Intégration de films minces piézoélectriques sur silicium

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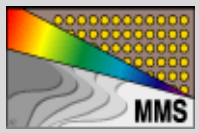

Outline

Introduction

Part 1: growth of piezoelectric thin films on Si/STO pseudo substrate

- Si/STO pseudo substrate
- PLD growth of oxide on Si/STO pseudo substrate

Part 2: Integration of piezoelectric in devices

- Anisotropy tuning in ferromagnetic metals
- Free-standing oxide structures for MEMS

Conclusions

Motivation of this work

• Study the coupling between materials with several physical properties such as Ferromagnetism and Ferroelectricity

Fully epitaxial oxide structures / mixed epitaxial oxide – Metals

- Manipulation of the magnetism by reverse magnetostriction
- Domain wall based memory
- Magneto-electric sensors

• Maximize the effects of strain

→ free standing structures

• Silicon allow high selectivity to free up oxide structures.

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  + Electrical properties
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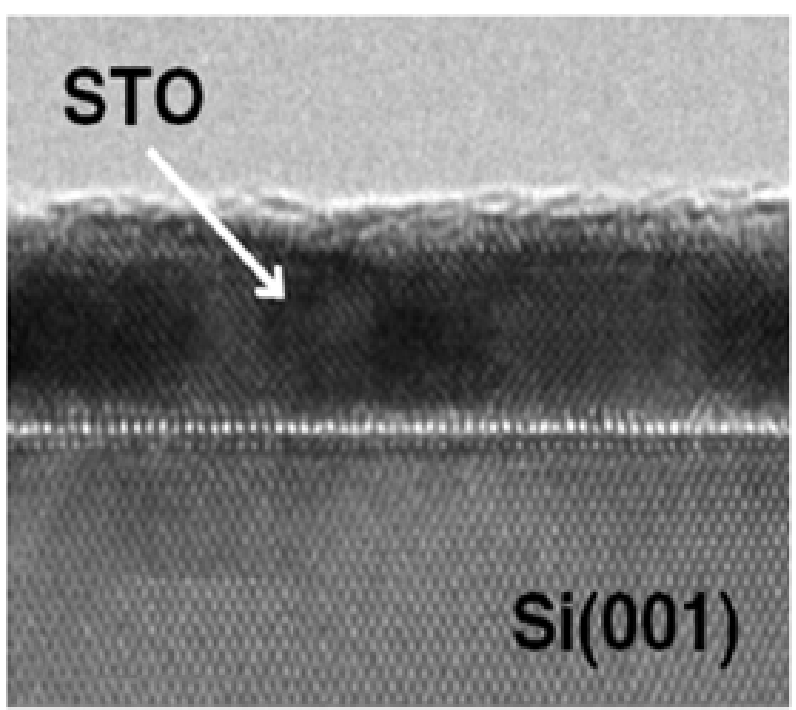
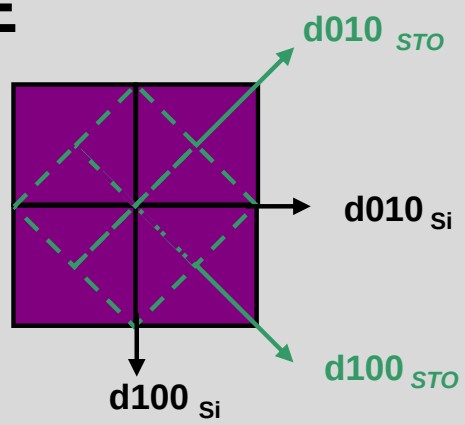
coll. INL Lyon *(Appl. Phys. Lett. **95**, 062902)*

