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Fabrication and Characterization of Epitaxial KNN Films

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Temperature-Insensitive $(K,Na)NbO_3$-Based Lead-Free Piezoactuator Ceramics

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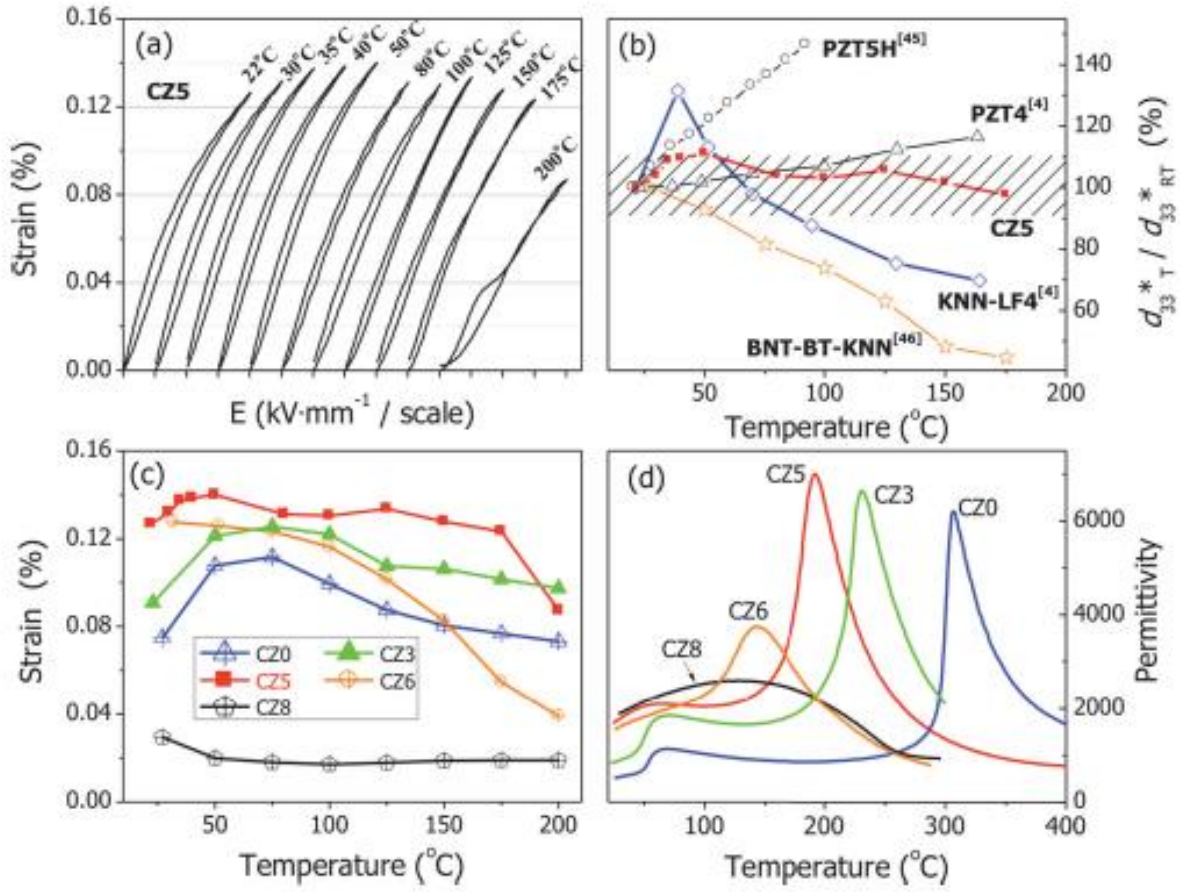


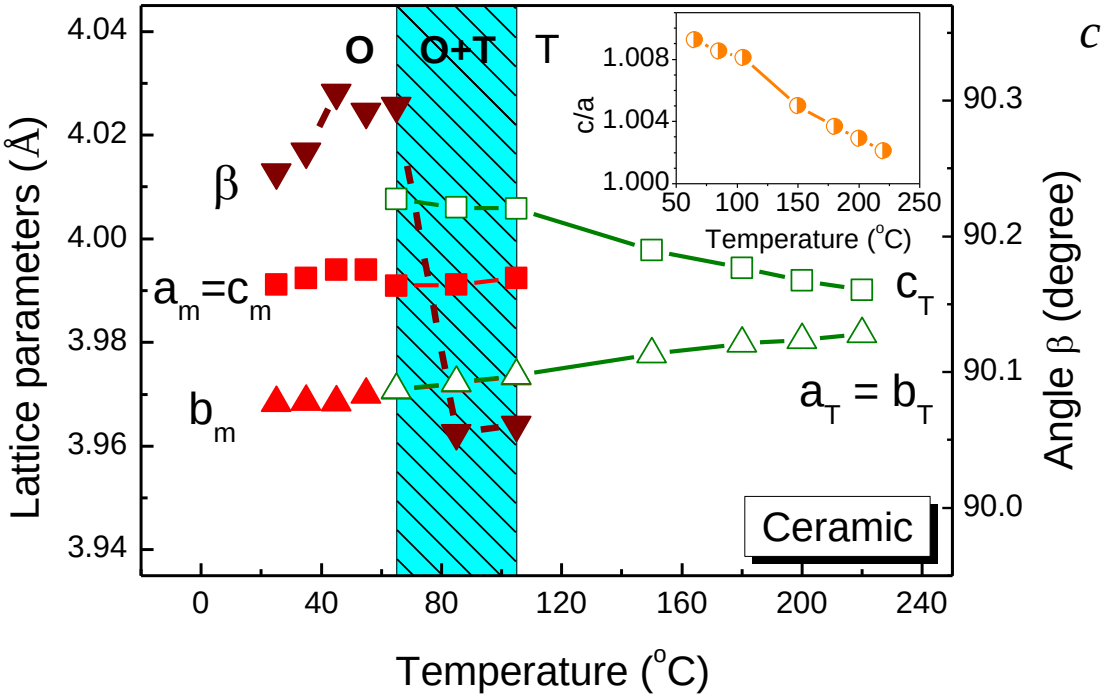
KNN: $0.95(Na_{0.49}K_{0.49}Li_{0.02})(Nb_{0.8}Ta_{0.2})O_3$-$0.05CaZrO_3$ with 2 wt% MnO_2

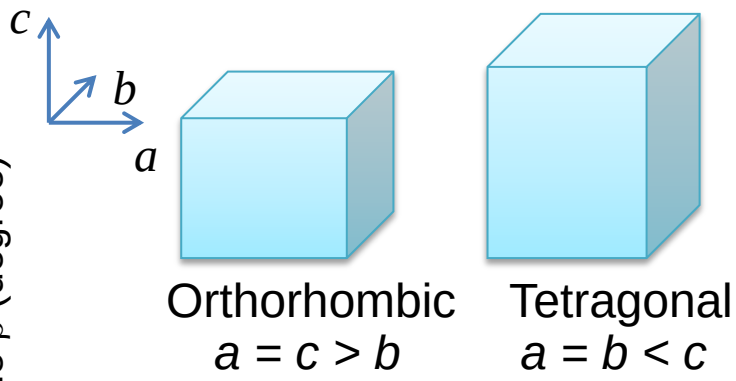
Adv. Funct. Mater., 23, 4079-86 (2013).

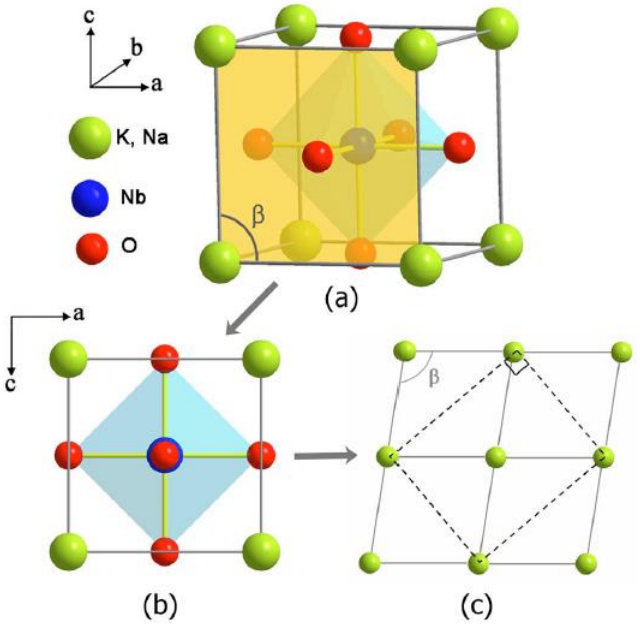
Outline

- Epitaxial KNN films growth with pulsed laser deposition (PLD)
- High fatigue resistance of KNN films
- KNN/Pt and PZT/Pt interfaces studied with X-ray photoelectron spectroscopy (XPS)

