Core-shell Domain Structure Investigation of Lead-free Incipient Piezoceramic by Piezoresponse Force Microscopy

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Outline

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1. Motivation

- $Bi_{1/2}Na_{1/2}TiO_3$-25$SrTiO_3$ lead-free incipient piezoceramic
- Core-shell microstructure

2. Piezoresponse Force Microscopy

- Domain imaging
- Domain switching

3. Results

- Visualization of non-ergodic core and ergodic shell domain structure
- Heterogeneous nucleation of domains at core/shell interface
- Topographical difference between the core and shell region

4. Conclusions

Motivation

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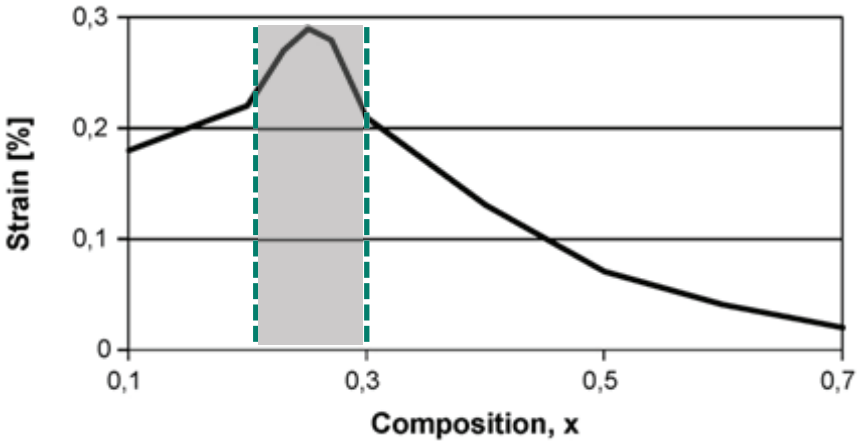
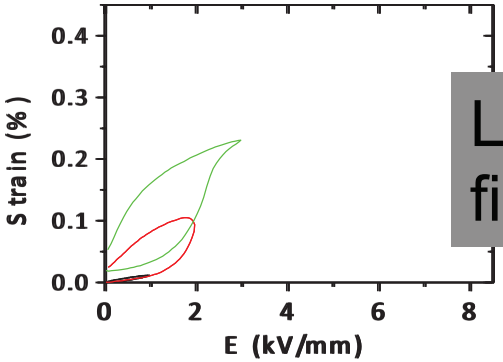
Lead-free incipient piezoceramic

$Bi_{1/2}Na_{1/2}TiO_3$-$25SrTiO_3$





Large electric-field-induced strain

Poster: P 01 by Matias Acosta

Jo, W., et al.. Journal of Electroceramics 29(1), 71-93 (2012).
Eu-Directive 2011/65/Eu: (RoHS), Off. J. Eur. Union, L 174, 88-110 (2011).
Krauss et al. JECerS 30 (2010)