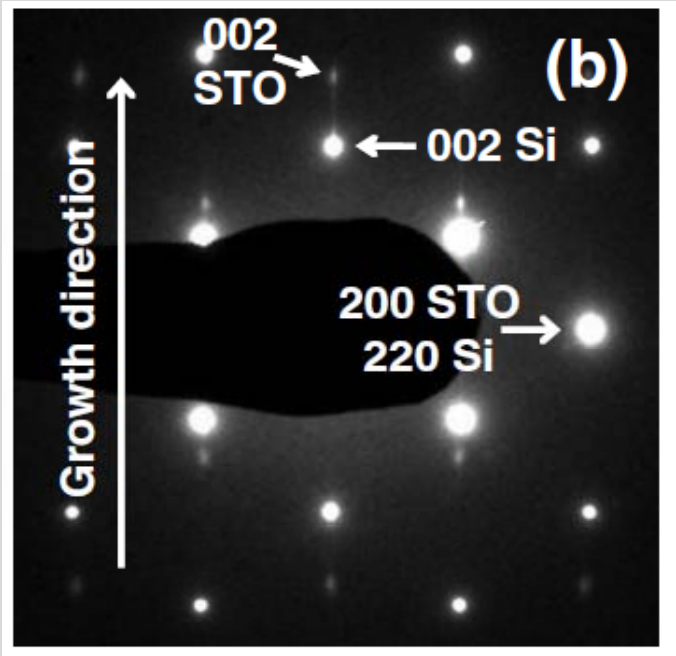
STO on Si deposited by MBE

TEM Cross section





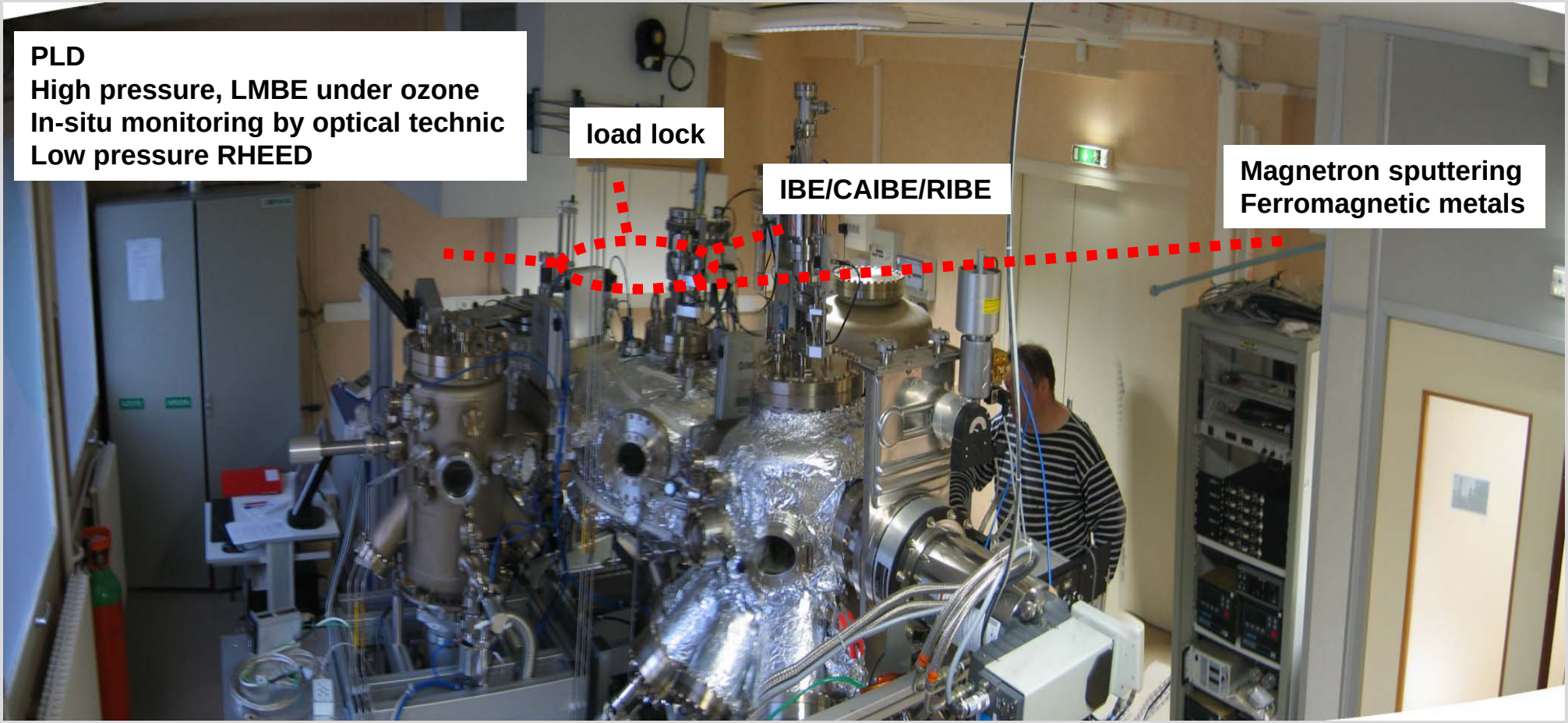
TEM Diffraction Pattern



Abrupt interface

Brief overview of the growth facilities:

Joint NST / CTM project: multi-technologies deposition/etch cluster

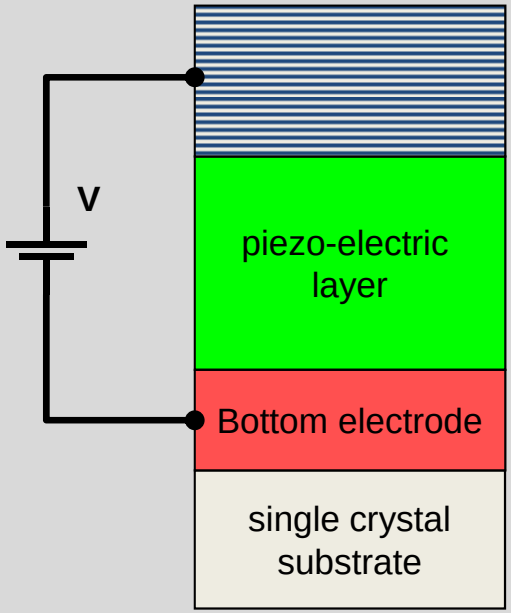


Réseau de grandes centrales technologiques pour la *Recherche Technologique de Base*

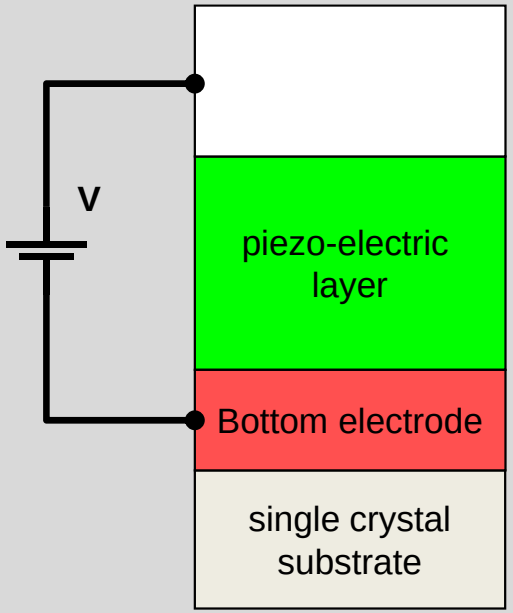
Aim: Grow PZT and PMN-PT on Si-STO pseudo-substrate

Coefficient	PZT (pm/V) $PbZr_{0.5}Zr_{0.5}O_3$	PMN-PT (pm/V) $0.7Pb(Mg_{1/3}Nb_{2/3})O_3$-$0.3PbTiO_3$
d_{33}	593	2200