Lattice constant of KNN ceramic







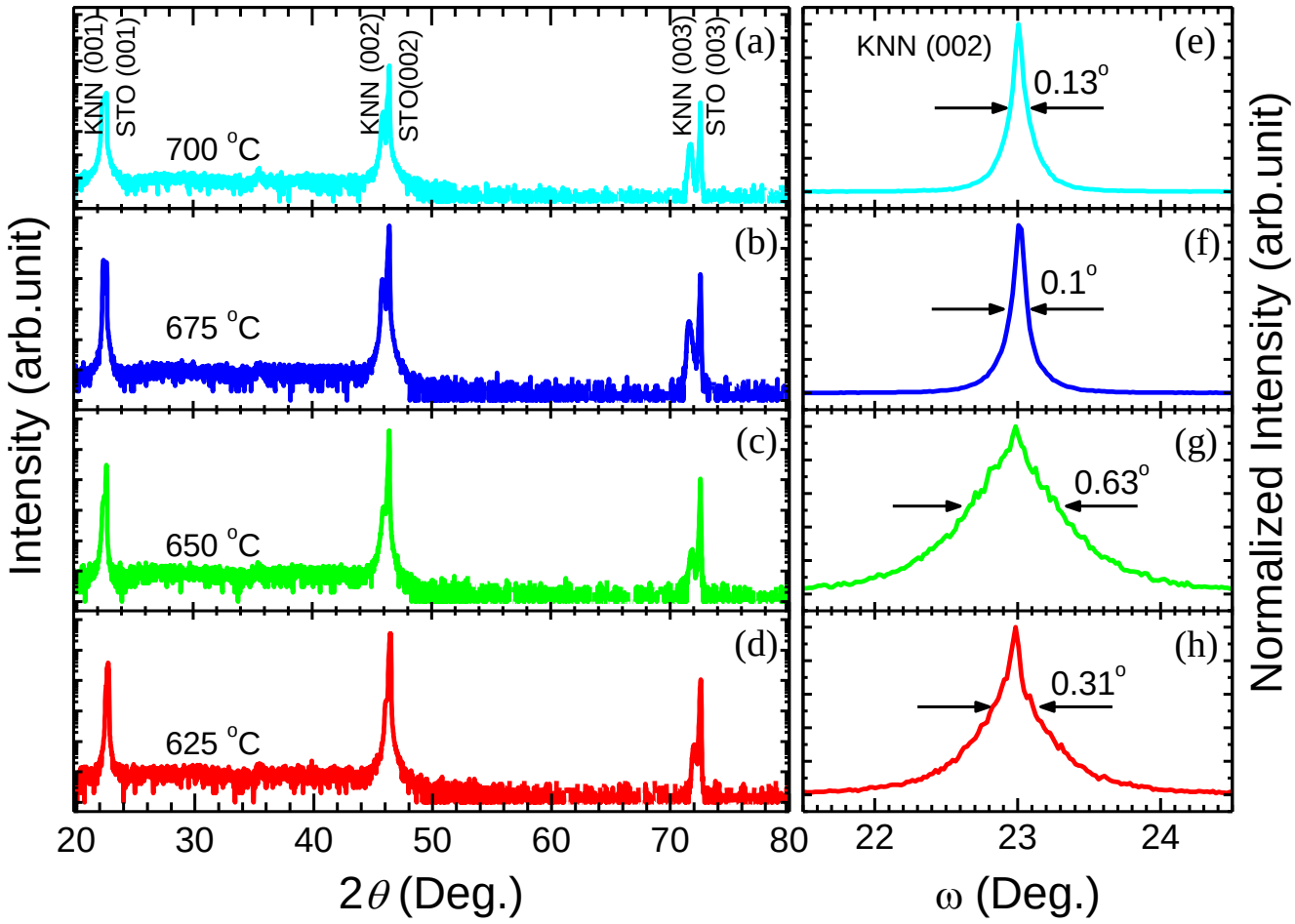
LSMO: $La_{0.7}Sr_{0.3}MnO_3$ a_{LSMO} = 3.873 Å

LSSO: $La_{0.07}Sr_{0.93}SnO_3$ a_{LSSO} = 4.035 Å

STO : $SrTiO_3$ a_{STO} = 3.905 Å

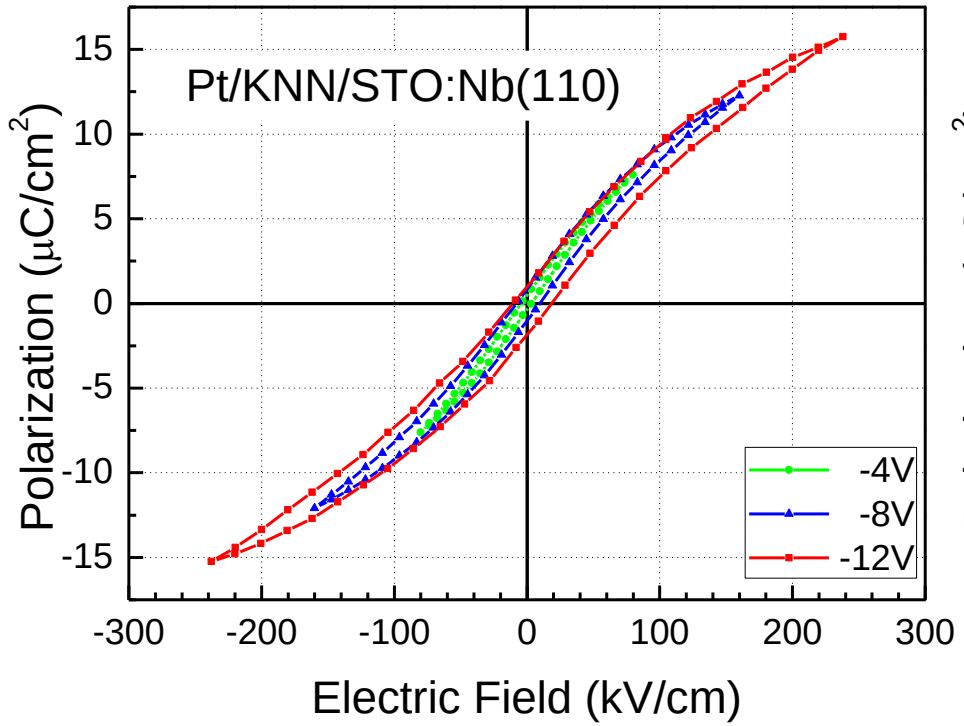
Ke Wang and J.-F Li, APL, 91, 262902 (2007)

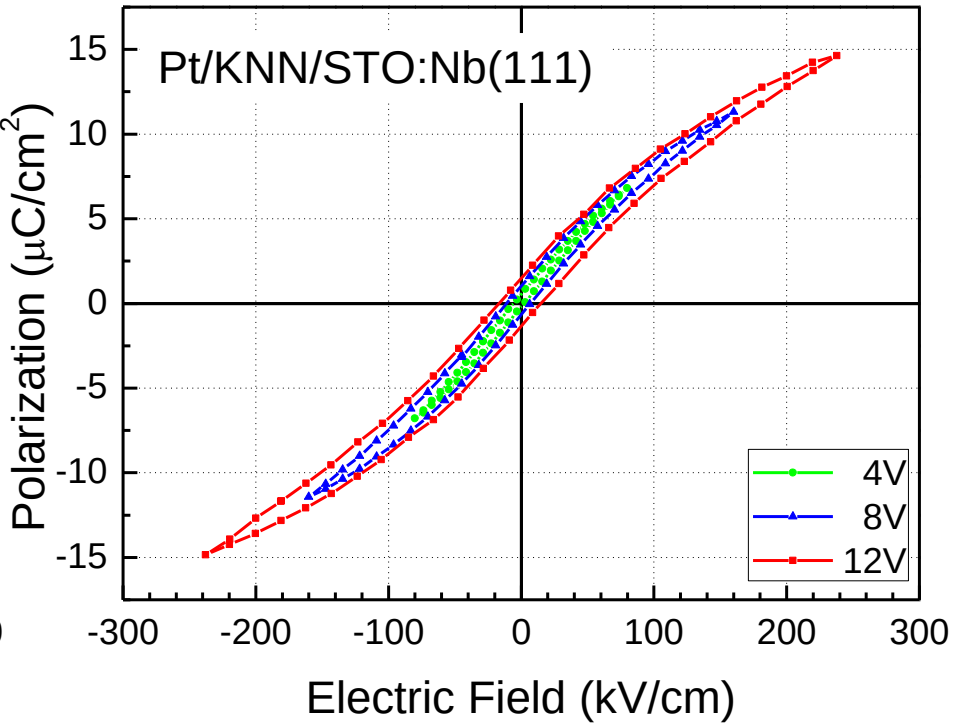
KNN film on STO:Nb (001) single crystalline