Motivation

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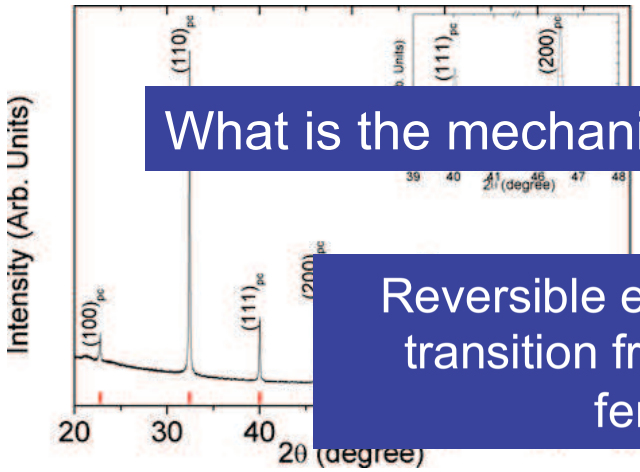
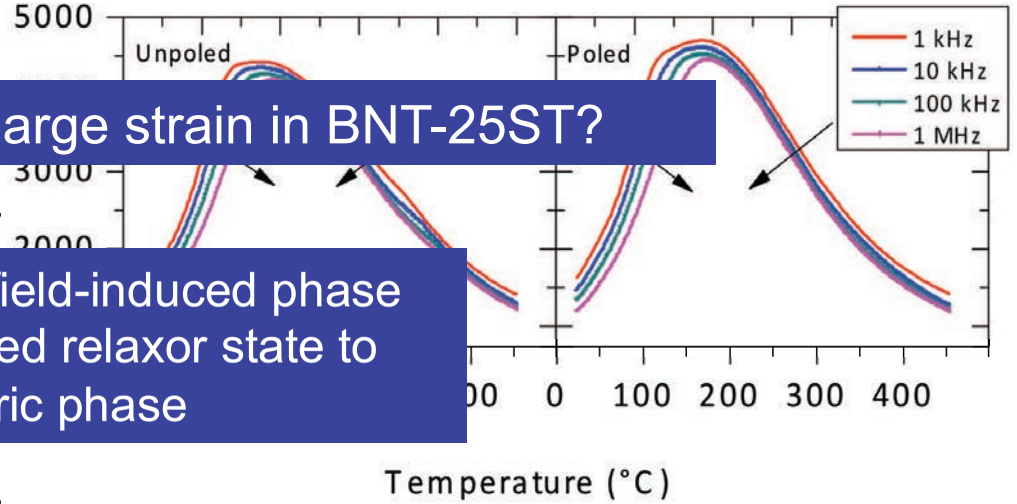
$Bi_{1/2}Na_{1/2}TiO_3$-$25SrTiO_3$ lead-free incipient piezoceramic

XRD



Dielectric Properties



What is the mechanism of large strain in BNT-25ST?

Reversible electric-field-induced phase transition from mixed relaxor state to ferroelectric phase

Core-shell microstructure

Macroscopically Pseudocubic and Relaxor

Acosta, M., et al.. Journal of the American Ceramic Society 97(6): 1937-1943.(2014)

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Motivation

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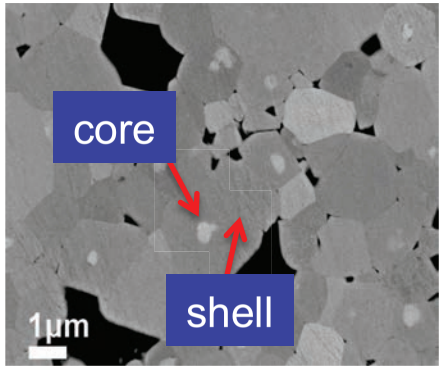
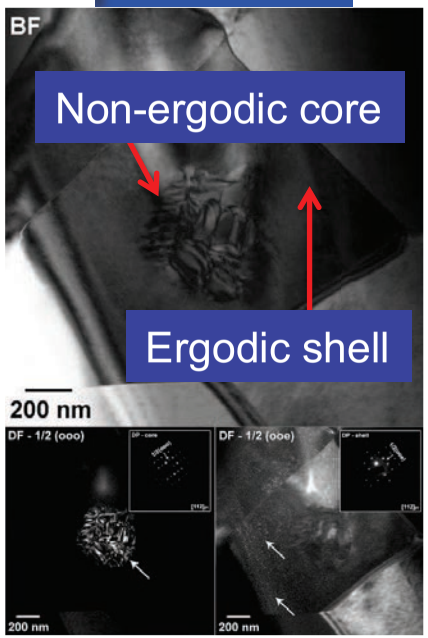
Core-shell microstructure