Requirement for perpendicular polarization: bottom electrode



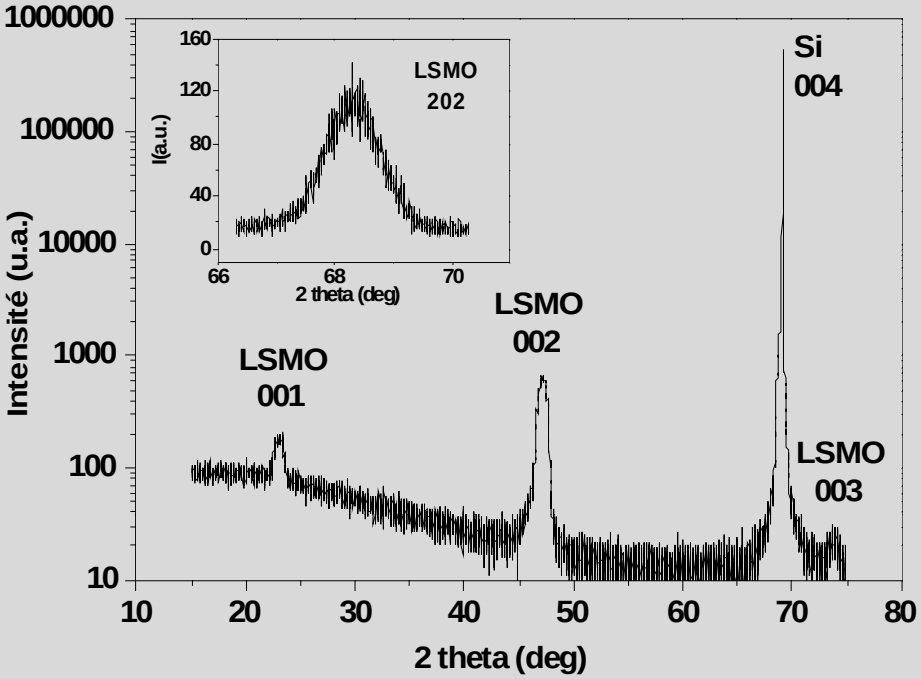
Magnetic metallic films

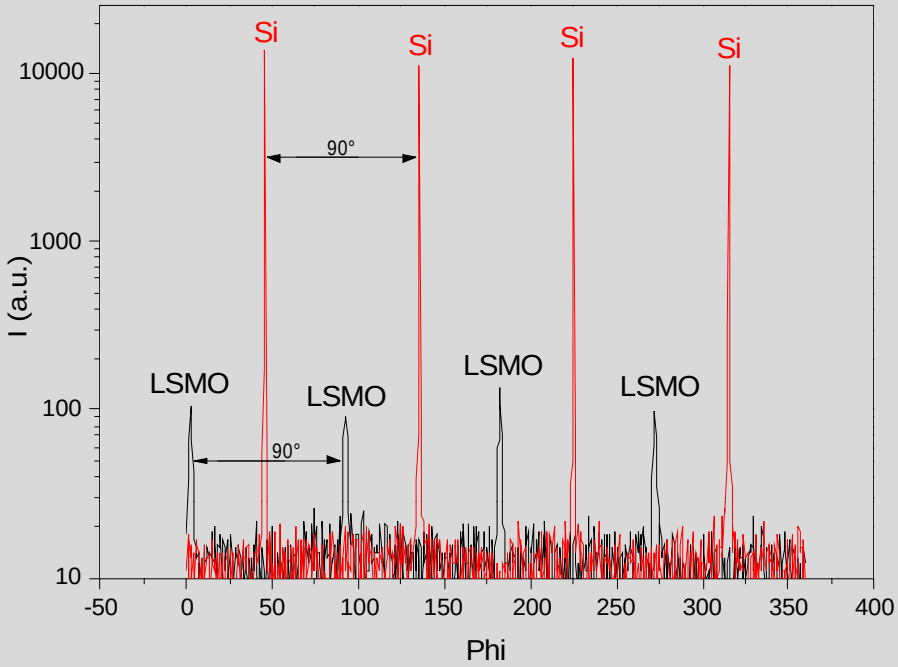


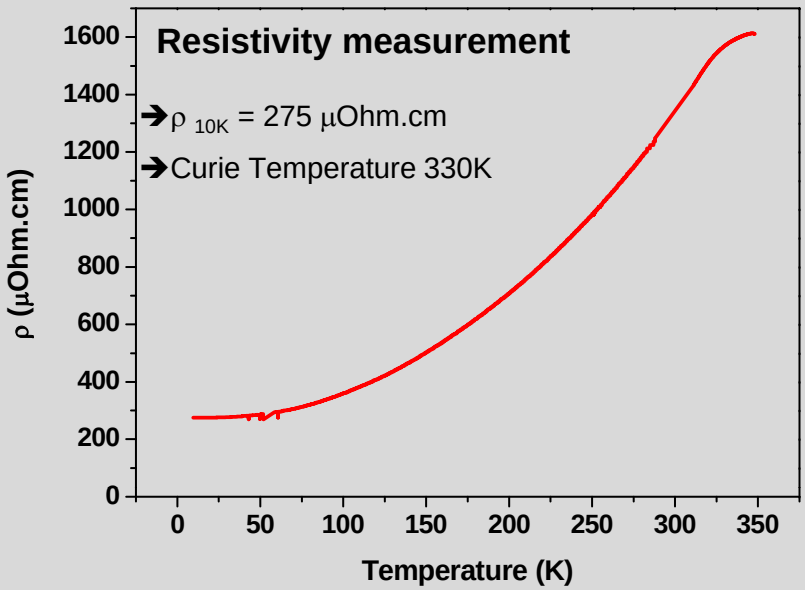
Magnetic oxide

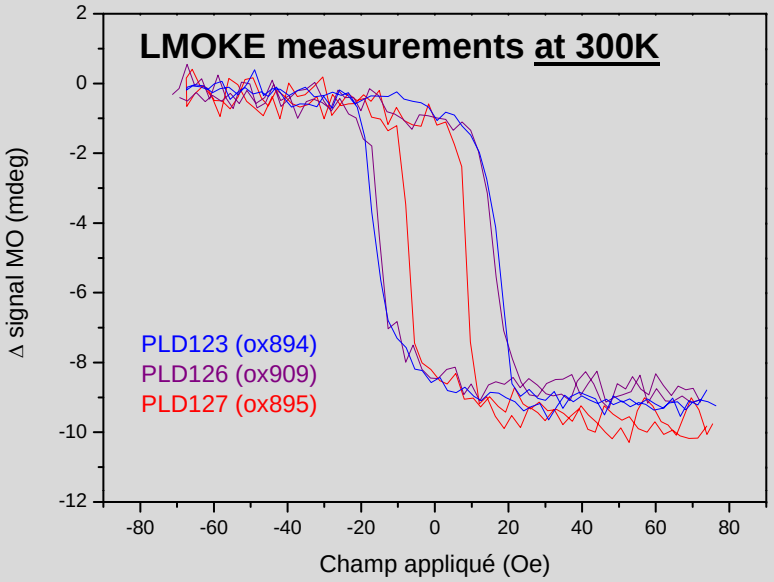
Growth of piezoelectric thin films on Si/STO pseudo substrate

XRD pattern









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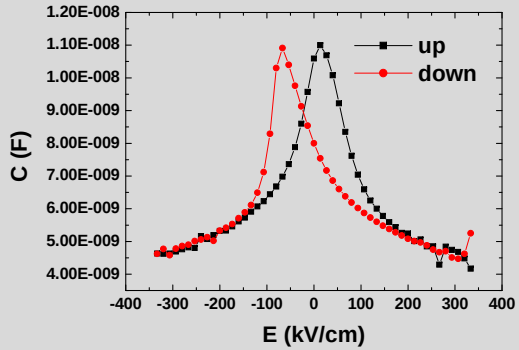
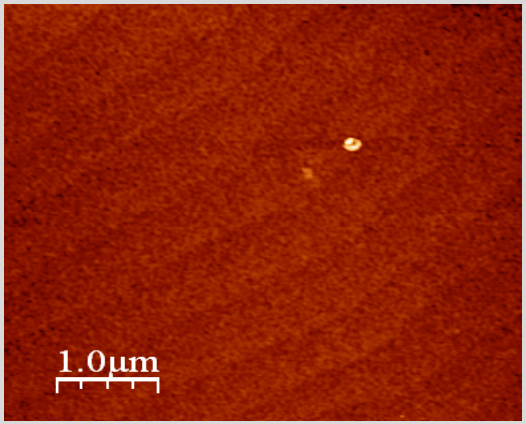
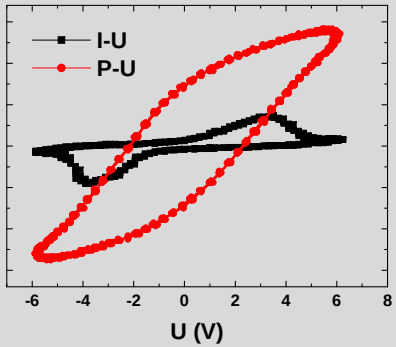
Our knowledge on STO substrate…

PZT on STO/LSMO:

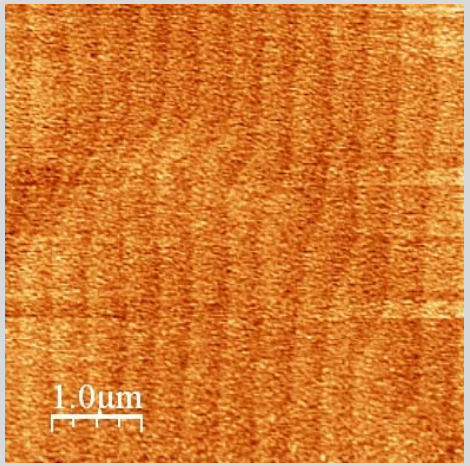


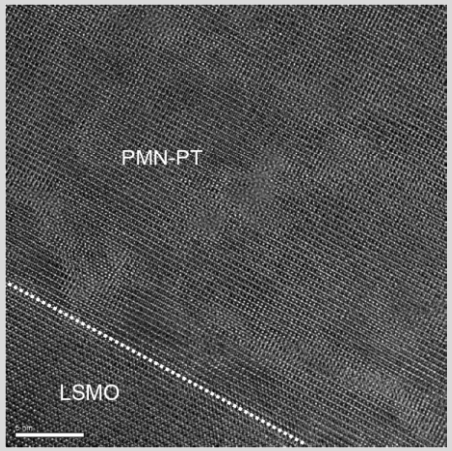




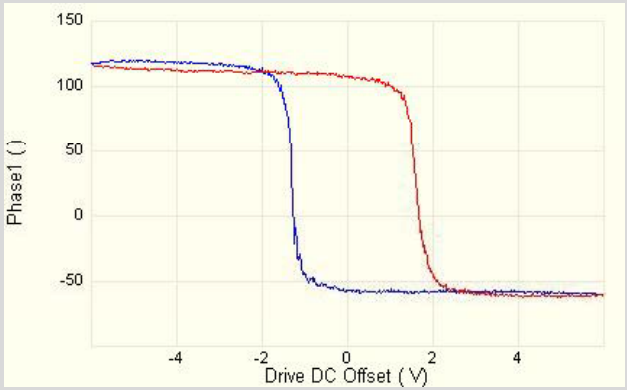
PMN-PT on STO/LSMO:

