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ASYLUM RESEARCH
Atomic Force Microscopes

2nd International Workshop on Piezoresponse Force Microscopy:

Instrumentation, Theory, & Applications

EPFL, Lausanne, Switzerland
May 26-29, 2008

Organizers:
Nava Setter (EPFL)
Sergei Kalinin (ORNL)

Invited lecturers:
Alexei Gruverman (U.Nebraska-Lincoln)
Sergei V. Kalinin (ORNL)
A. Kulik (EPFL)
A. Tagantsev (EPFL)

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The SPM Application Experts

2nd International Workshop on Piezoresponse Force Microscopy: Theory, Techniques, and Applications

EPFL, Lausanne, Switzerland, 26-29 May, 2008

Nava Setter and Sergei V. Kalinin

Ceramics Laboratory, Swiss Federal Institute of Technology, EPFL 1015 Lausanne Switzerland
The Center for Nanophase Materials Sciences and Materials Sciences and Technology Division,
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Nanoscale ferroelectrics and multiferroics are rapidly becoming the mainstay of information technology due to emerging applications in FeRAM, data storage, and tunneling barriers. Utilization of ferroelectric electronic and electromechanical devices necessitates probing electromechanical activity, domain structure and dynamics, polarization switching and fatigue mechanisms on the nanoscale, as well as understanding the role of surfaces, interfaces, and defects on these processes. This workshop aims to provide in-depth description and recent advances in Piezoresponse Force Microscopy, including theory of operation, recent technical developments, and applications for ferroelectrics and multiferroics, polar nitrides, and biological systems. The workshop will introduce basic principles of PFM operation, relevant instrumental aspects, and image interpretation. The theory of cantilever dynamics, PFM contact mechanics, and resolution theory, as well as their implications for qualitative and quantitative data interpretation in PFM, will be presented and illustrated experimentally. The recent technical advances in PFM, including high-frequency (1-8 MHz) imaging, imaging and polarization switching in liquids, mapping polarization dynamics in ferroelectric capacitor structures, and switching spectroscopy PFM will be presented. Applications of PFM for mapping nucleation centers in ferroelectrics will be demonstrated. Finally, electromechanical probing of biological, electroactive polymer, and soft-condensed matter systems beyond classical ferroelectric applications will be discussed.

The 3.5 day workshop aimed for intermediate and advanced PFM users will include lectures given by S.V. Kalinin (ORNL), A. Gruverman (U. Nebraska-Lincoln), A. Tagantsev (EPFL) and A. Kulik (EPFL). The lectures are complimented with experimental tutorials on PFM imaging and SS-PFM studies of polarization dynamics. Ultimately, we aim to build a network of advanced PFM practitioners to promote rapid dissemination of theoretical knowledge, experimental protocols, and novel technique development in this rapidly growing area, as well as to establish links to areas such as electrophysiology and physical biology.

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Course LECTURES

1. Electromechanical coupling on the nanoscale: Bonds, cells, and molecules (Kalinin)
2. Nanoscale Ferroelectrics: Size effects on stability and polarization dynamics (Tagantsev)
3. Probing forces and structure on the nanoscale by scanning probe microscopy (Kulik)
4. Principles and instrumental aspects of piezoresponse force microscopy (Gruverman)
5. PFM of piezoelectric materials: contact mechanics and resolution theory (Kalinin)
6. Cantilever dynamics in PFM (Kulik)
7. High-frequency PFM and advanced imaging modes in PFM (Kalinin)
8. PFM studies of polarization dynamics in capacitors (Gruverman)
9. Polarization patterning and single point PFM spectroscopy (Gruverman)
10. Switching Spectroscopy PFM and imaging nucleation centers (Kalinin)
11. Advanced topics in PFM and SPM of ferroelectrics: surface chemistry effects and imaging in vacuum (Kalinin)
12. PFM of biological systems and imaging in liquids (Kalinin)

Lectures by PFM producers

R. Proksch, Asylum: Enhanced resonance imaging modes- dual frequency tracking and band excitation.

Sh. Wu, Agilent: Multi-frequency approach in AFM electric modes: KFM and PFM.

B. Pittenger, Veeco: HarmoniX microscopy - A technique for high resolution mapping of adhesion and stiffness.

Demonstrations (for groups of 4 persons)

Equipment of (Asylum, Agilent, Veeco, Nanonis)

Demo 1: Low-frequency PFM Imaging

1. Basic experimental set-up for PFM
2. Polarization patterning and lithography

Demo 2: **PFM of capacitor structures**

1. Imaging of capacitor structures
2. Polarization dynamics in capacitors

Demo 3: Polarization dynamics in films

1. PFM spectroscopy
2. Switching Spectroscopy PFM

Demo 4: Dynamics PFM modes

1. Dual resonant frequency tracking PFM
2. Band excitation PFM

Demo 5: Special modes of ferroelectric characterisation

Demo 6: additional features of PFM

(Support: Kalinin, Stolichnov, Colla, Gruverman, Kulik)