High quality epitaxial KNN films can be obtained on STO:Nb substrate

Ferroelectric properties of KNN/NSTO films

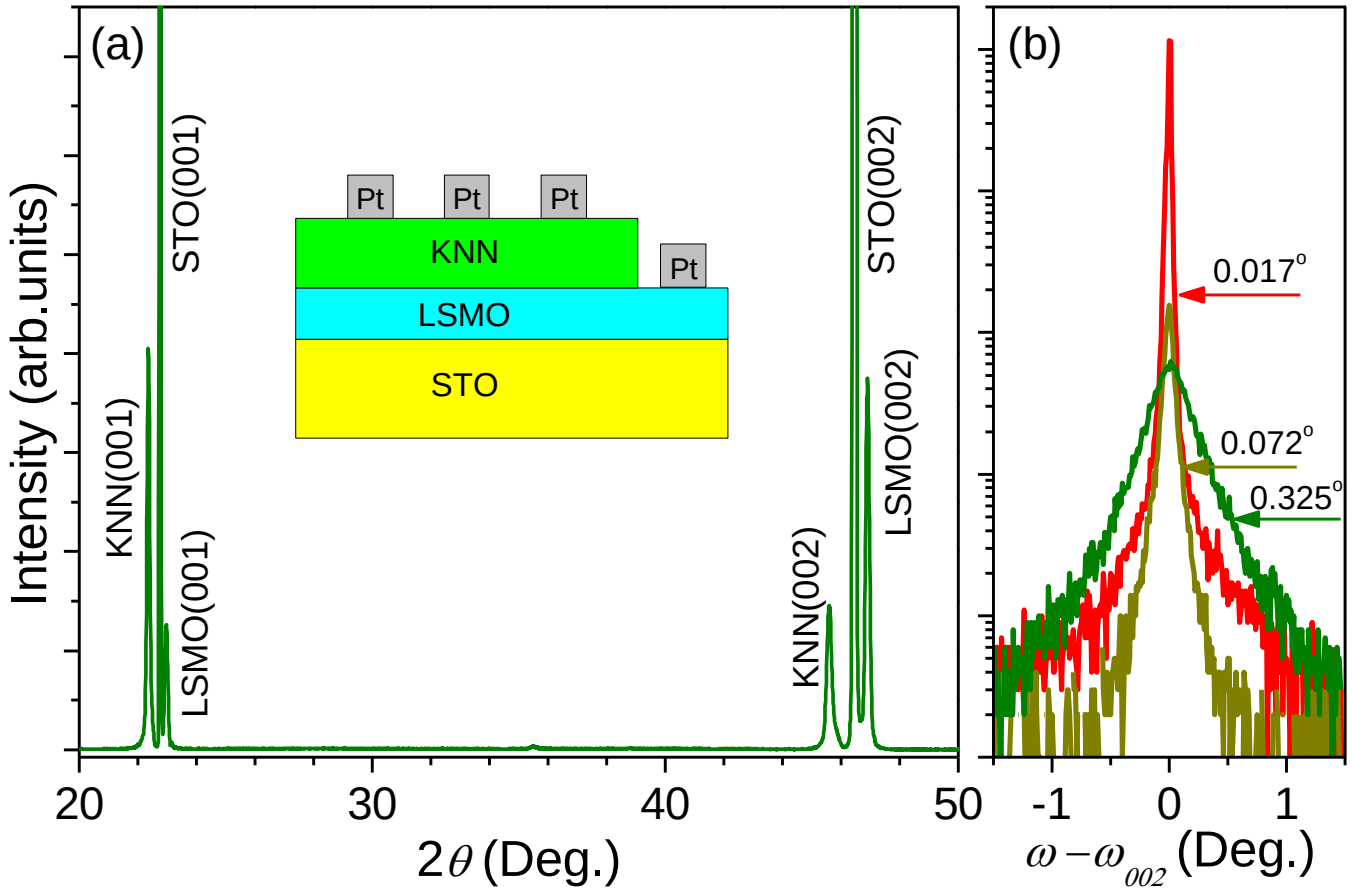




Slim hysteresis

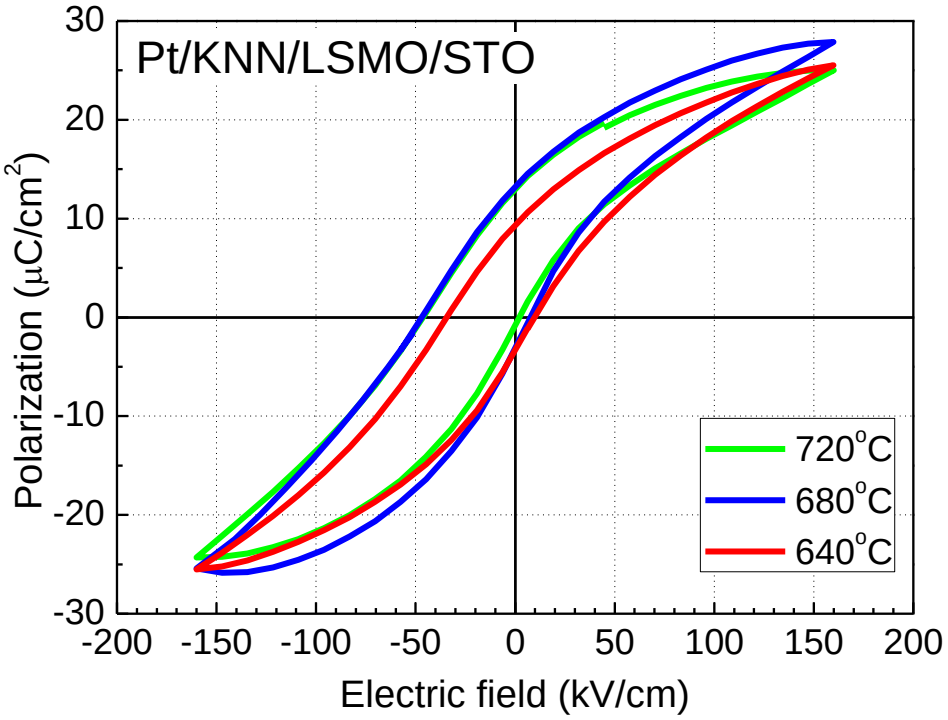
Small *E*c and Pr

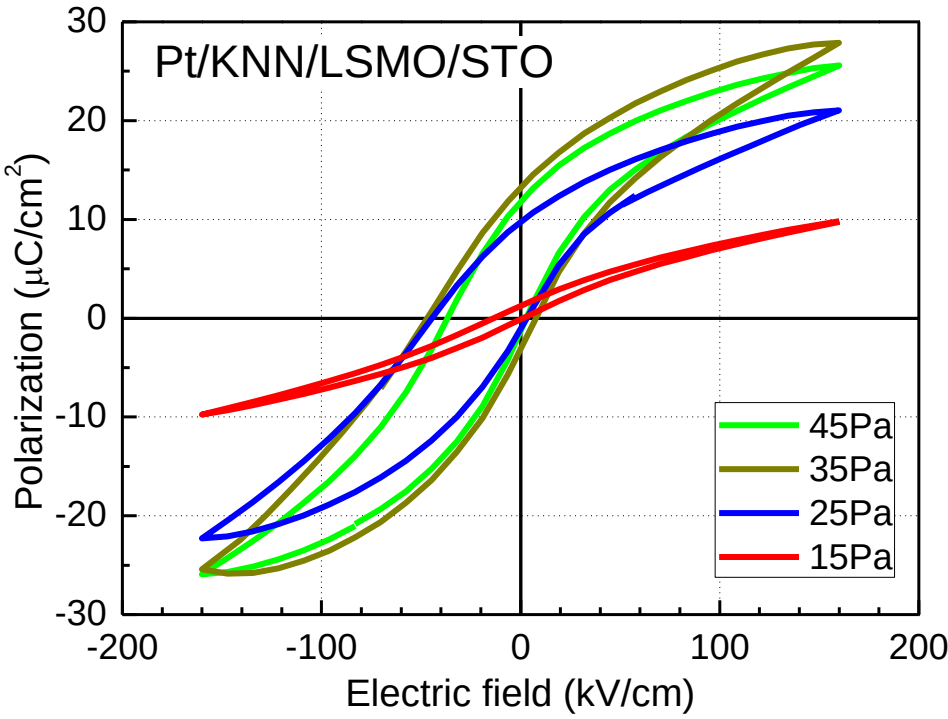
Epitaxial KNN films grown on conductive oxide electrode



- Epitaxial film since only 00l reflections were recorded
- A broad rocking curve of KNN (002) peak

Ferroelectric properties of KNN films

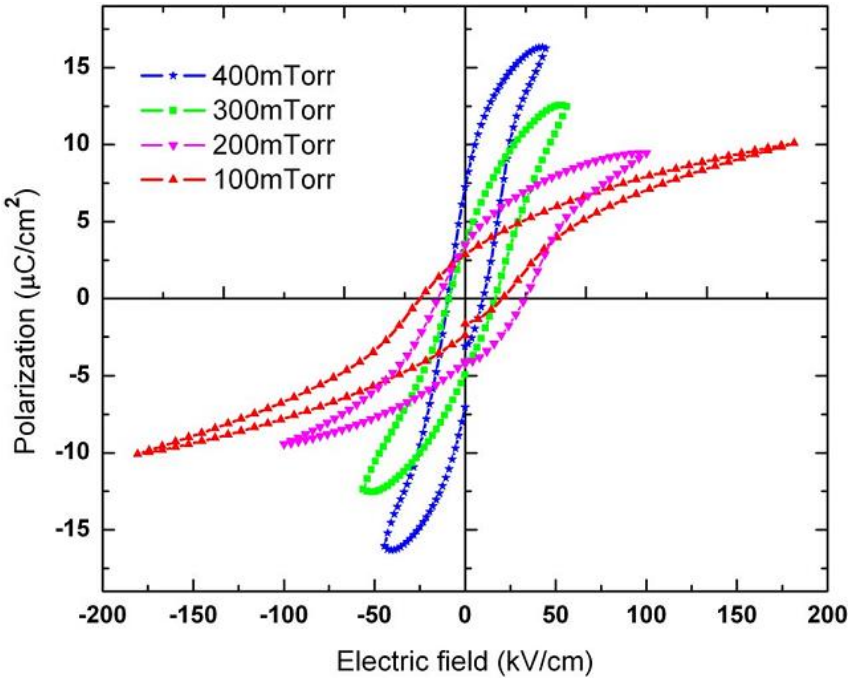




- The saturated P-E loops are measured at 1k Hz
- The asymmetric loop might be induced by the asymmetric interfaces

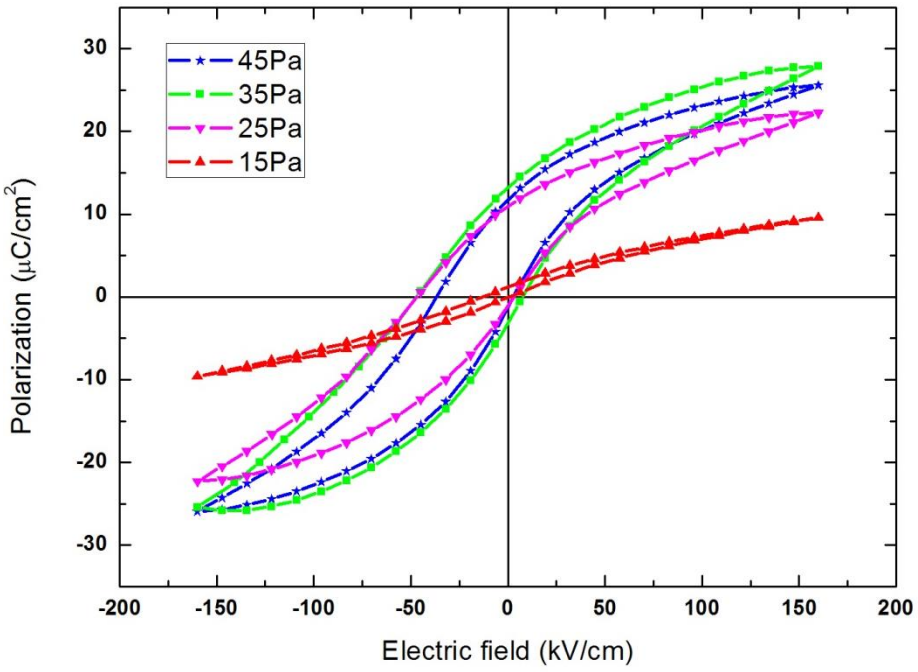
Hysteresis of KNN film capacitor

$SrRuO_3$/KNN/$SrRuO_3$/STO(001)



M. Abazari *et al.,* APL 93, 192910 (2008).

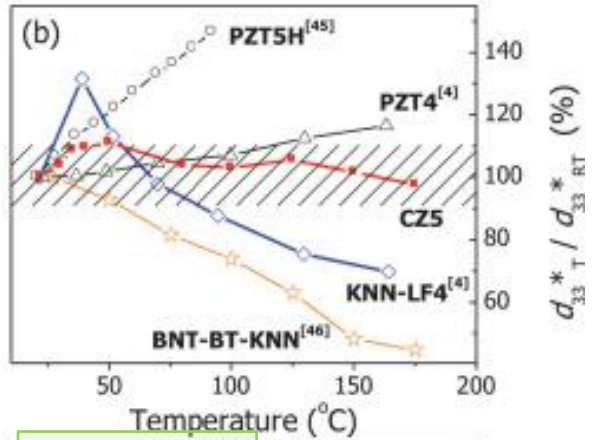
Pt/KNN/LSMO/STO(001)

