

# PHD DISSERTATION DEFENSE

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**2219 Engineering Building**

## **“IMAGE PROCESSING ENHANCEMENTS FOR SCANNING PROBE RECOGNITION MICROSCOPY”**

### **ABSTRACT**

The family of scanning probe microscopy (SPM) techniques has revolutionized studies of micro and nano objects. Nanobiology is one field which is being dramatically impacted by the newly available direct information provided by SPM techniques. Although SPM has great potential in nanobiology, it is important to realize that it also has challenges: image artifacts; slow scanning speed; difficulty in efficient recognition of the region of interest; optimization of scanning parameters. A new mode of SPM operation, Scanning Probe Recognition Microscopy (SPRM), has been developed by our group in partnership with Veeco Instruments Inc. Scanning Probe Recognition Microscopy is a new scanning probe microscopy technique which allows us to adaptively track individual structures using a fine resolution scan restricted to the region of interest, and providing statistically significant data for multiple properties. Two implementation methods, an off-line processing scheme and an on-line dynamically adaptive multi-resolution scanning mode, are developed and presented in this thesis.

A second challenge in AFM data is the distortion of the measured image due to tip-sample interaction which is significant in nanoscale metrology. Two approaches for deconvolution are investigated and applied for the first time in the estimation of true topological shape of nanoscale features from the measured height data. The first approach is based on morphological image processing and uses the geometrical tip and sample information. The second approach is a physics based deconvolution method and involves the modeling and characterization of tip/sample interaction

forces. Initial results based on modeling only Van der Waals component of the over all tip-sample interaction, show the feasibility of the method for determining true topographic shapes of the sample.

SPRM was developed within an application framework for two reasons. One was to challenge the instrument development with real versus ideal problems. Another reason was to immediately use the new SPRM capability to investigate significant problems. Tissue scaffolds built from electrospun carbon nanofibers whose purpose is bridging injuries in damaged spinal cords were characterized in terms of properties that influence neural cell growth and attachment, such as surface roughness and elasticity. The results of SPRM investigations of the surface roughness and elasticity of tissue scaffolds are presented. SPRM provided the first capability to acquire force curves directly along an individual nanofiber under optimal conditions where the tip and hence applied force is exactly normal to the curved nanofiber surface. Statistical methods based on histograms were developed to analyze the surface roughness and elasticity properties of the tissue scaffold nanofibers. This is the first time that statistically meaningful information has been extracted along individual nanofibers using an automatic procedure that maintains uniformity of experimental conditions.

### List of Publications

1. **Y. Fan**, Q. Chen, S. Kumar, A.D. Baczewski, L. Udpa, V.M. Ayres and A. F. Rice, " *Scanning Probe Recognition Microscopy*," submitted to *MRS Fall 2007* (2007)
2. **Y. Fan**, Q. Chen, S. Kumar, A.D. Baczewski, L. Udpa, V.M. Ayres and A. F. Rice, "Scanning Probe Recognition Microscopy Investigation of Nanoscale Mechanical and Surface Roughness Properties Along Nanofibers," in *Surface and Interfacial Nanomechanics*, edited by R.F. Cook, W. Ducker, I. Szlufarska, R.F. Antrim (Mater. Res. Soc. Symp. Proc. Volume 1021E, Warrendale, PA, 2007), 1021-HH05-26
3. **Y. Fan**, Q. Chen, V.M. Ayres, A.D. Baczewski, L. Udpa and S. Kumar, "Scanning Probe Recognition Microscopy Investigation of Tissue Scaffold Properties," Vol. 2, Issue 4, *Int. J. Nanomedicine* (2007)
4. Sally Meiners, Ijaz Ahmed, Abdul S. Ponery, Nathan Amor, Virginia M. Ayres, **Yuan Fan**, Qian Chen and Ashwin N. Babu, "Engineering Electrospun Nanofibrillar Surfaces for Spinal Cord Repair: A Discussion," *Polymer Int.*, Vol. 56, pp. 1340-1348 (2007)
5. Q. Chen, **Y. Fan**, L. Udpa, and V.M. Ayres, "Cell Classification by Moments and Continuous Wavelet Transform Methods," Vol. 2, Issue 2, *Int. J. Nanomedicine* (2007)
6. **Y. Fan**, Q. Chen, S. A. Kumar A.D. Baczewski, N.V. Tram, V.M. Ayres, A.F. Rice, L. Udpa, "Registration of Tapping and Contact Mode Atomic Force Microscopy Images", *2006 6th IEEE Conference on Nanotechnology Proceedings*, ISBN 1-4244-0078-3(2006)
7. (Invited) Lalita Udpa, Virginia M. Ayres, **Yuan Fan** Qian Chen and Shiva Arun-Kumar, "Deconvolution of Atomic Force Microscopy Data for Cellular and Molecular Imaging," *IEEE Sig. Proc. Mag., Special Issue on Molecular and Cellular Bioimaging*, Vol. 23, No. 3, pp. 73-83 (2006)

8. **Y. Fan**, Q. Chen, V.M. Ayres, L. Udpa and A. F. Rice, "Scanning Probe Recognition Microscopy Investigation of Cell Elastic Properties", *American Physical Society March Meeting*, Los Angeles CA, 21-25 March, 2005
9. Q. Chen, **Y. Fan**, V.M. Ayres, L. Udpa, M.S. Schindler and A. F. Rice, "Scanning Probe Recognition Microscopy Investigation of the Elastic Properties of Tissue Scaffolding", in *Mater. Res. Soc. Symp. Proc. Vol. 838E: Scanning-Probe and Other Novel Microscopies of Local Phenomena in Nanostructured Materials*, edited by S.V. Kalinin, B. Goldberg, L.M. Eng, and B.D. Huey, The Materials Research Society, Warrendale, PA (2005), O15.2, Electronic: ISBN 1-55899-802-0
10. **Y. Fan**, L. Udpa, Q. Chen and V.M. Ayres, "Scanning Probe Recognition Microscopy Investigation of Tissue Scaffolding Properties", No. 388, Conference Proceedings of the Biomedical Engineering Society Annual Meeting, 13-16 October, 2004, Philadelphia, PA