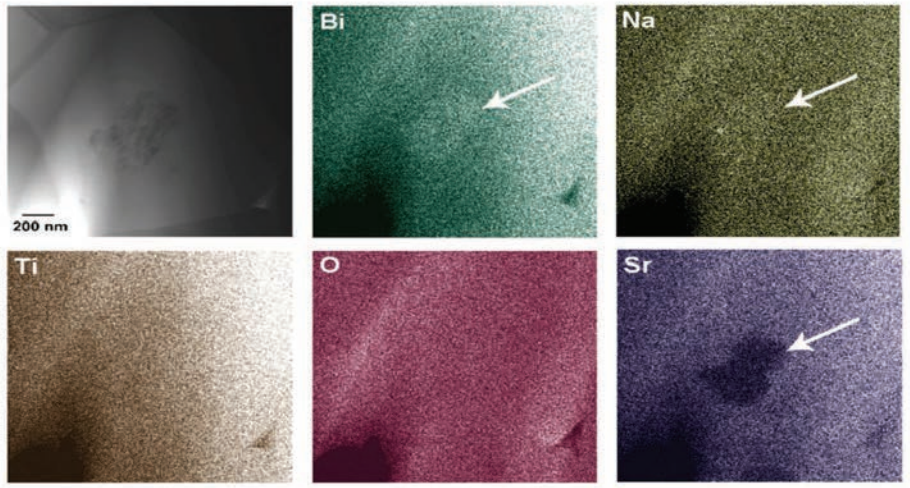
SEM-BSE



TEM



STEM



Core: Sr-depleted/(Bi,Na)-rich
Shell: Sr-rich/(Bi,Na)-depleted

Nanoscale → PFM

Courtesy of Acosta et al. and B3

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Piezoresponse Force Microscopy

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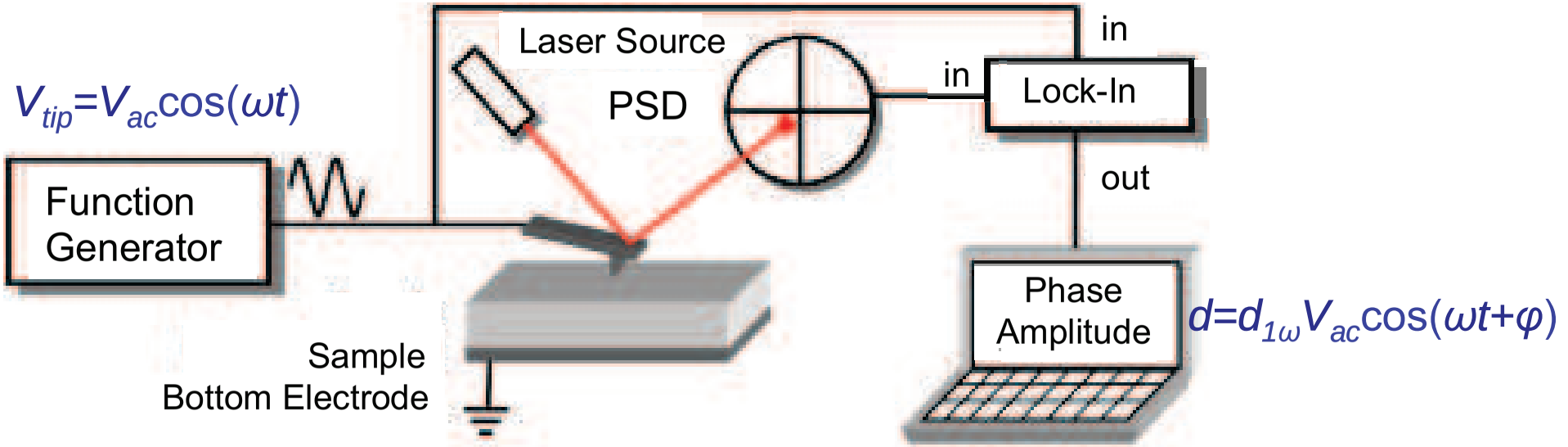
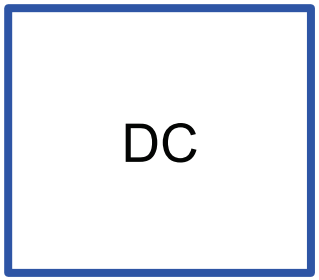
Domain imaging



Domain switching



http://www.ntmdt.com/spm-principles/

Balke, N., et al.. Journal of the American Ceramic Society 92(8): 1629-1647. (2009)