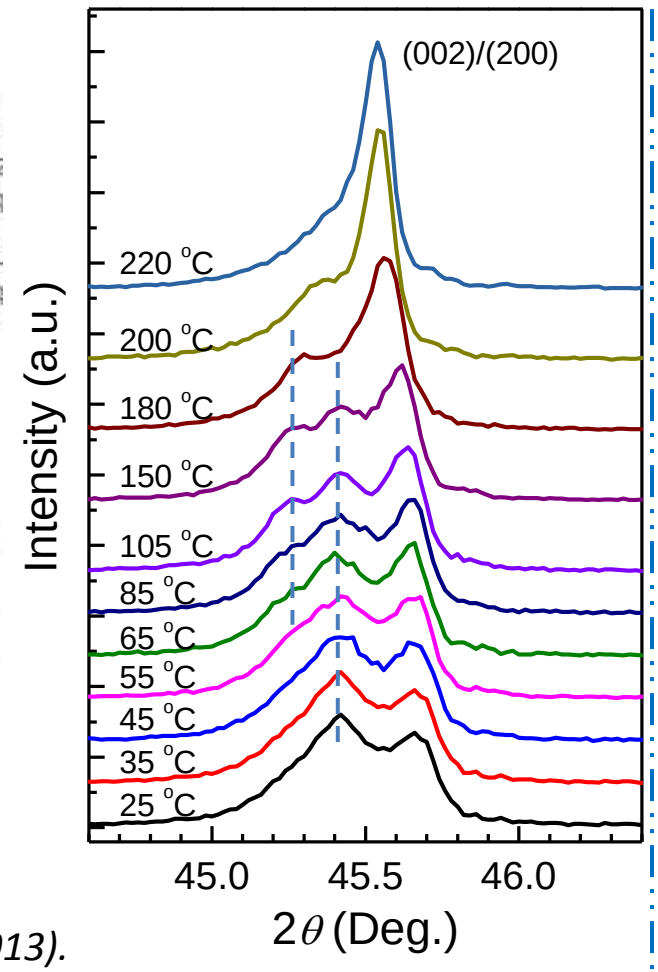


- 2Pr ~ 15 μC/cm^2
- Higher Ps and saturated loops

Structure variation of KNN films with temperature

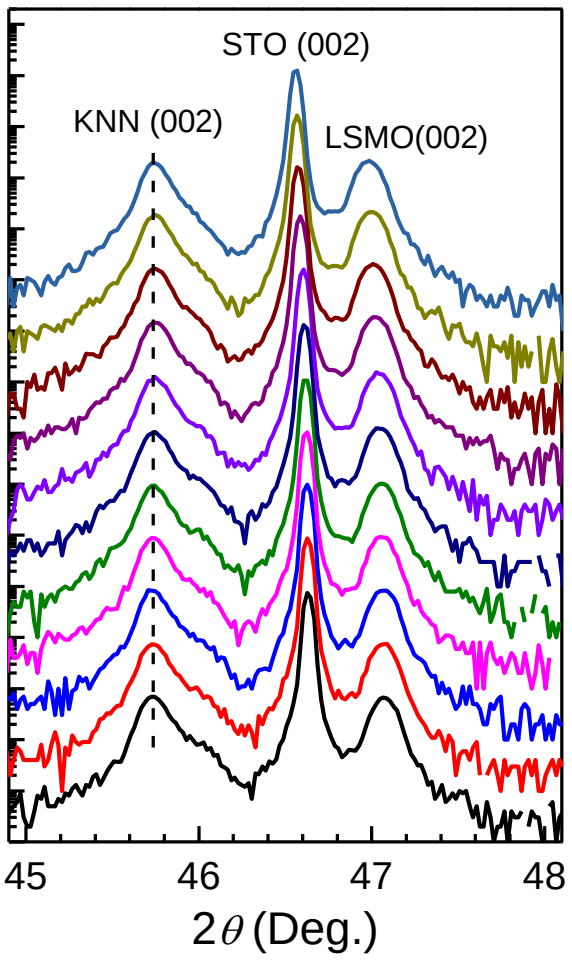
Ceramic





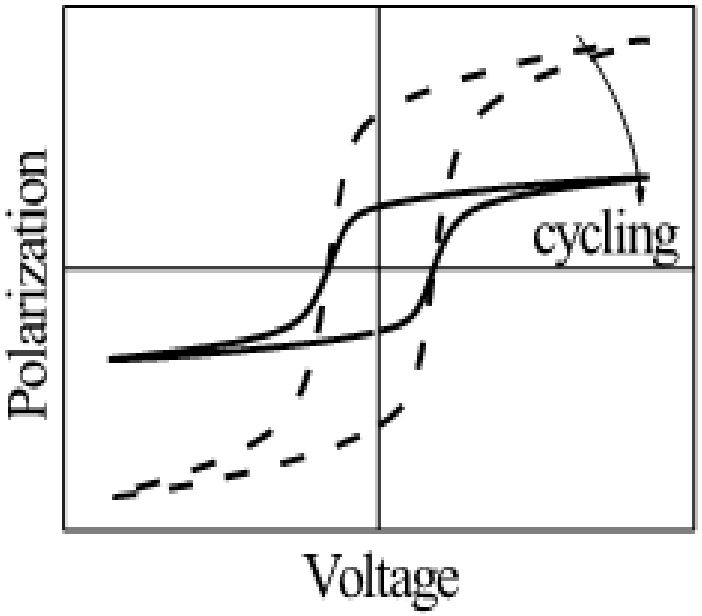
Adv. Funct. Mater., 23, 4079-86 (2013).

Film

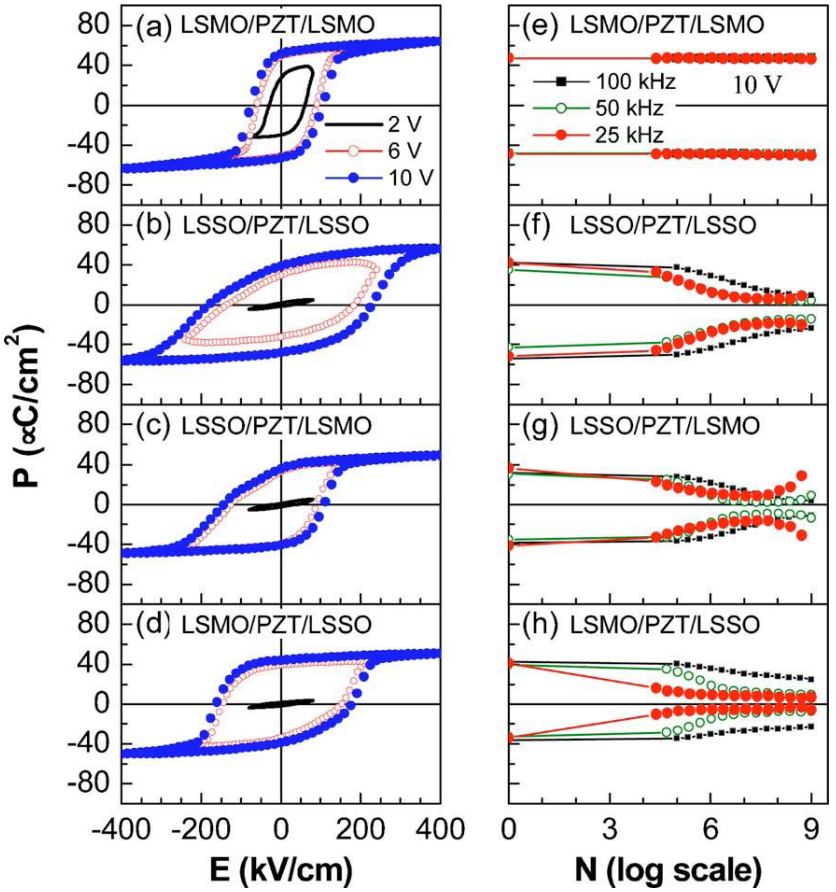


The KNN films might have a even higher thermal stability than that of the ceramic