30 nm PMNT/ 17nm LSMO/STO(001)

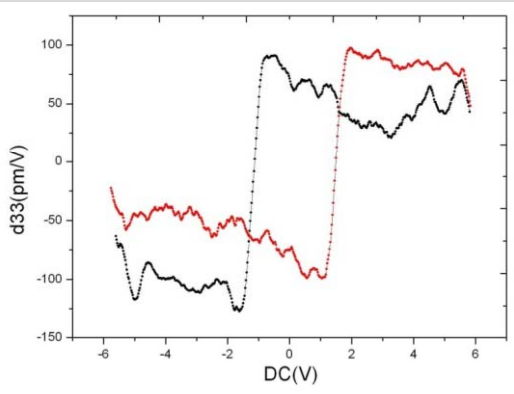




PFM measurement



Phase rotation of the PFM signal between up and down domains



Effective piezoelectric response measured by d_{33} coefficient

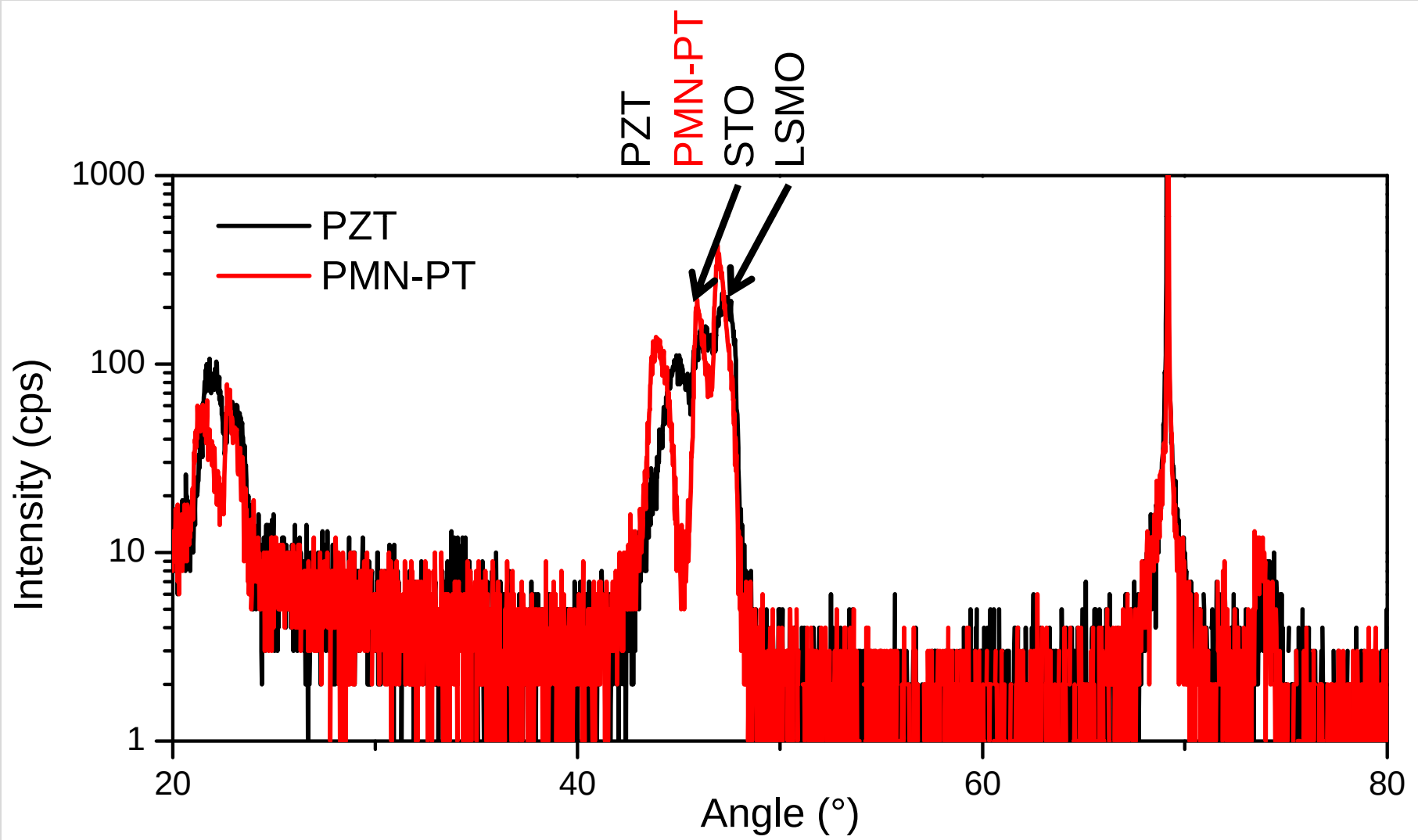
Coll. Xia Xiao and Yizheng Wu from Fudan University (China)

Good ferroelectric properties, PFM measurements confirm the piezoelectric response

