

# Voltage control of magnetism in $\text{La}_{0.67}\text{Sr}_{0.33}\text{MnO}_3/\text{PMN-PT}$ heterostructures

T.Bhatnagar<sup>1,2</sup>, A. Sarkar<sup>1</sup>, E. Kentzinger<sup>1</sup>, A. Kovács<sup>2</sup>, Q. Lan<sup>2</sup>,  
P. Schöffmann<sup>1</sup>, M. Waschk<sup>1</sup>, B. Kirby<sup>3</sup>, A. Grutter<sup>3</sup>,  
R. E. Dunin-Borkowski<sup>2</sup> and Th. Brückel<sup>1</sup>

<sup>1</sup>Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institut (PGI-4), JARA-FIT, 52425 Jülich, Germany

<sup>2</sup>Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

<sup>3</sup> NIST Center for Neutron Research, NIST, Gaithersburg, MD

## Motivation

Current information devices based on spin and charge

Quest for higher data density without need of magnetic field to manipulate magnetization

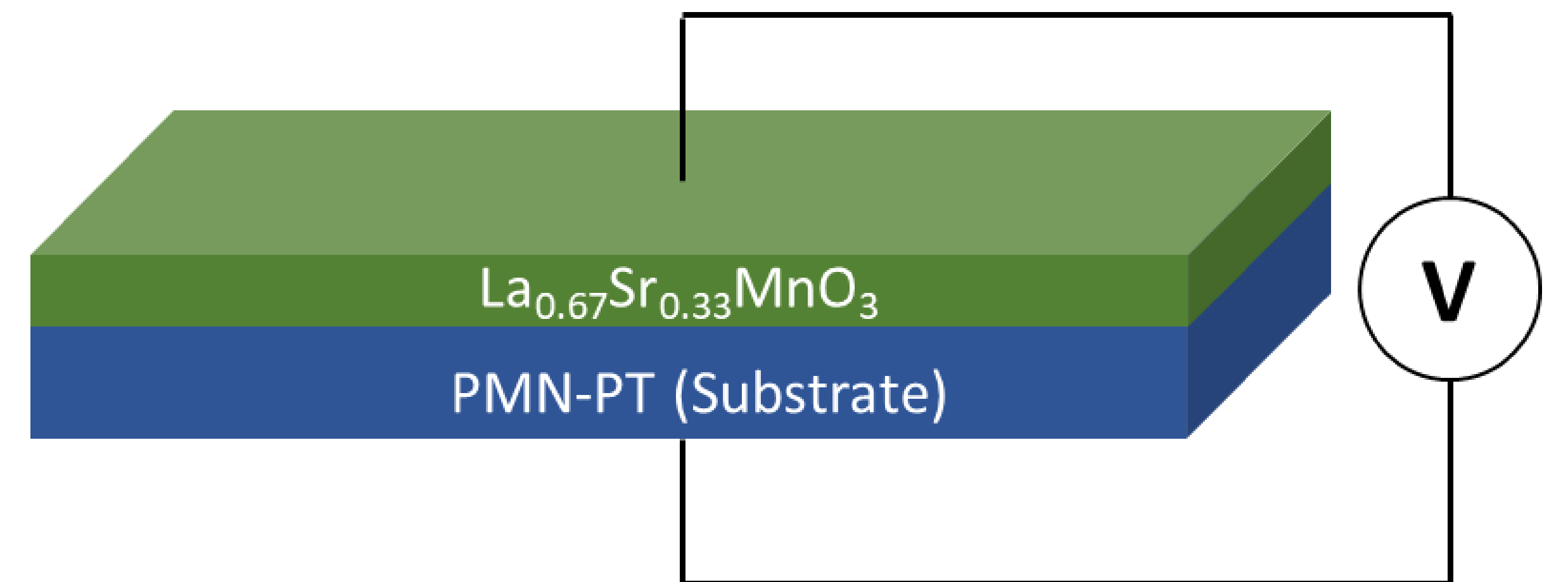
Complex oxides- strong coupling between lattice, charge, spin & orbital degrees of freedom

