Nanoscience on the tip
a workshop in scanning probe microscopy

Seattle, Washington
June 25–29, 2007
# TABLE OF CONTENTS

**Scope**

Motivation, Objective and Preface........................................................................................................ 3

**Organization of the 2007 SPM Workshop**

Format – Daily Schedule.................................................................................................................. 4
Local Maps.................................................................................................................................. 5

**NUE UNIQUE Partners and Sponsors**

Biographical Sketches

Instructors................................................................................................................................. 9
Teaching Assistants.................................................................................................................... 10

Acknowledgment ........................................................................................................................ 10

Workshop 2007 Participants........................................................................................................ 11

**Laboratory Unit Descriptions and Assignments**

LAB UNIT 1: Scanning Force Microscopy & Nanolithography.................................................. 13
LAB UNIT 2: AC-Mode SFM and Electrostatic Force Microscopy............................................ 41
LAB UNIT 3: Force Spectroscopy Analysis............................................................................... 58
LAB UNIT 4: Force Modulation Microscopy ............................................................................. 85
LAB UNIT 5: Scanning Tunneling Microscopy......................................................................... 113
Scope

Motivation
Since the invention of the scanning tunneling microscope (STM) in 1981 by Gerd Binnig and Heinrich Rohrer (Nobel Prize in Physics 1986) scanning probe microscopy (SPM) techniques have dazzled scientists and engineers in nearly every field from natural sciences to liberal arts, and nucleated the new discipline of Nanoscience and Nanotechnology. The birth of such a highly interdisciplinary field is an attest to the changing times in a world that moves from educating specialists to generalists. The true power of SPM techniques, which assisted in removing boundaries between disciplines, lays in its simplicity to provide access to the nanoworld in terms of visualization and manipulation. Hence, it is only perceivable that SPM offers an outstanding educational tool for schools.

Objective
The overarching objective of the NUE UNIQUE Program is to develop a nationally replicable model of a sustainable and up-to-date undergraduate teaching laboratory of scanning probe methods applied to nanosciences and nanotechnology. To this end, a partnership between researchers and educators at the University of Washington (UW) and the North Seattle Community College (NSCC), and two companies - Nanosurf, AG (Liestal, Switzerland) and nanoScience Instruments (Phoenix, AZ) has been forged within this partnership a new paradigm of initiating, operating and maintaining a SPM laboratory will be developed and tested that provides a truly hands-on experience in a classroom laboratory setting for a small number of students per instrument involving a variety of SPM techniques and nanoscience/engineering topics.

Preface
This first workshop organized within the boundaries of this paradigm of initiating, operating and maintaining a SPM laboratory serves a class of 16 undergraduate students of diverse academic background with a one-week hands-on experience in small groups of 4 students per instrument. The students gain experience in a variety of different areas from nanolithography, photovoltaics, contact mechanics, polymer relaxation, Van der Waals and capillary forces to quantum mechanical properties.

René M. Overney, Director
NUE UNIQUE
University of Washington, Seattle, WA 98195
roverney@u.washington.edu