Result: visualization of core-shell domain structure

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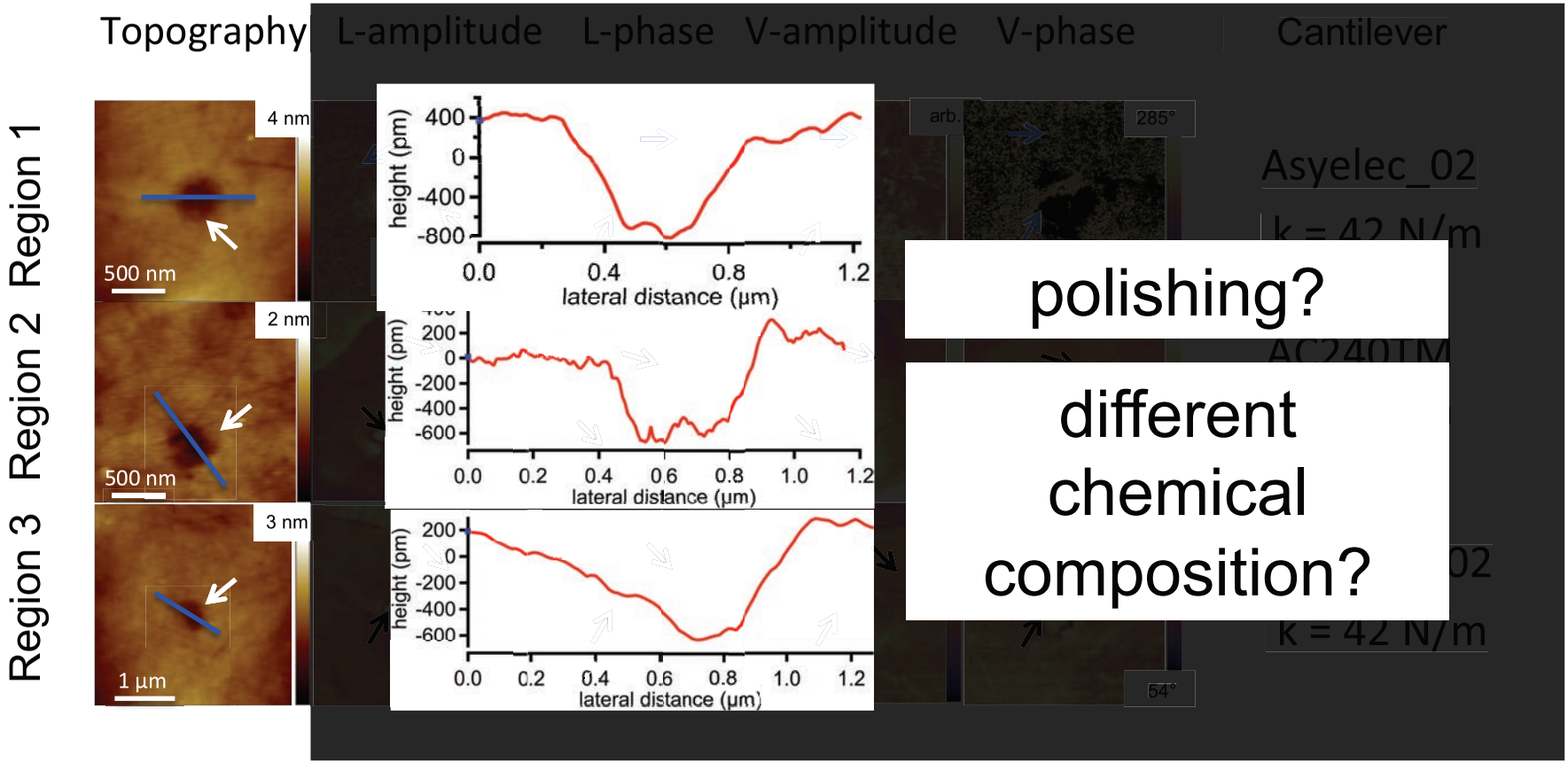

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Result: electric-field-induced ferroelectric domain evolution