Voltage control of magnetism

Ferromagnetic/Ferroelectric heterostructures (FM/FE)

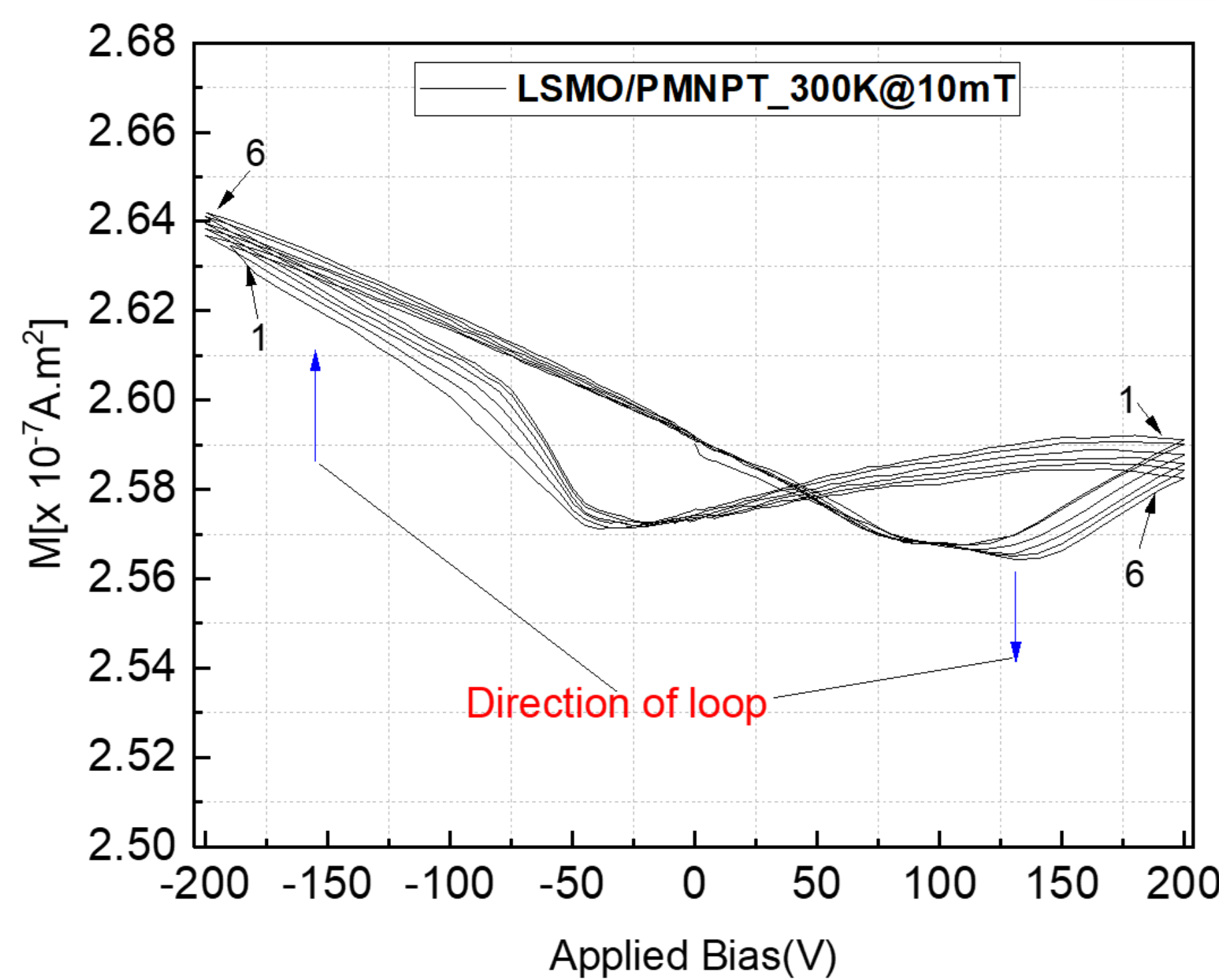
Magnetoelectric coupling

## System

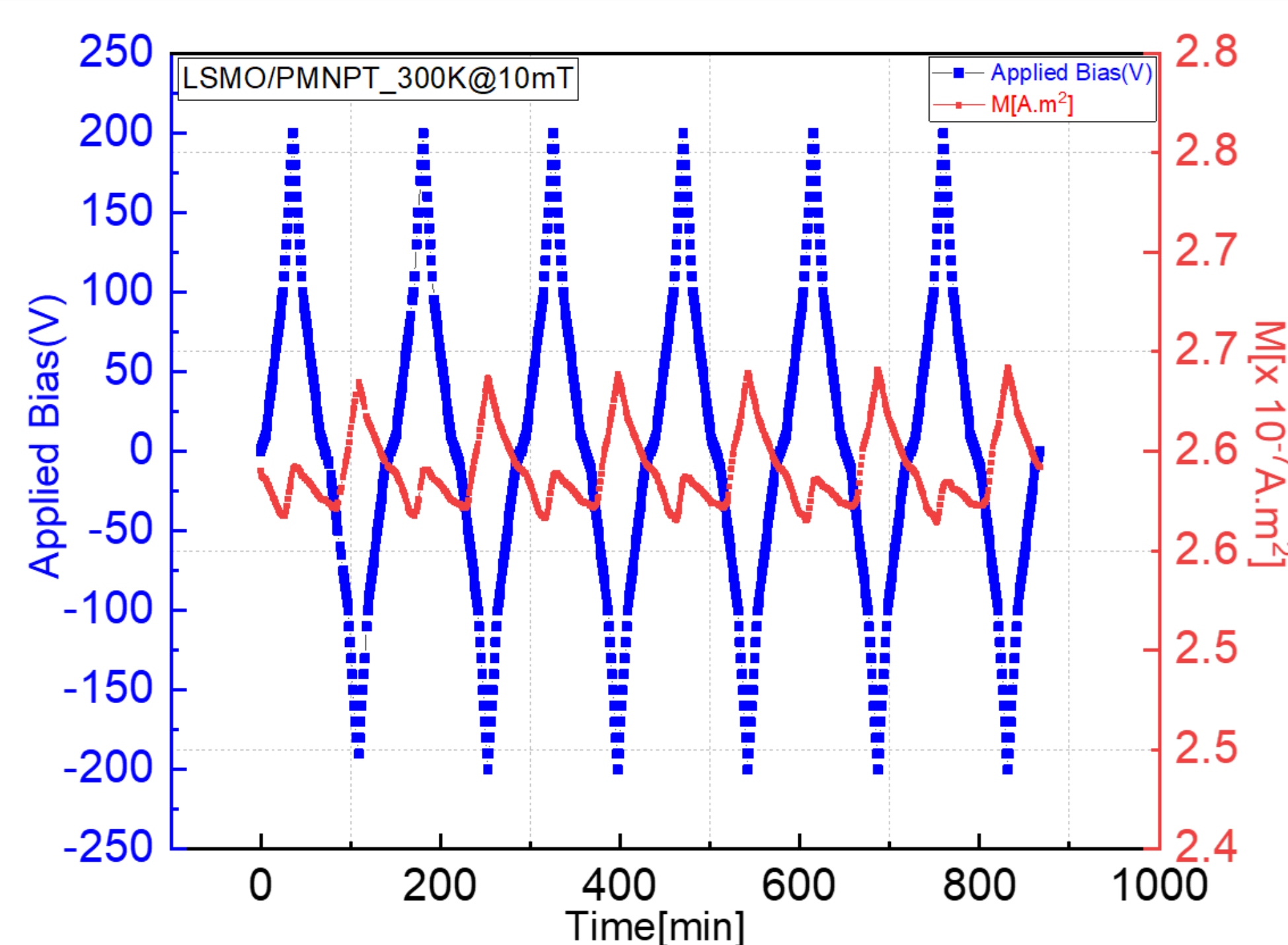


**FM layer** -  $\text{La}_{0.67}\text{Sr}_{0.33}\text{MnO}_3$  (LSMO-30nm)  
**Piezoelectric substrate** – PMN-PT ( $0.7\text{Pb}(\text{Mg}_{1/3}\text{Nb}_{2/3})\text{O}_3$ - $0.3\text{PbTiO}_3$  (001))