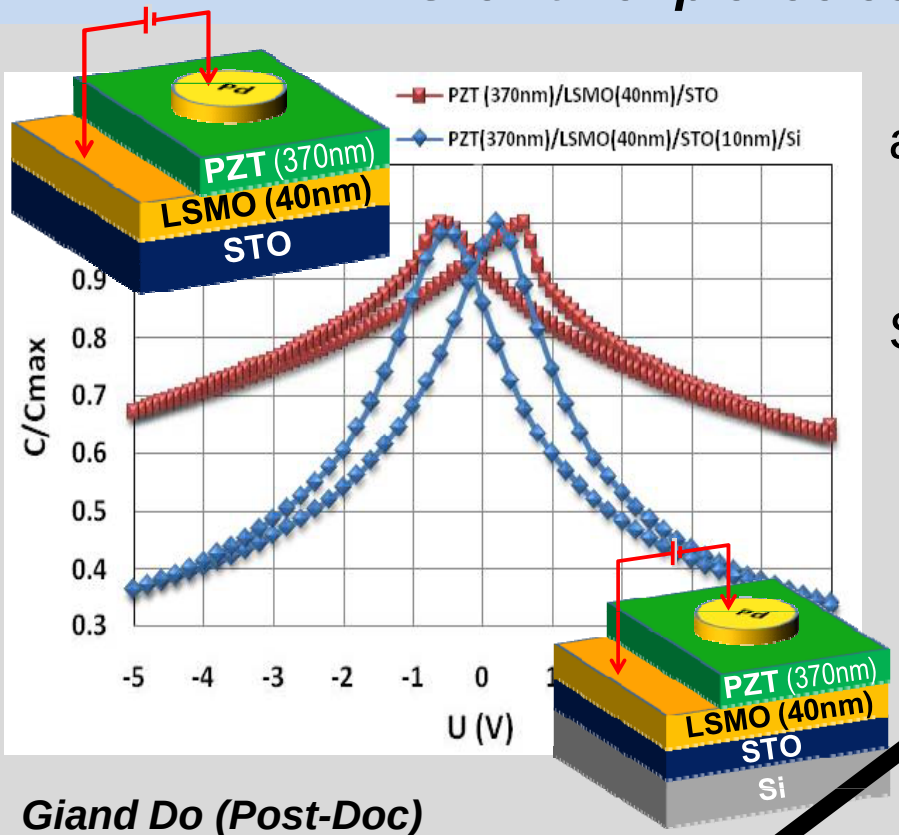
Transferred to Si/STO

PZT	c=0.408 nm
PMN-PT	c=0.402 nm

Value close to bulk



Growth of piezoelectric thin films on Si/STO pseudo substrate



PZT films on Si/STO are ferroelectrics

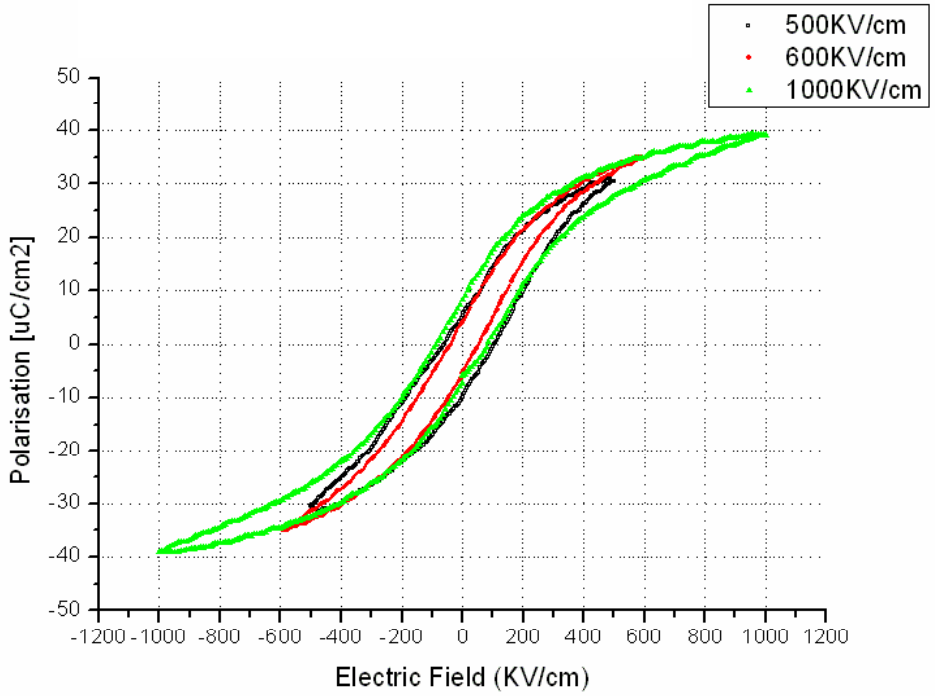
Coercivity is similar to STO substrates

PMN-PT

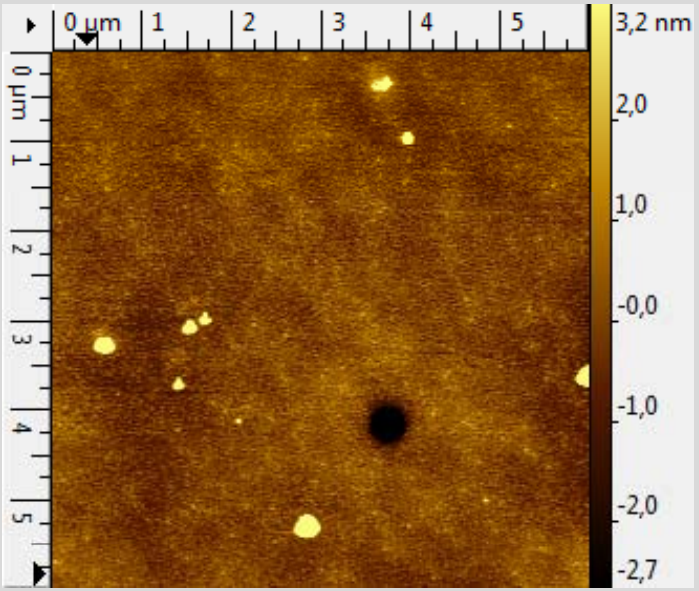
Coll. Thales TRT
Kim Ahn Bui Thi work (PhD)

Giand Do (Post-Doc)

PZT



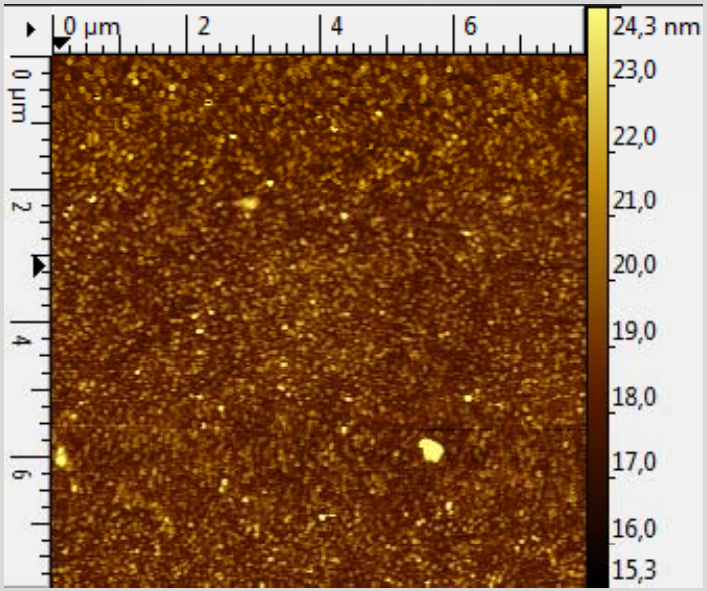
PMN-PT films can bear very high electric fields