Fatigue of PZT films



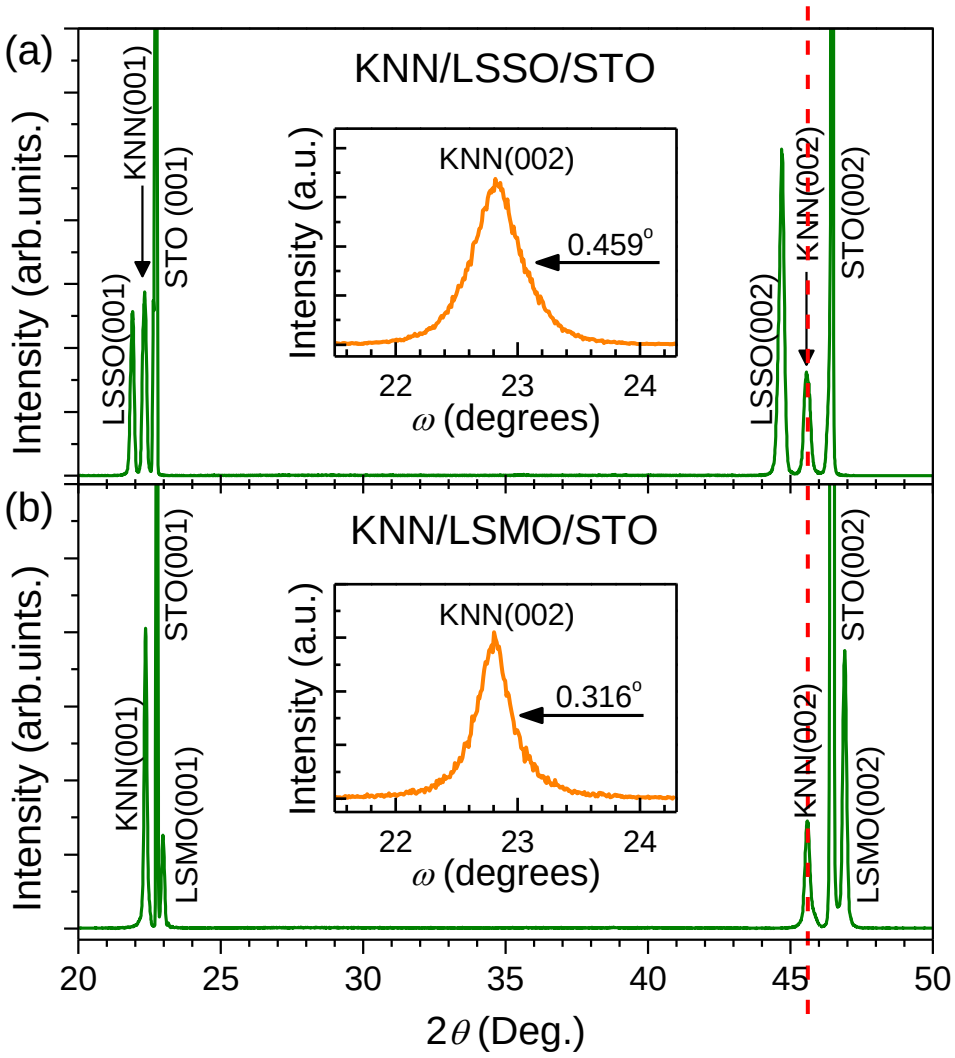
Fatigue



F. Chen et al. APL, 90, 192907 (2007)

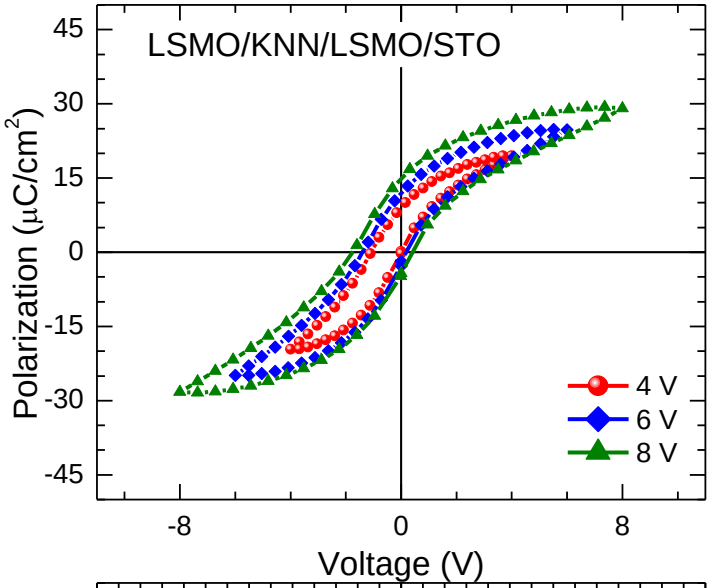
The fatigue behavior of PZT epitaxial films highly depends on the (p/n-)type of the conductive oxide electrode

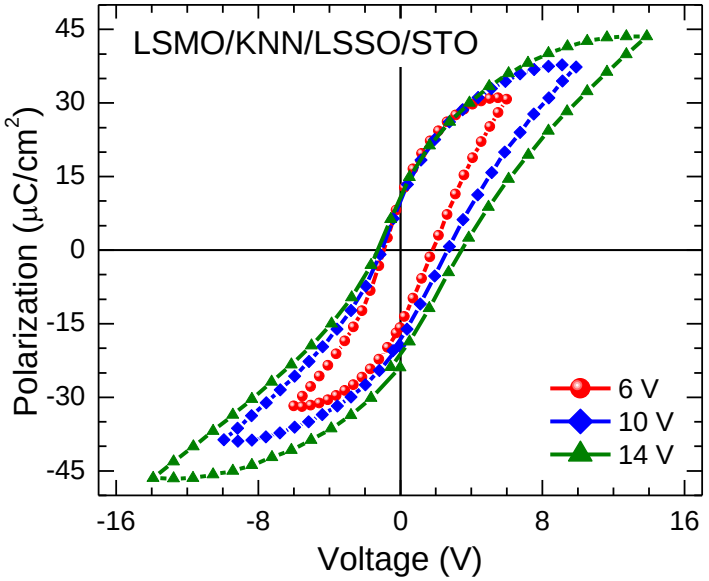
Epitaxial KNN films grown on conductive oxide electrode

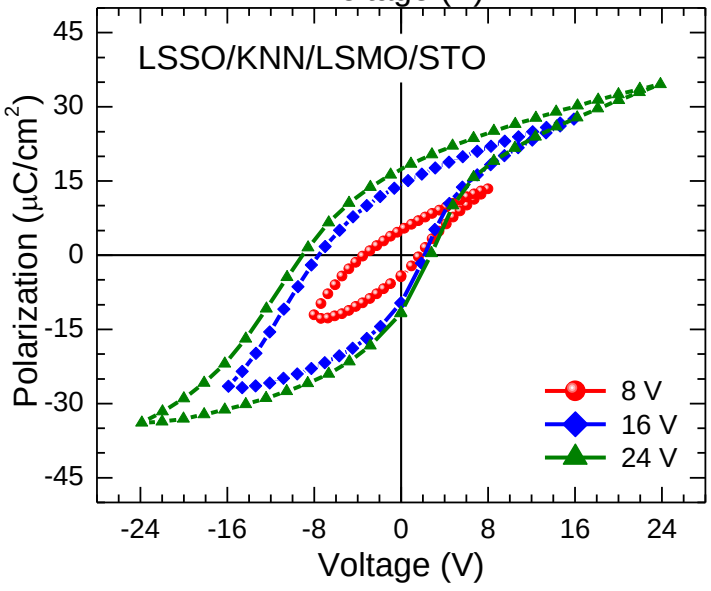


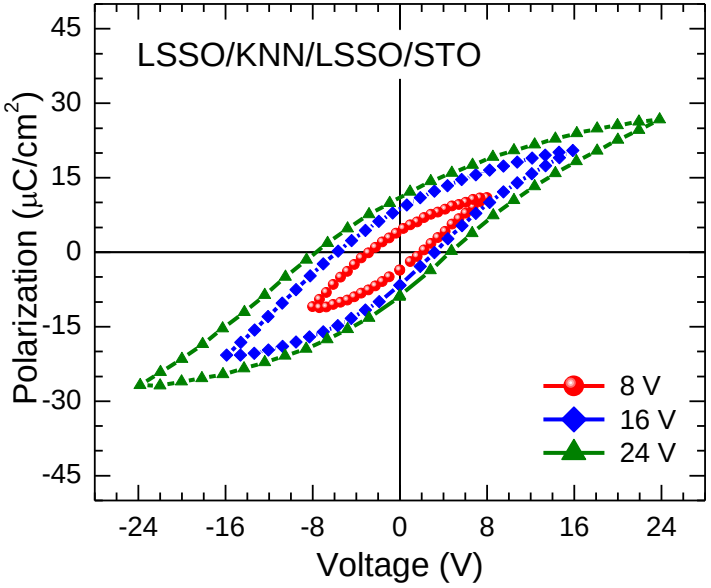
The strain in the films is relaxed reflecting by the same KNN (002) position