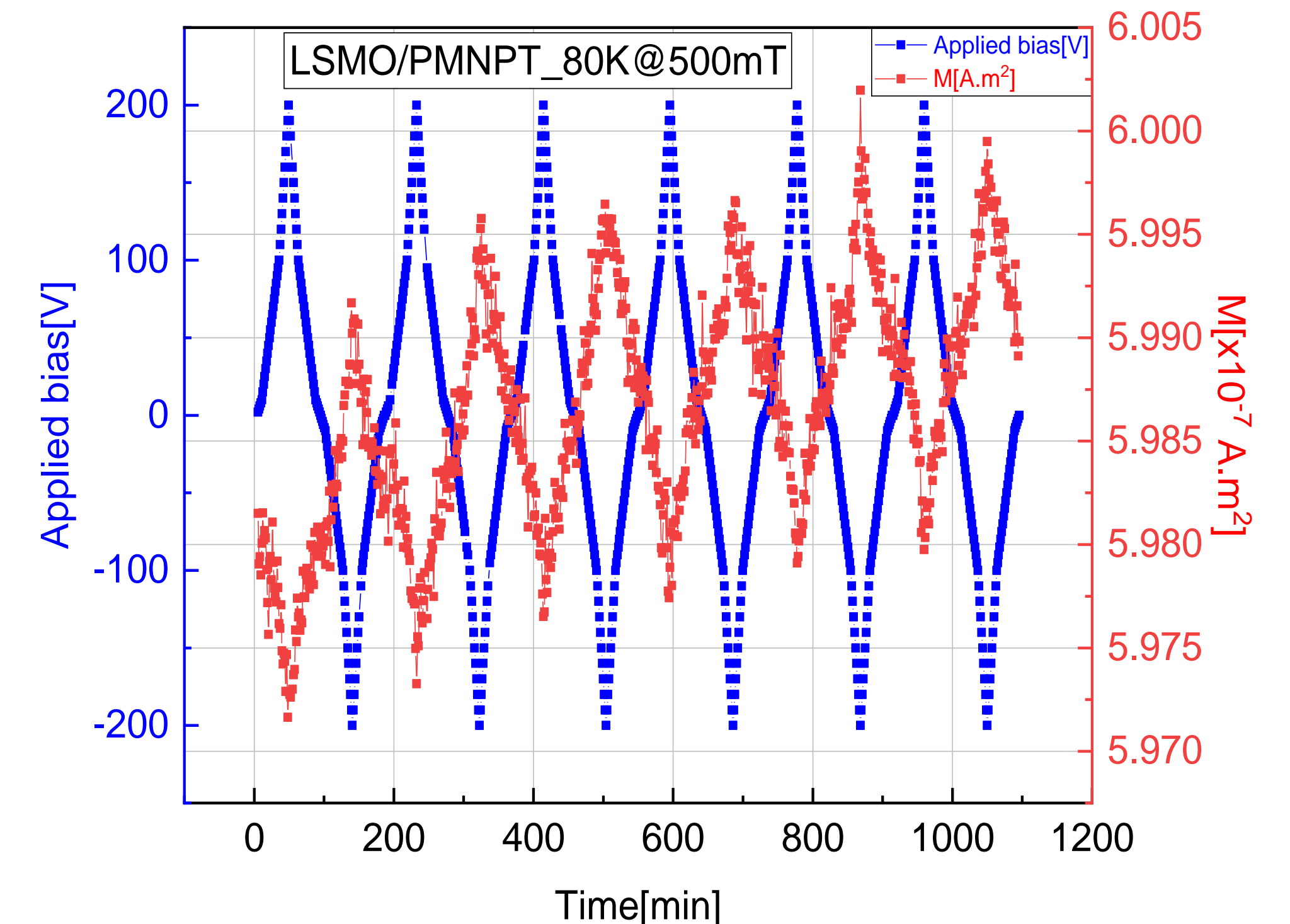
## Magnetoelectric SQUID