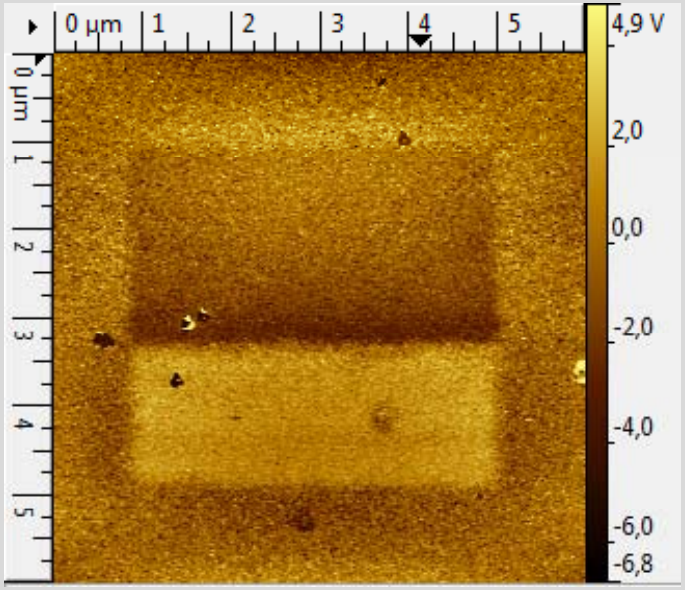
PZT

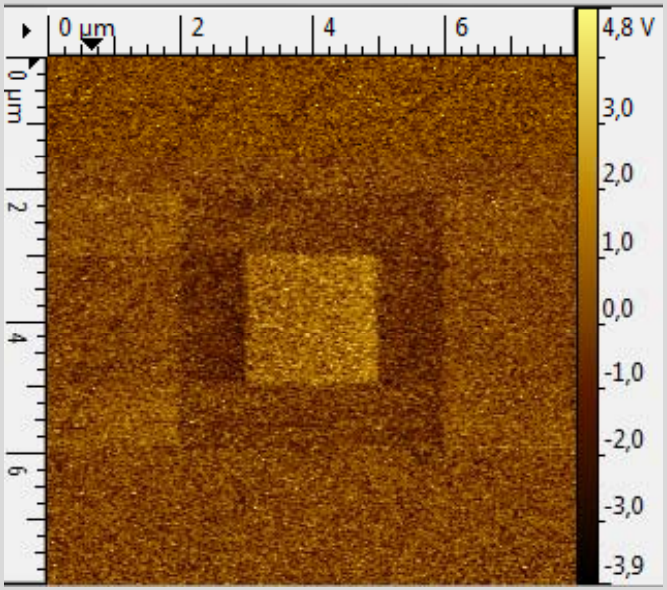
Piezoresponse Force Microscopy

Alexis Borowiak, Brice Gautier
(INSA Lyon)



PMN-PT





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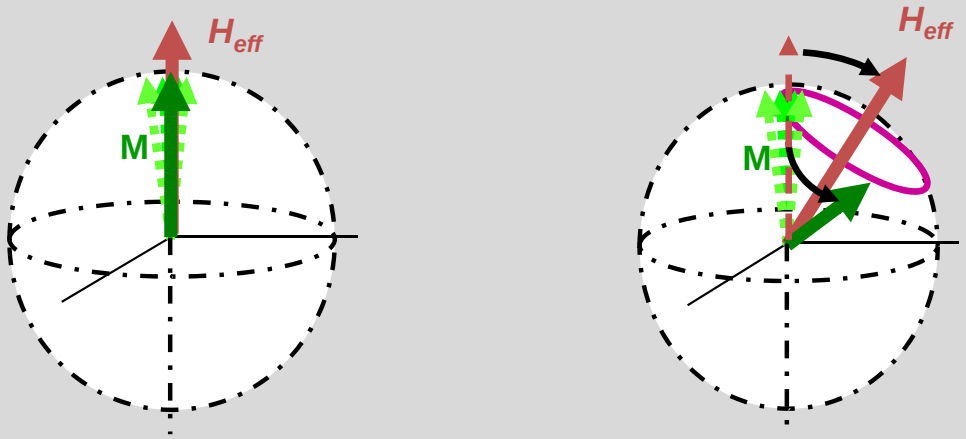
Part 2: Integration of piezoelectric layers for anisotropy tuning

Aim of this work:

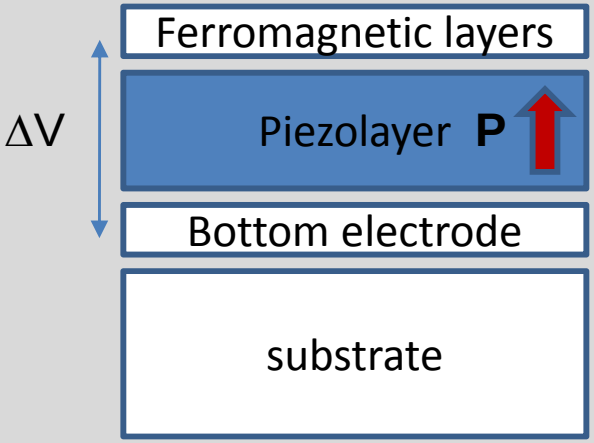


Na Lei
Sanghwan Park
Guillaume Agnus
Philippe Lecoeur
Dafine Ravelosona
Claude Chappert

Coll. INL Lyon

Basic idea : Easier spin-torque transfer by shifting the magnetization to its equilibrium position

=> Reliable M switching through assistance by inverse magnetostriction



Requirements:

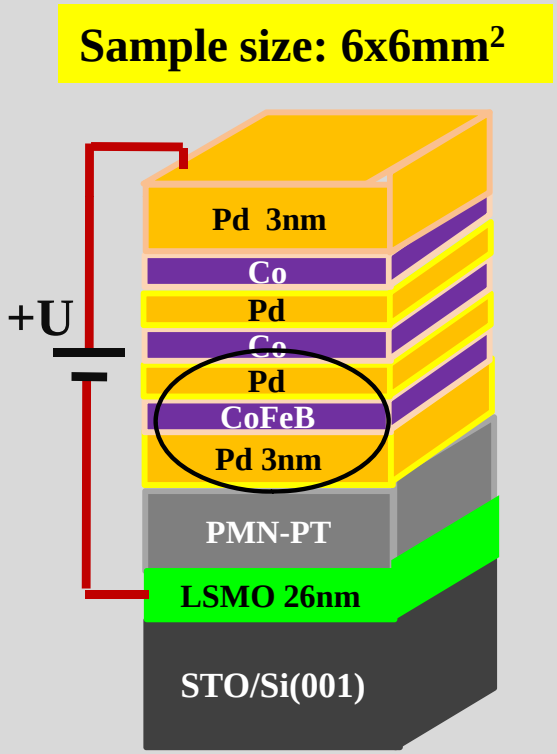
- **Integration on epitaxial bottom electrode**
- **high piezoelectric response for the piezo layer embbeded in the device**
- **soft ferromagnetic layers with low defects density**

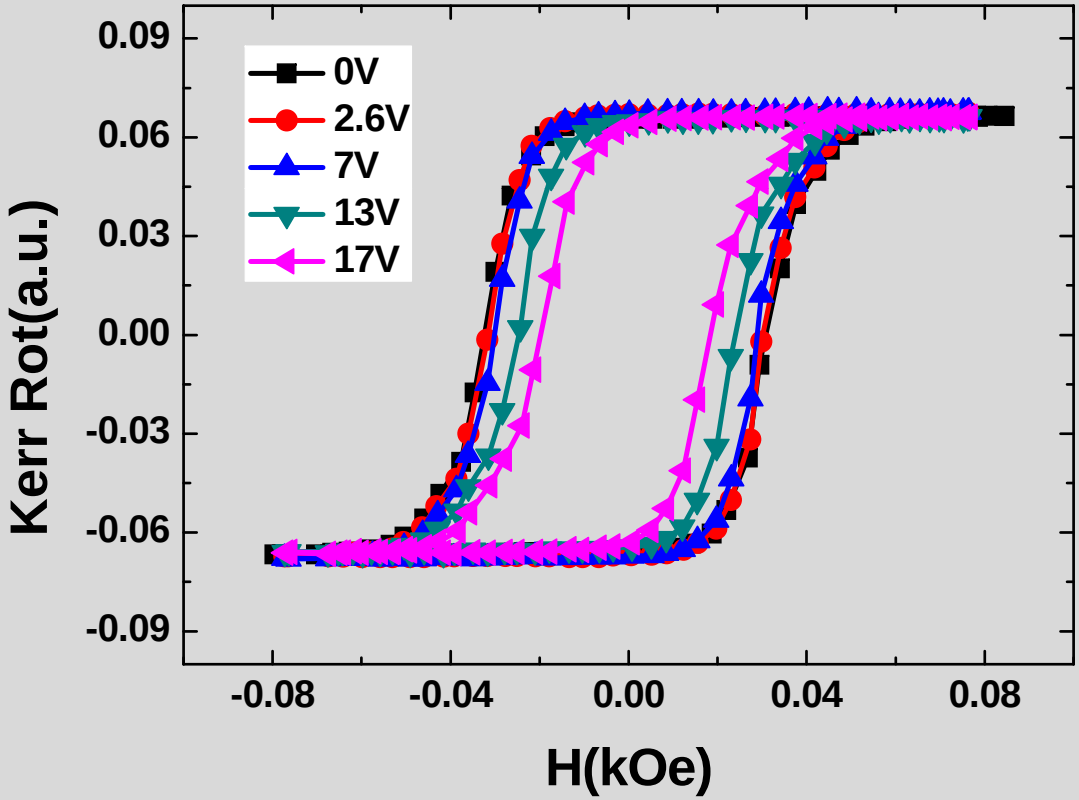
Existing devices use only piezoelectric actuator