P-E loops of KNN films

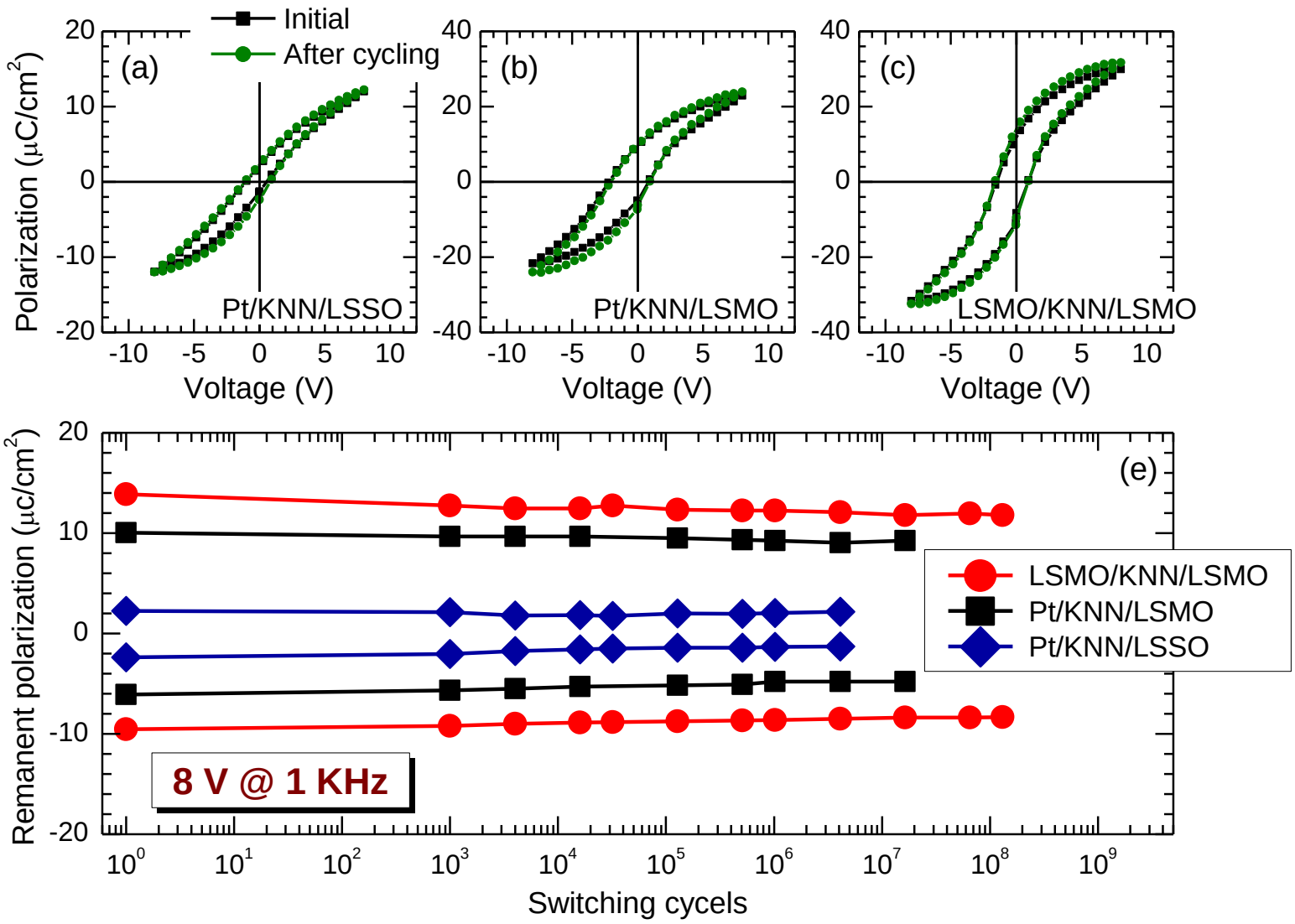






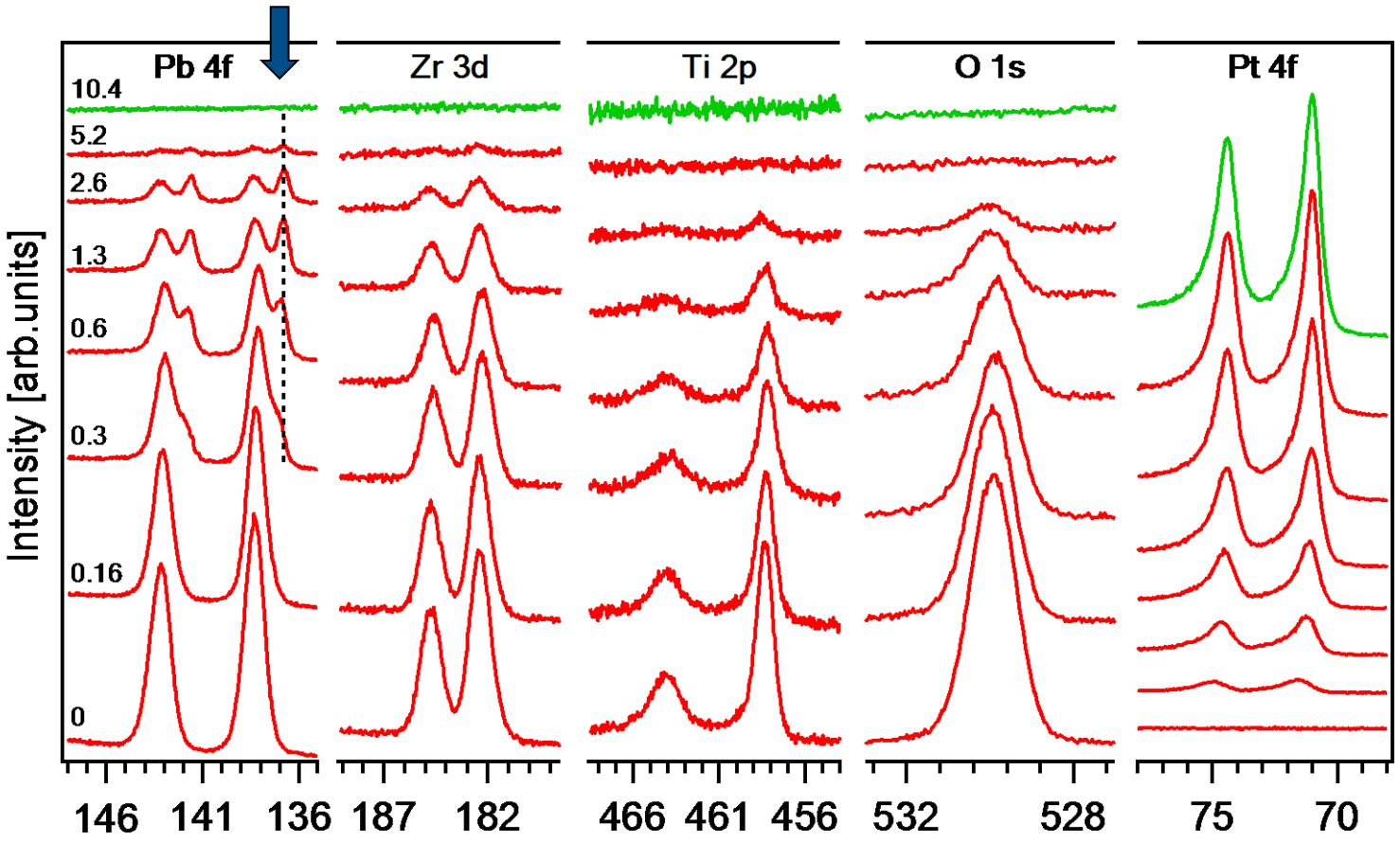


Fatigue of KNN films



KNN films show a high fatigue resistance under bipolar cycling

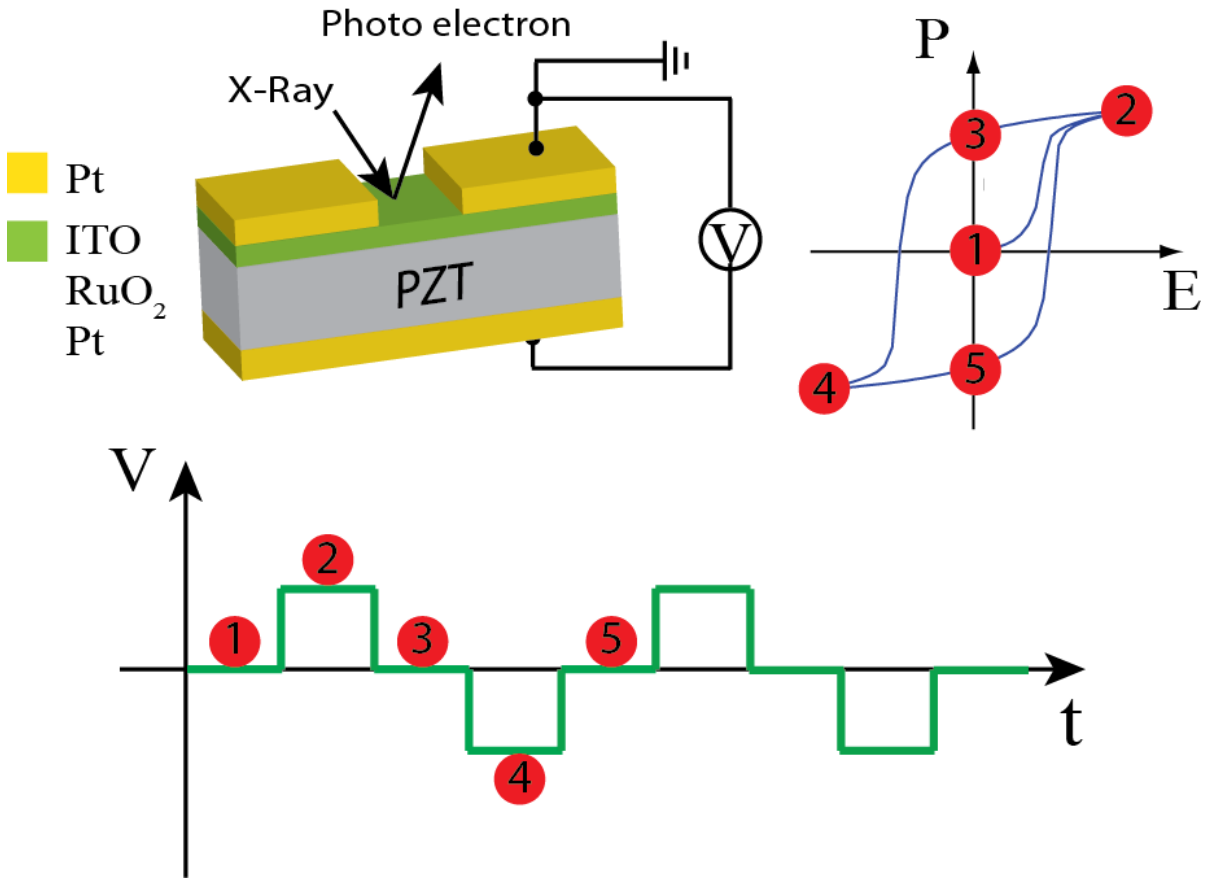
Reaction at PZT/Pt interface



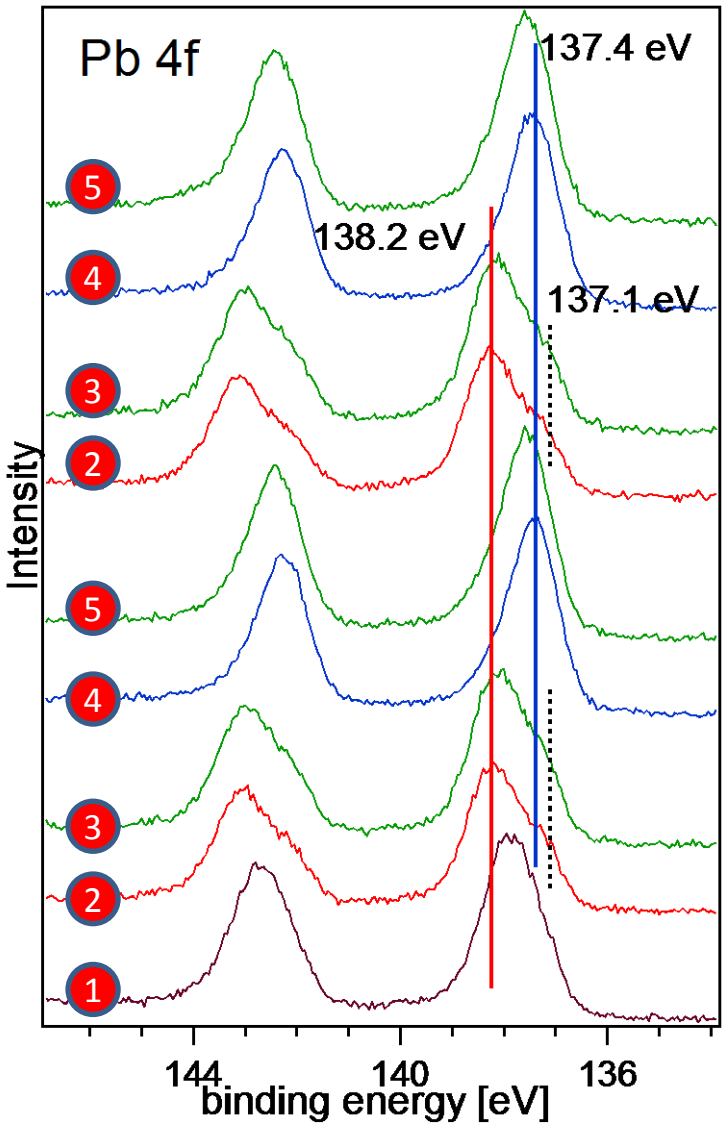
Chemical decomposition of PZT during Pt deposition