measurements



Strain-mediated magnetoelectric coupling

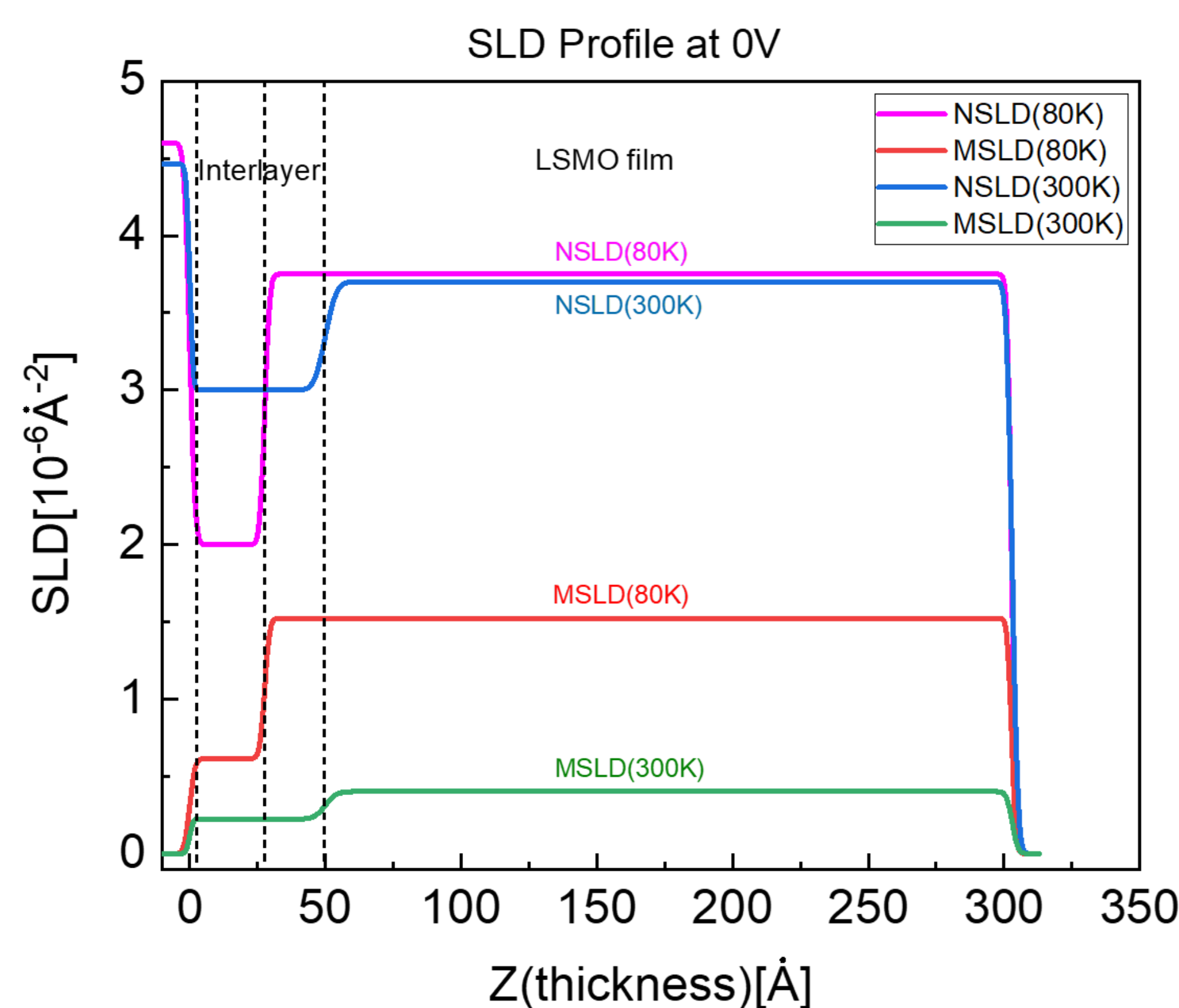
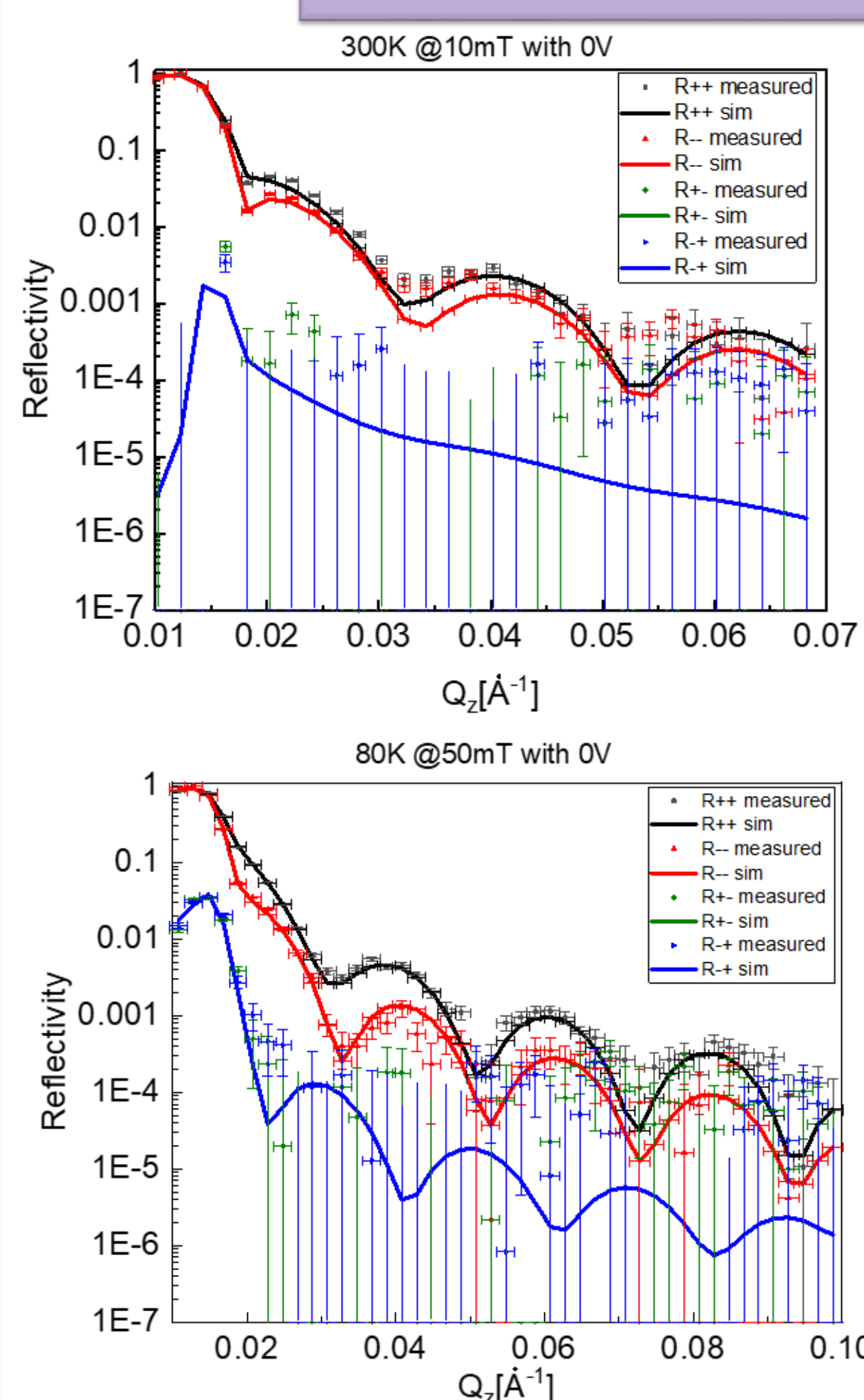