FP7 – Namaste (2009-2011)

Piezoelectric effect with soft magnetic films

Si(001)/STO/26 LSMO/ 300PMN-PT/3Pd/0.54CFB/1.7Pd/0.2Co/0.6Pd/0.2Co/ 3nm Pd





Hc changed 44% at 17V

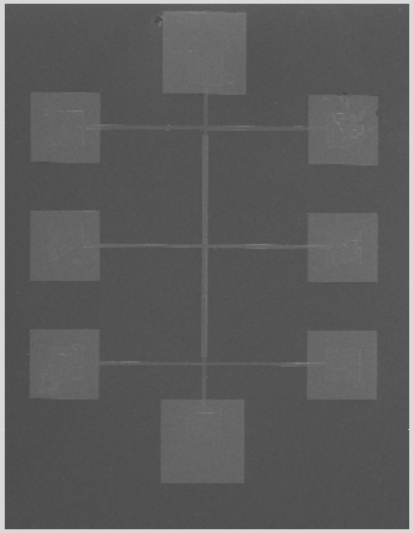
Film scale: conclusions

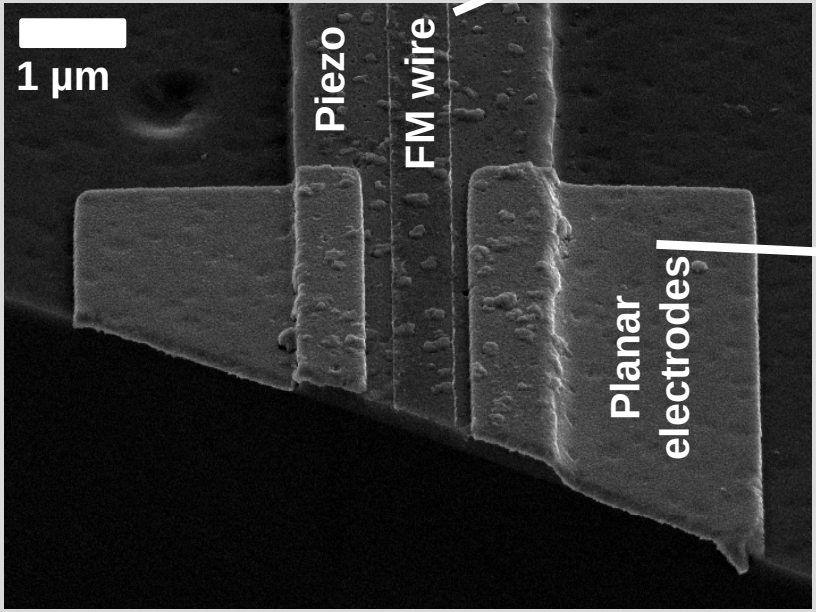
- Full hybrid piezo-ferromagnetic stack with perpendicular anisotropy has been developed

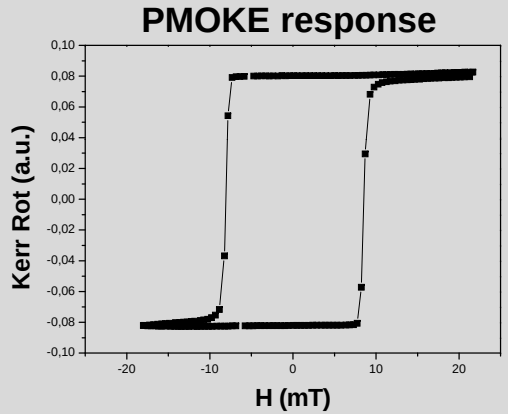
- Nucleation field is found to be highly affected by the applied voltage

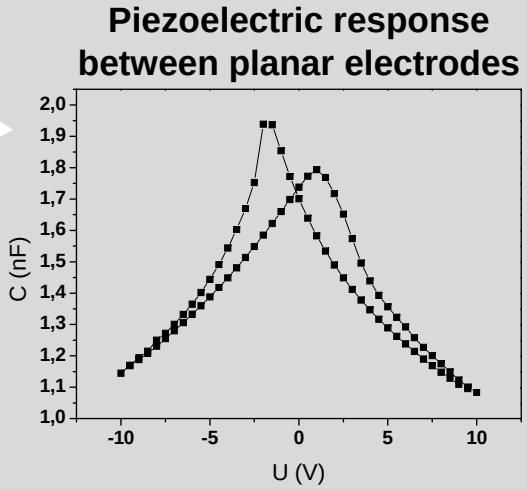
⇒ Further work, devices under developement

Switching to the device scale: AHE device development









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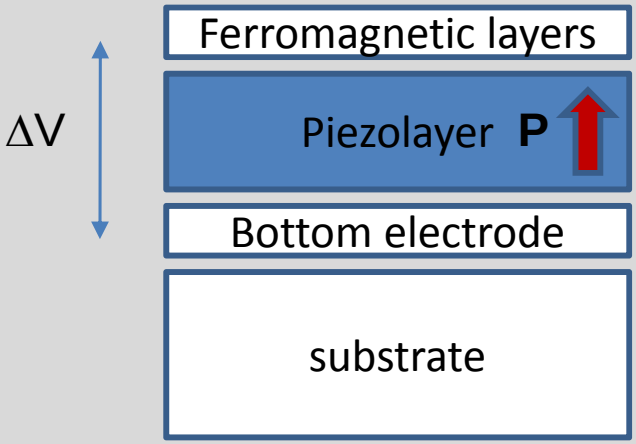
Embedded film in the structure: role of the clamping effect[1]