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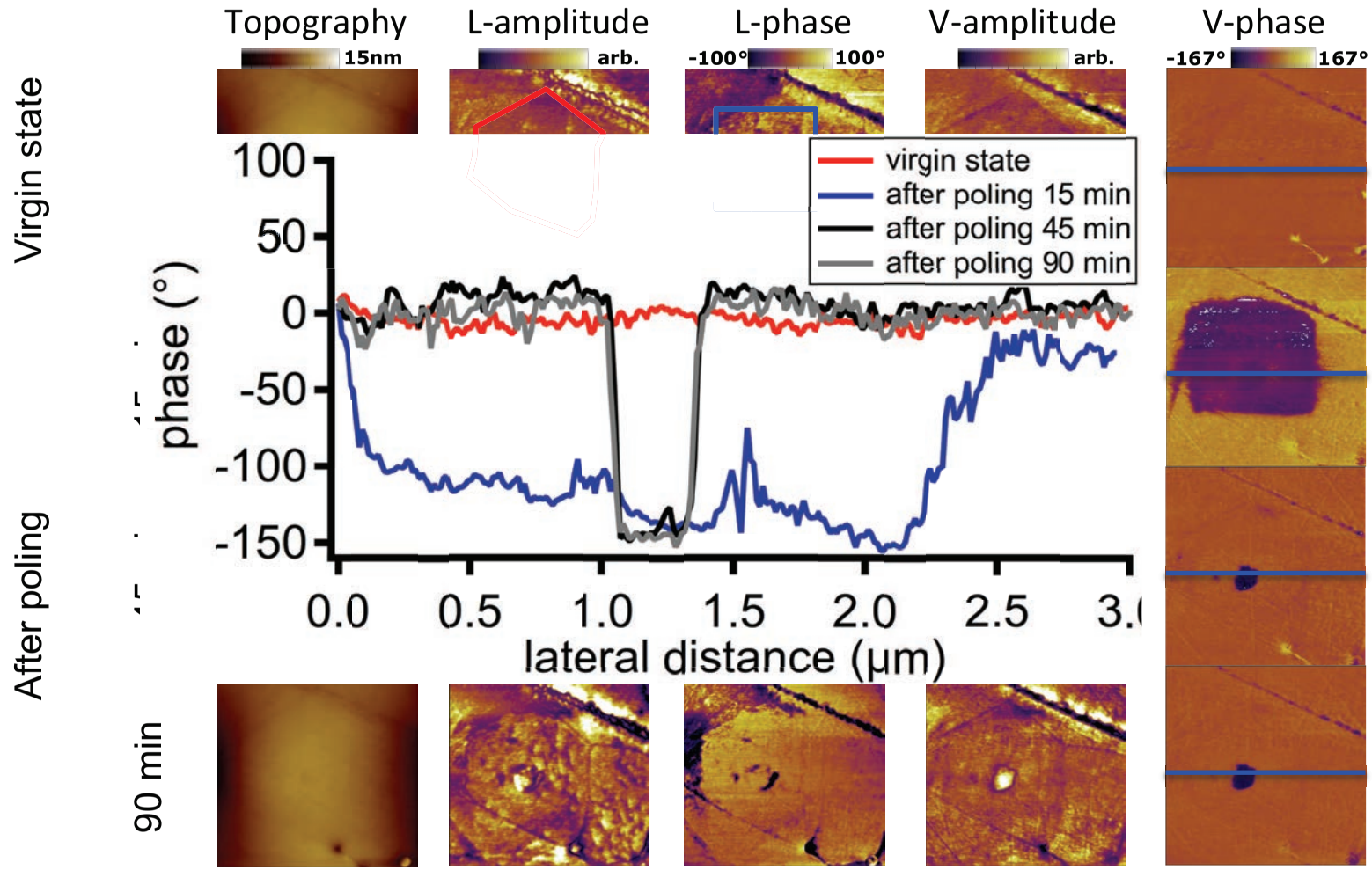

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Result: electric-field-induced ferroelectric domain evolution