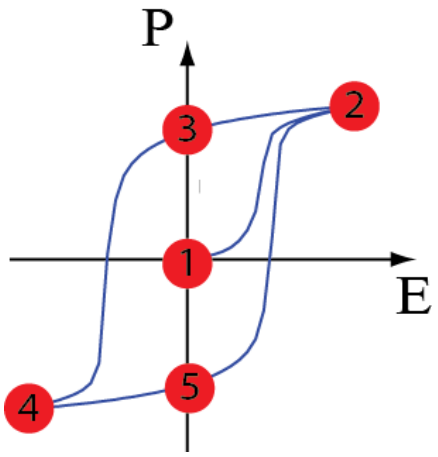
Chen *et al.* J. Phys. D **42**, 215302 (2009)

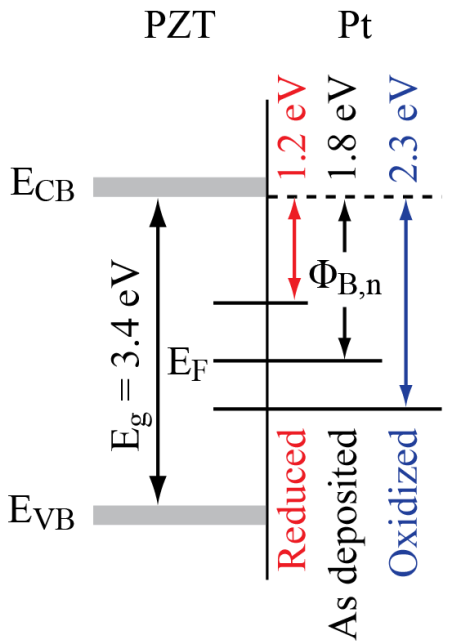
In-situ XPS measurement in poling process



E_F variation at PZT/Pt interface during switching

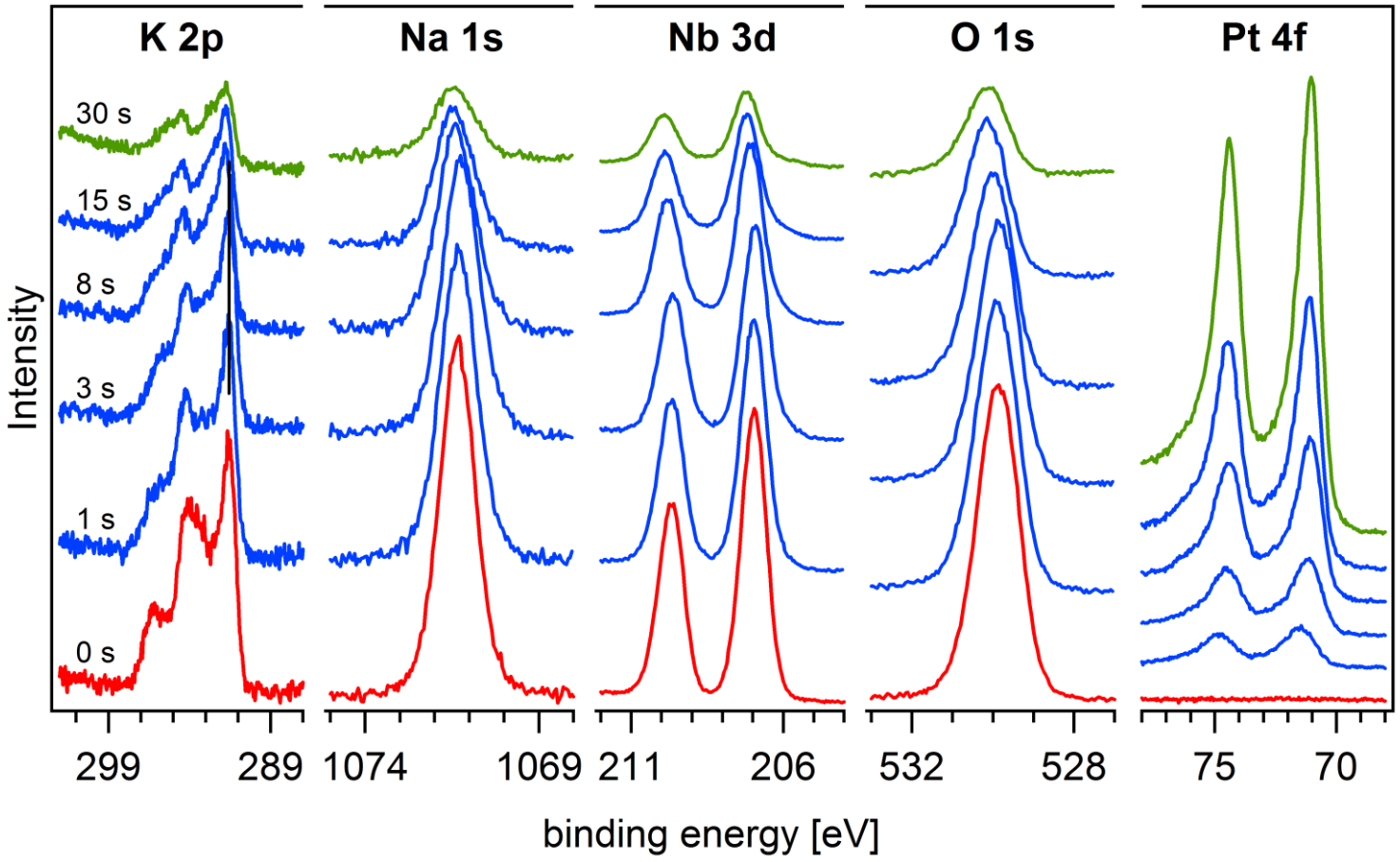






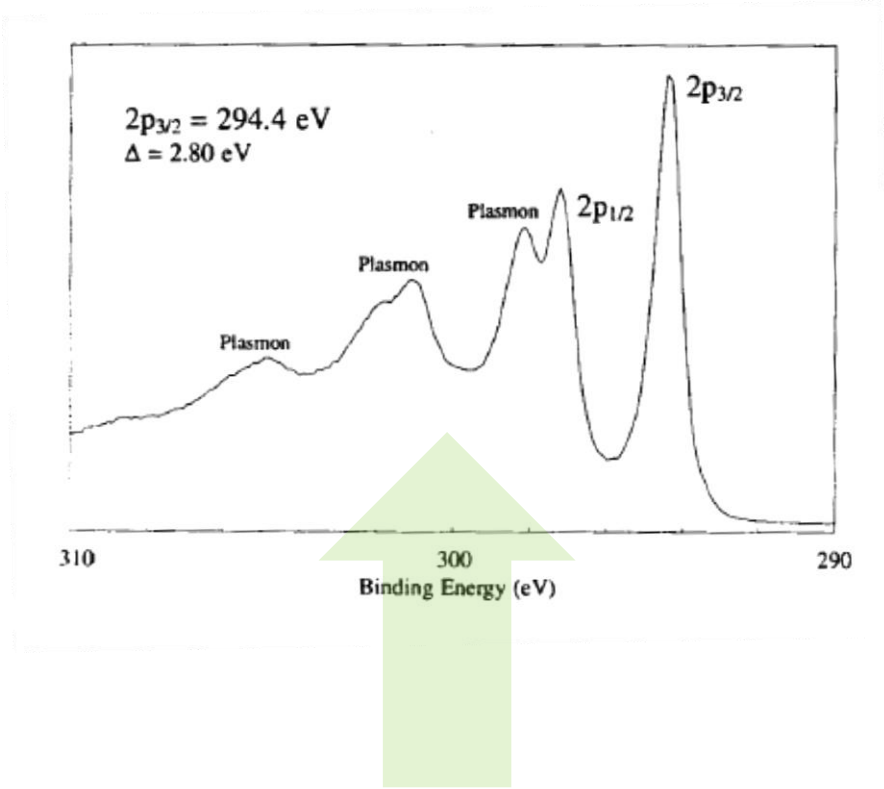
- **PZT/Pt interface is weakly *p*-type**
- **Positive state, E_F shift upward, acceptor defects appear**