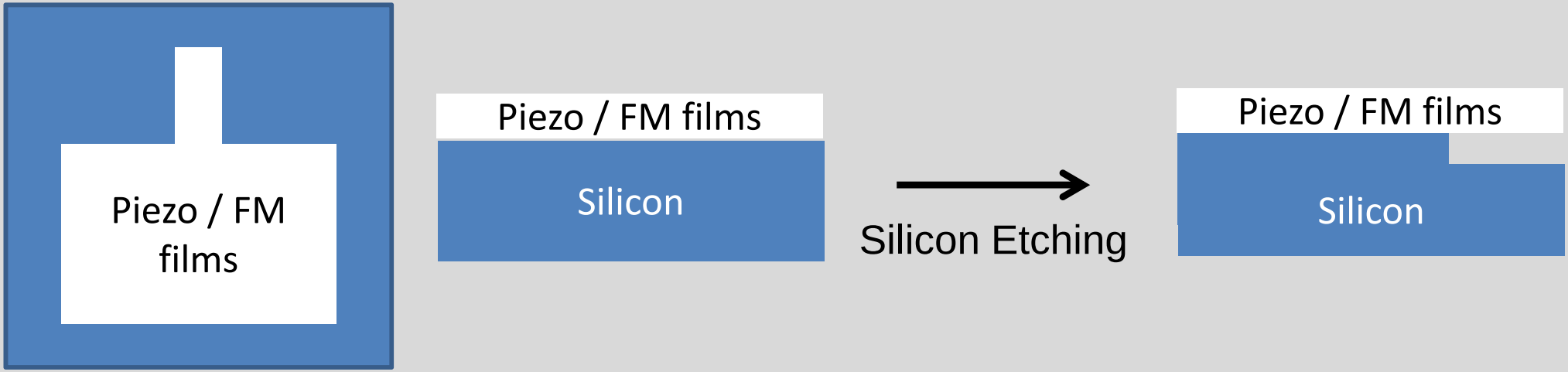


$$d_{33}^{eff} = d_{33} - \frac{2d_{31}(s_{13}^E + \nu/Y)}{s_{11}^E + s_{12}^E}$$

S_{ij} are the elastic compliances of the film at constant electric field

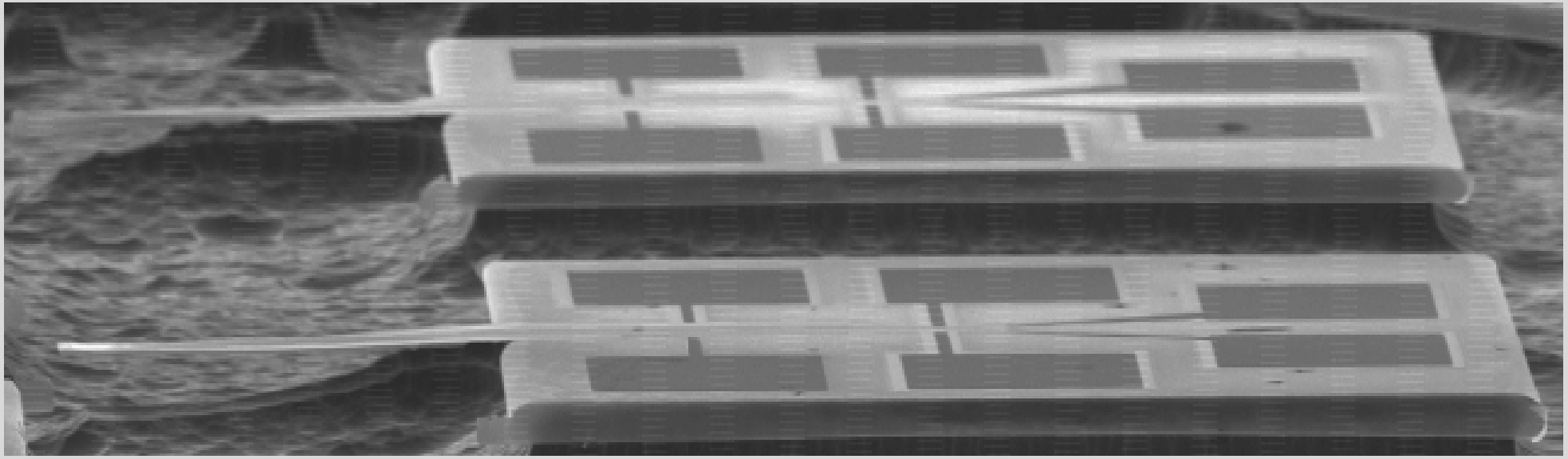
ν : Poisson's ratio of the substrate
Y : Young's modulus of the substrate

Fabrication of free-standing device allow to overcome this limitation.
Silicon substrate is removed using standard clean room techniques



1 - K. Lefki and G.M. Dormans, J. Appl. Phys. 76, 1764 (1994)

LSMO (40nm)/ PZT (200nm)/ LSMO (40nm) / SRO (60nm) /STO (53nm)/ Si



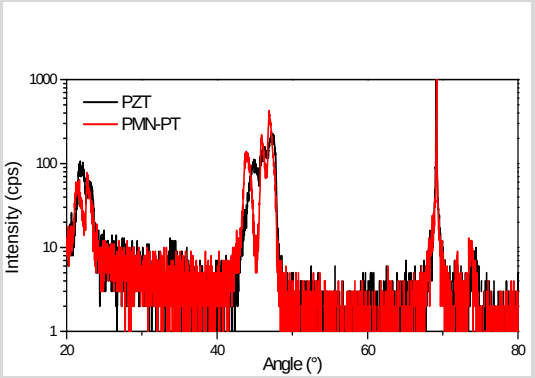
Ferro-electric PZT

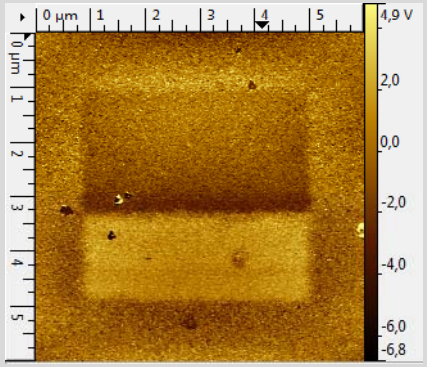
bottom and top layer LSMO

Maintained physical properties

Ability to grow piezoelectric film on silicon thanks to STO buffer

- **PZT**
- **PMN-PT**

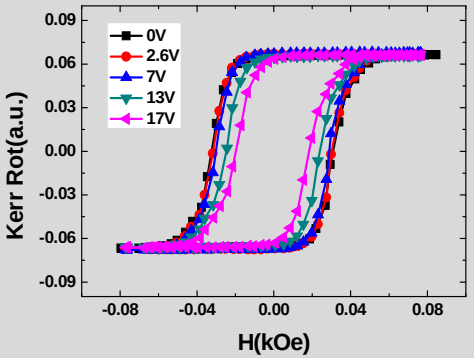


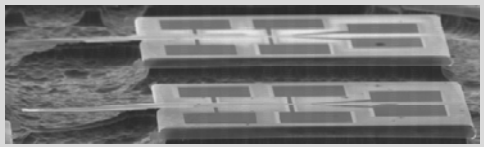


This films grow epitaxialy and exhibit good:

- **Crystallinity**
- **Ferroelectric properties.**

We demonstrate on this films the ability to manipulate the anisotropy of metallic magnetic film





To enhance the piezo effect, we fabricated free standing structures (MEMS devices)

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Institut des Nanotechnologies de Lyon – INSA Lyon

Gang Niu, Bertrand Vilquin
Institut des Nanotechnologies de Lyon – Ecole Centrale de Lyon

Thank you for your attention

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CNano IDF Emfones (2010)
FP7 Namaste (2008-2011)