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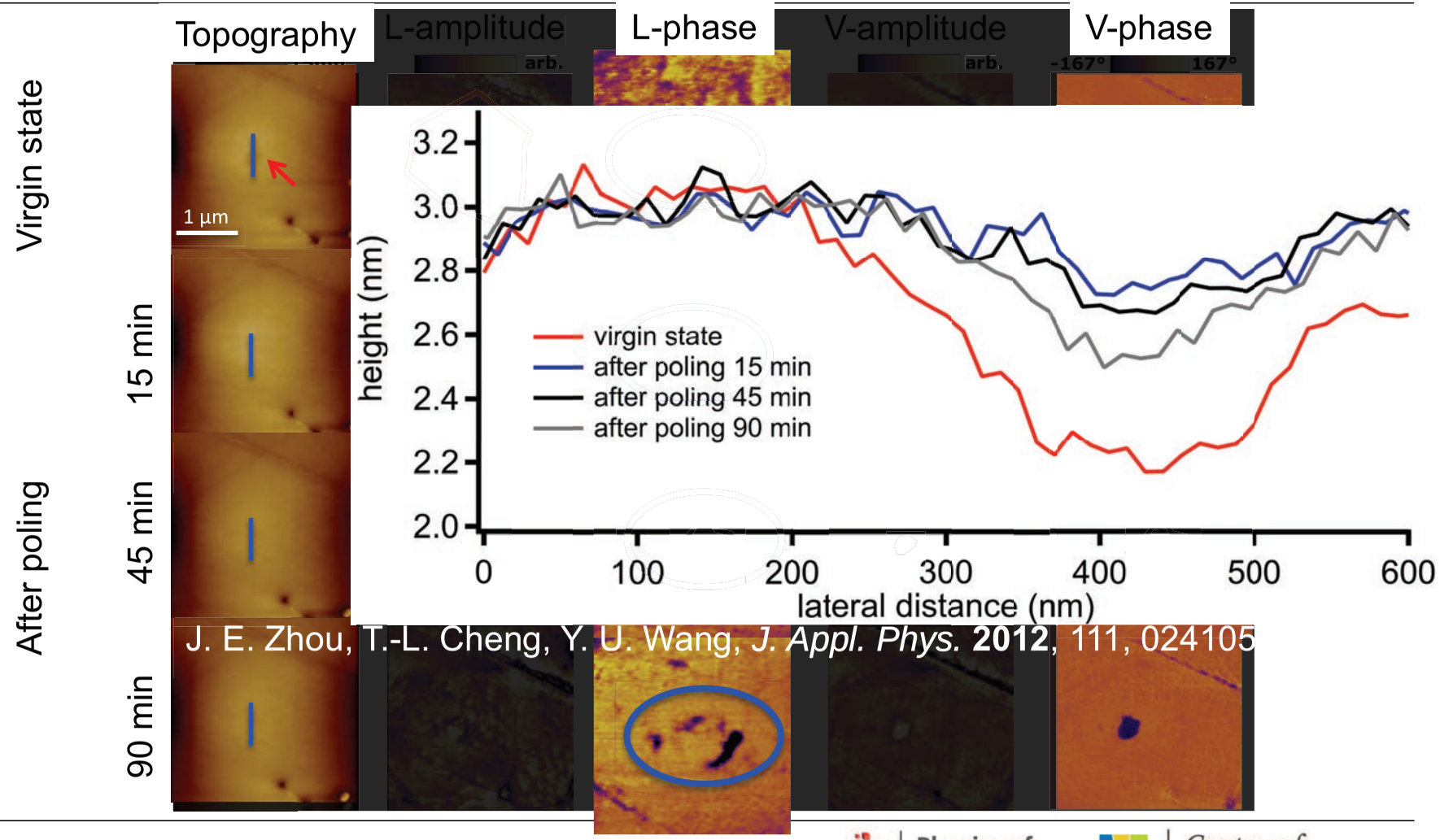

J. E. Zhou, T.-L. Cheng, Y. U. Wang, *J. Appl. Phys.* **2012**, 111, 024105

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Conclusions

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- non-ergodic core / ergodic shell domain structure
- heterogeneous nucleation of domains at the core/shell interface
- electric-field-sensitive topographical hollow in the core

Open questions:

- What is the mechanism behind the topographical change in the core region before/after applying electrical field?
- At core/shell interface, strain mismatch? Charge accumulation?

Thank you for the Attention!

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Back row (f.l.t.r.): Limor Zemel, Marek Janko, Christian Dietz, Agnieszka Voß, Simon Schiwek, Marie-Christin Apfel; Front row (f.l.t.r.): Kim Phuong Lieu, Asma Siddique, Robert Stark, Suman Narayan, Na Liu; (Missing: Imke Murschel, Elke Kämmerer, Andreas Plog, Maximilian Köhn)

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