KNN/Pt interface

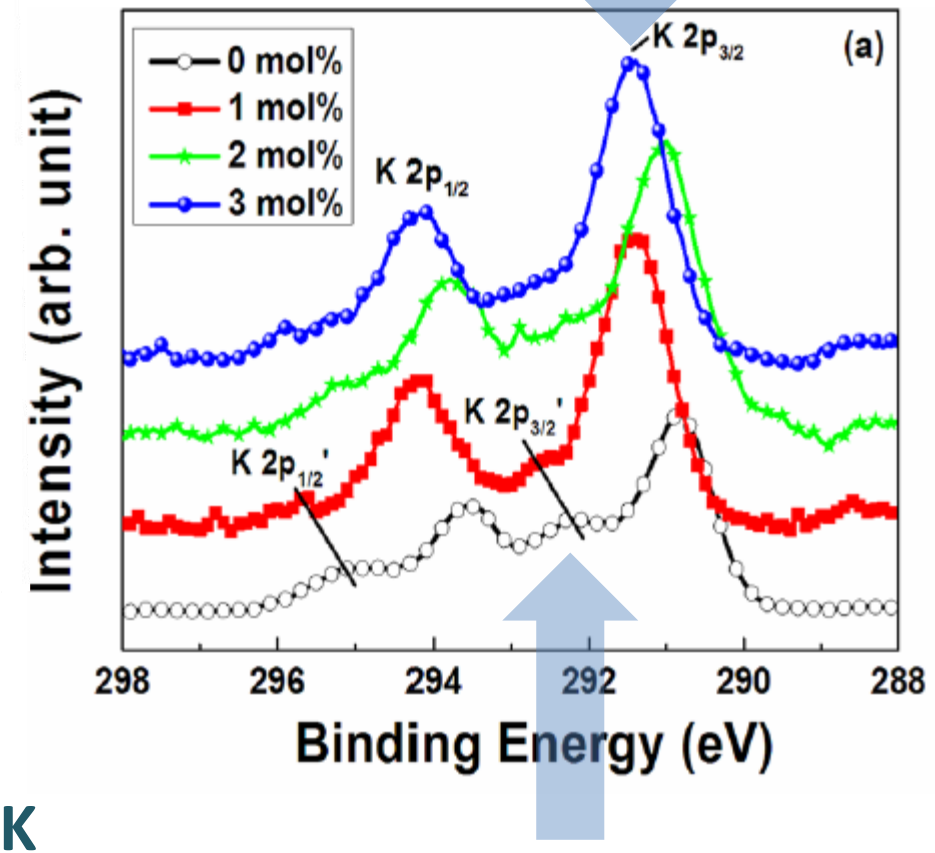


Obvious decomposition of KNN during Pt deposition was Not found

KNN/Pt interface



Perovskite

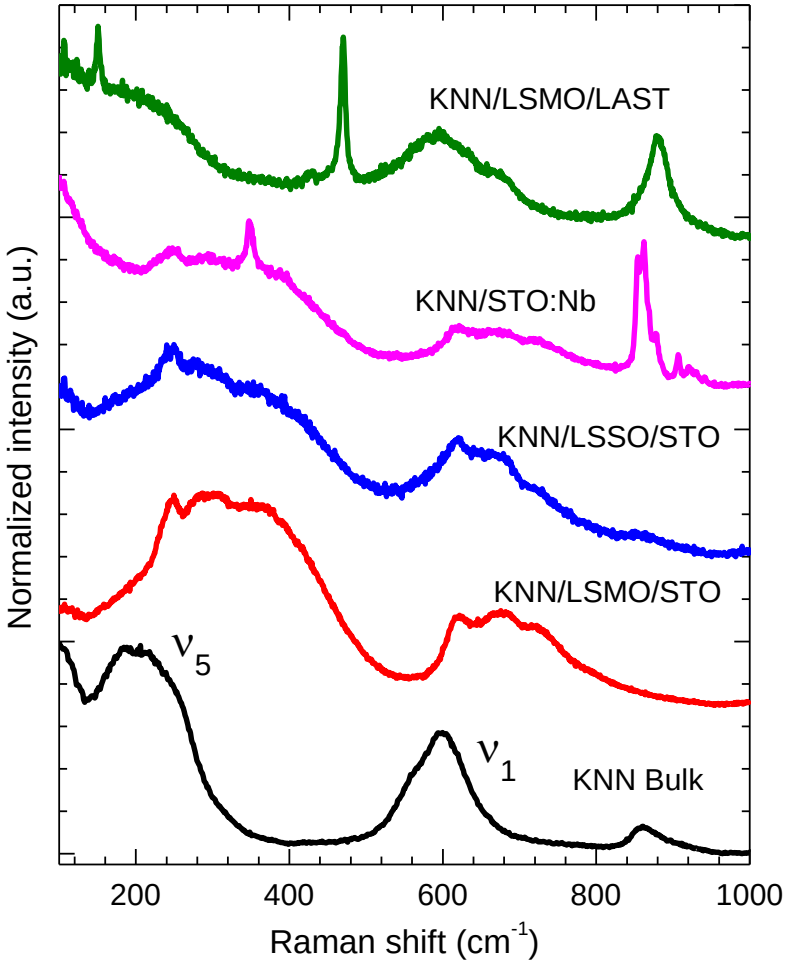


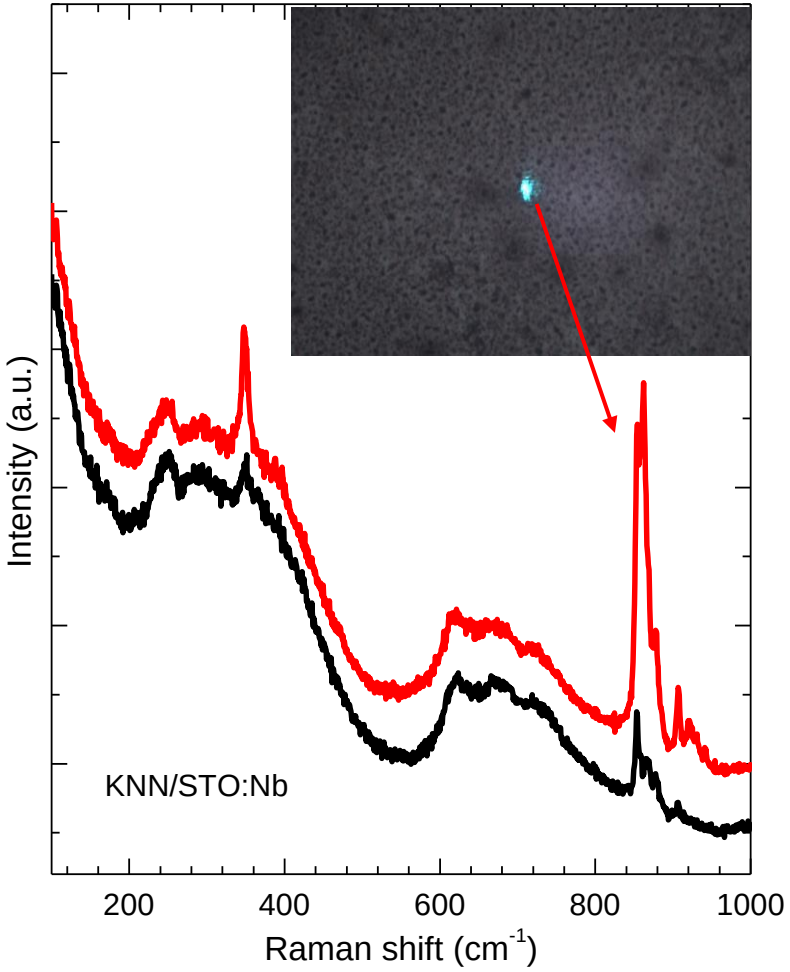
Plasmon peak with metallic K

Non-Perovskite

Wang *et al.* JAP, 115, 034104 (2014)

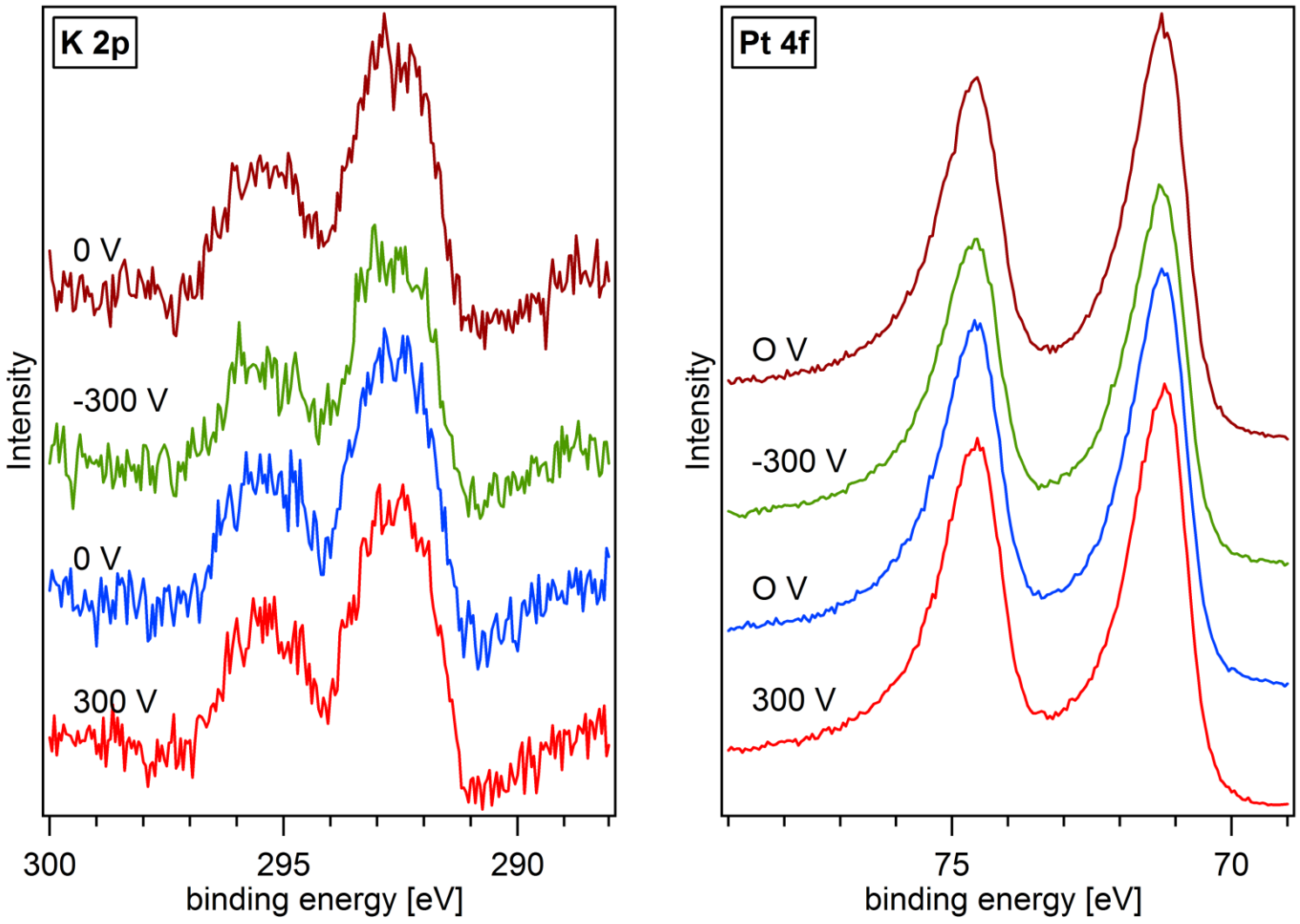
Raman scattering spectrum





Raman shift of the KNN epitaxial films is sensitive to the electrode and substrate used

KNN/Pt interface (switching)



No binding energy shift and KNN decomposition during switching

Conclusions

- KNN epitaxial films can be fabricated on conductive oxide substrates with PLD
- Their crystalline quality and ferroelectric property depend on the substrate (electrode)
- Epitaxial KNN films might have a even higher thermal stability
- KNN films show a high fatigue resistance behavior during bipolar switching, which might be induced by the phase separation at the surface

Thanks for you attention!