June 25, 2007
### Organization of the 2007 SPM Workshop

**Format – Daily Schedule**

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 25</td>
<td>June 26</td>
<td>June 27</td>
<td>June 28</td>
<td>June 29</td>
</tr>
<tr>
<td>8:00 a.m.</td>
<td>8:00 a.m.</td>
<td>8:00 a.m.</td>
<td></td>
<td>8:00 a.m.</td>
</tr>
<tr>
<td>SFM Lecture on Surface Electronic Properties</td>
<td>SFM Lecture on Contact Mechanics</td>
<td></td>
<td>Work on the assigned Lab Unit for the day</td>
<td></td>
</tr>
<tr>
<td>Prof. Ginger</td>
<td>Prof. Overney</td>
<td></td>
<td></td>
<td>(a) Prelab Assignment</td>
</tr>
<tr>
<td>Mueller 154</td>
<td>Mueller 154</td>
<td></td>
<td></td>
<td>(b) Lab Assignment</td>
</tr>
<tr>
<td>9:00 a.m.</td>
<td></td>
<td></td>
<td></td>
<td>(c) Lab Report</td>
</tr>
<tr>
<td>Welcome</td>
<td></td>
<td></td>
<td></td>
<td>(start with the lab report around 1 p.m.)</td>
</tr>
<tr>
<td>Profs Overney and Ginger</td>
<td></td>
<td></td>
<td></td>
<td>2:30 p.m. Final Discussion</td>
</tr>
<tr>
<td>Mueller 154</td>
<td></td>
<td></td>
<td></td>
<td>Certificates and Awards</td>
</tr>
<tr>
<td>9:15 a.m.</td>
<td></td>
<td></td>
<td></td>
<td>Evaluation</td>
</tr>
<tr>
<td>Lab Overview</td>
<td></td>
<td></td>
<td></td>
<td>Mueller 154</td>
</tr>
<tr>
<td>Prof Overney</td>
<td></td>
<td></td>
<td></td>
<td>3:30 p.m. Adjourned</td>
</tr>
<tr>
<td>Mueller 154</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:00 a.m.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratory UNIT 1: Introduction to SFM and Nanolithography</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilcox 233 and 335</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4:30 p.m. Daily discussion about the lab</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milnor-Roberts Room</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Individual preparation for the assigned Lab Unit the next day: Involves reading of the background information and answering the theoretical questions. Due at the beginning of the lab the next morning.

See maps on next pages for directions.
Local Map

Map of University of Washington Campus with NUE-UNIQUE Facilities Highlighted

Parking Information at the UW:
http://www.washington.edu/commuterservices/get_to_uw/maps_directions/
Organization of the 2007 SPM Workshop

Local Map

Map of Mueller Hall

Stairs down to Courtyard

Courtyard

Entrance to Mueller

Mueller 154
NUE UNIQUE
Lecture Room

Stairs down to Courtyard

Entrance to Mueller

To Roberts Hall & Wilcox Hall
Organization of the 2007 SPM Workshop

Local Map

Map of Wilcox 2nd Floor

To Roberts Hall & Mueller Hall

Entrance on 1st Floor

Stairs to 2nd Floor

Shared Experimental Facilities of GEMSEC

Rm 235
NUE-UNIQUE
SPM Lab

Rm 233 -
NUE-UNIQUE
SPM Lab

Entrance on 1st Floor

Stairs to 2nd Floor

Entrance on 1st Floor
NUE UNIQUE PARTNERS & SPONSORS

- UW - Genetically Engineered Materials Science & Engineering Center GEMSEC (NSF-MRSEC)
- UW - Center for Nanotechnology (CNT)
- North Seattle Community College (NSCC), Seattle, WA
- Nanosurf, AG (Liestal, Switzerland)
- nanoScience Instruments (Phoenix, AZ)

NUE UNIQUE (Nanotechnology Undergraduate Education - Using Nanoscience Instrumentation for Quality Undergraduate Education), Grant 06-538, is a National Science Foundation sponsored program.
Biographical Sketches

Instructors

David Ginger (ginger@chem.washington.edu, Prof. in Chemistry) research focuses on the creation and study of nanostructured materials with unique optoelectronic and photonic properties. His group has pioneered novel scanning probe microscopy and lithography methods to further our understanding of nanostructured organic solar cells. His group is also developing bio-inspired assembly strategies for controlling near-field electromagnetic coupling between fluorophores and plasmon resonant nanoparticles. Ginger is also known for his work in the development of semiconductor nanocrystals for photovoltaics and LEDs, and as a pioneer of Dip-Pen Nanolithography methods for biomolecules. In recognition of his research and education efforts, he has been named a Research Corporation Cottrell Scholar.

René Overney (roverney@u.washington.edu, Prof. in Chemical Engineering) is known for his pioneering work in nanorheology and transport properties. His group has developed various SPM nano-characterization methods particularly applicable to polymer science and related technologies. The research of his group ranges from mesoscale material aspects in photonics, optoelectronics, electronic storage media, separation membranes, tribology to human implant technology. Overney coauthored one of the early textbooks in Nanoscience (Nanoscience, World Scientific 1998), and is teaching on the undergraduate and graduate level nanoscience related courses since 1996.