Rich correlation between magnetization and applied voltage



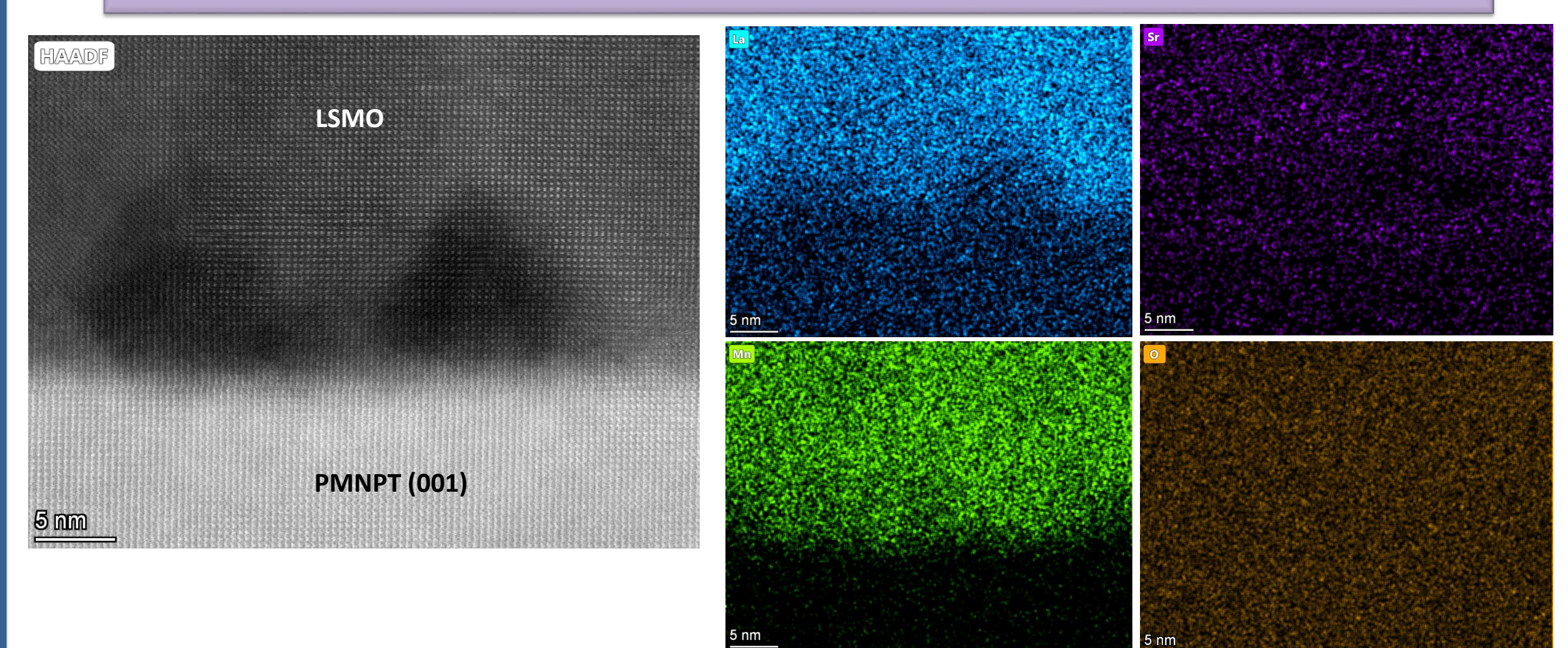
Low temperature magnetoelectric coupling

