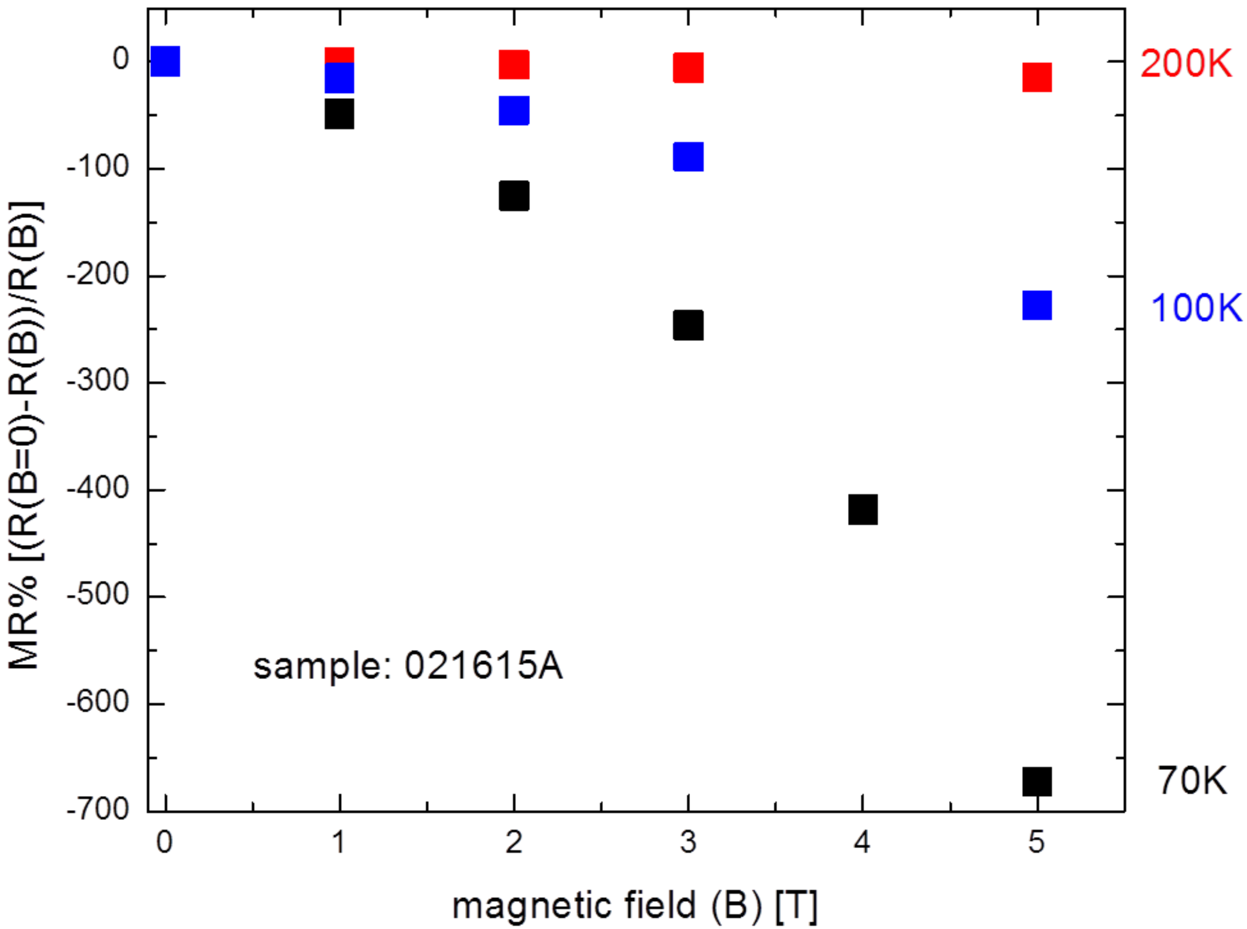
$R \propto \exp(-\Delta/2k_BT)$.

$\Delta \sim 190\text{meV}$

Giant magneto-resistance (GMR)



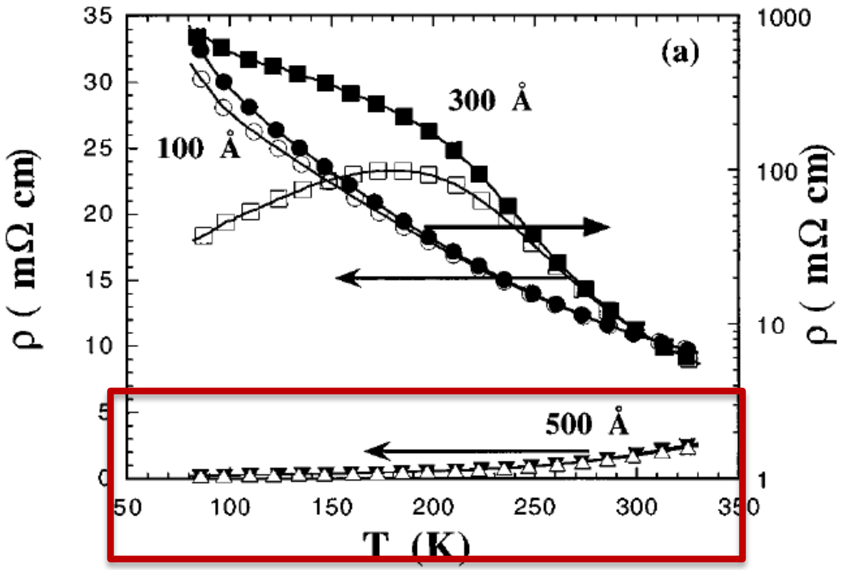

sample: 021615A
T = 200K
B=5Tesla
B=3T
B=2T
B=1T
B=0T
I_{DS} (μA)
V_{ds} (V)
40
30
20
10
0
-10
-20
-30
-40
-10
-5
0
5
10