## Polarized Neutron Reflectometry

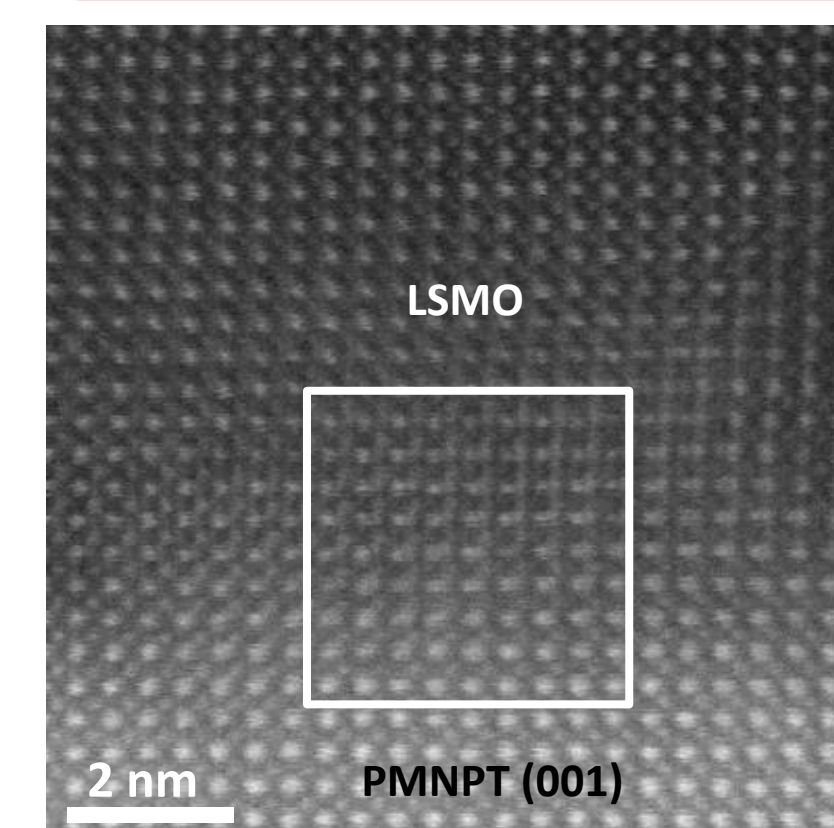


- The magnetic depth profile deduced from PNR datasets indicate the presence of interlayer between LSMO/PMNPT.
- Spin-flip signal indicates presence of canted magnetic moments due to the strain imparted by the substrate.

## Transmission Electron Microscopy



Darker contrast regions show La- deficiency at the interface



LSMO has grown epitaxially on PMNPT and is strained at the interface

## Conclusions and outlook

- ✓ Clear proof of strain-mediated magnetoelectric coupling.
- ✓ Possible indication of charge-mediated magnetoelectric coupling due different magnetization values for opposite polarity of applied voltage.
- ✓ Presence of interlayer with reduced SLD and La-deficiency at the interface.
  - Analysis of PNR curves with voltages is in progress.
  - Further structural investigation will be done using TEM.

## Acknowledgement

- PNR measurements were performed at NIST Center for Neutron Research, Gaithersburg, Maryland, USA
- All other measurements were performed at Forschungszentrum Jülich GmbH, Germany

Contact: [t.bhatnagar@fz-juelich.de](mailto:t.bhatnagar@fz-juelich.de)