This sample shows a strong negative magneto-resistance at low temperatures, reaching ~ 700% at B = 5T at T = 70K.

Origin of GMR?

ZnO nanopillars must play an import role!



$La_{0.67}Sr_{0.33}MnO_3$ single-phase film on LAO

Evolution of strain-dependent transport properties in ultrathin La 0.67 Sr 0.33 MnO 3 films

H. L. Ju, Kannan M. Krishnan, and D. Lederman

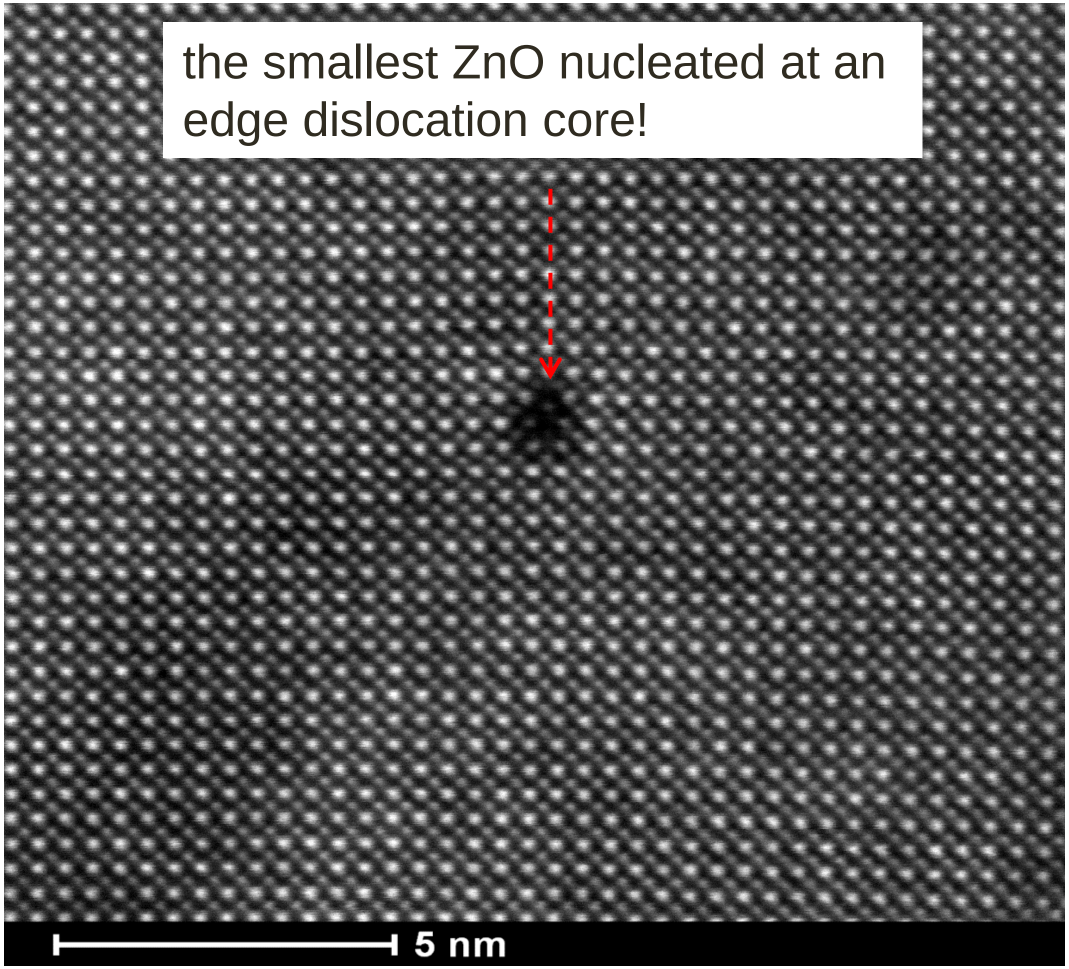
Citation: Journal of Applied Physics **83**, 7073 (1998); doi: 10.1063/1.367864

cases, for $t = 500$ Å a metallic behavior with a room temperature resistivity of ~ 2 mΩ cm, along with a large MR effect near and above room temperature, but with insignificant MR at low temperature, is observed.

(1 Tesla)

Extra slides

- **film/substrate crystal orientation:**
  - **LSMO[001]//LAO[001], LSMO[010]//LAO[010]**
  - **ZnO[110]//LAO[001], ZnO[001]//LAO[110]**



LAO substrate

Presence of Zn at the core was confirmed by EDS!