Mehmet Sarikaya (sarikaya@u.washington.edu, Prof. in Materials Science and Engineering) is known for his pioneering efforts and ideas in Molecular Biomimetics. By merging recent advances in molecular biology and genetics with state-of-the-art engineering and nanocharacterization from the physical sciences, his and his collaborators' goal is to shift the biomimetic materials science paradigm from imitating Nature to designing materials to perform artificial nanofunctions. It is the intent to combine Nature's proven molecular tools, such as proteins, with synthetic nanoscale constructs to make molecular biomimetics a full-fledged methodology. To this end, at the Genetically Engineered Materials Science and Engineering Center, an NSF-MRSEC, Sarikaya is directing a multidisciplinary team with diverse expertise to genetically select inorganic-binding short polypeptides, tailoring them via molecular manipulation and bioinformatics to make heterofunctional molecular constructs and using them as synthesizers, assemblers, and molecular erectors in materials science and medicine.

Teaching Assistants

Yeechi Chen (yeechi@u.washington.edu) is a graduate student working with Prof. David Ginger. She received her A.B. in physics from Dartmouth College in 2000, and her M.S. from the University of Washington in 2003. Her research focuses on the characterization of metal nanoparticle-modified fluorescence.
Biographical Sketches

Teaching Assistants cont.

Hanson Fong (hfong@u.washington.edu) received his Ph.D. in Materials Science & Engineering from the University of Washington in 2003. He is currently a post-doc fellow at the University of Washington working under the supervision of Drs. Mehmet Sarikaya and Martha Somerman on dental tissue regeneration. He is also the facilities coordinator for GEMSEC at the University of Washington.

Dan Knorr (knorrd@u.washington.edu), currently a graduate student, is studying with Dr. René Overney and Dr. Alex Jen in the fields of atomic force microscopy and photonic materials. Dan earned B.S. and M.S. degrees in chemical engineering at Texas A&M University and then spent five years in the chemical industry as a process engineer with Chevron Phillips before returning to school to pursue a Ph.D.

Jason Killgore (killgoj@u.washington.edu) is a 5th year graduate student studying with Dr. René Overney. Jason received a BS degree from Western Washington University in 2002 and an MS degree from the University of Washington in 2005. His research focuses on using scanning probe microscopy to study local fluxes in nanocomposite polymer membranes. He expects to complete his Ph.D. in spring 2008.

Chris So (crso@u.washington.edu) graduated in 2006 with a BS from the Biochemistry program at the University of Washington. He is currently a graduate student in the Materials Science and Engineering Department working with Prof. Mehmet Sarikaya at the Genetically Engineered Materials Science and Engineering Center (GEMSEC). He is interested in bio-inspired materials and molecular biomimetics, particularly in using the AFM as a tool for their study.

Joseph Wei (wei@u.washington.edu) is a Chemical Engineering graduate student working in the lab of Prof. David Ginger. His current interests are applying Dip-Pen Nanolithography to template-directed organization in polymer thin films, assembling engineered polypeptides on inorganic surfaces, and direct patterning of positive etch resists. He received his BS (2002) and MS (2004) degrees in Chemical Engineering from the University of Washington under the direction of Prof. René Overney on direct surface permeability analysis and nanoscopic material characterization of membrane systems using scanning probe microscopy.

Acknowledgment

Our foremost thanks go to Dr. Tomoko Gray (UW, ChemE) for developing a great part of the laboratory units. Furthermore, we gratefully acknowledge the lab unit development efforts by Michael Brasile, Yeechi Chen, Dan Knorr, Jason Killgore, and Joseph Wei, and the logistic support efforts by Dr. Hanson Fong (UW, GEMSEC). We also like to express our gratitude to Dr. Ethan Allen (UW, CNT) and Dr. Tom Griffith (NSCC) for their support of this program from the very beginning. NUE UNIQUE is funded by the Nanotechnology Undergraduate Education (NUE) program of the National Science Foundation (Grant 06-538) and supported by GEMSEC (a UW based Mat. Res. and Eng. Center), Nanosurf AG (Switzerland) and nanoScience Instruments (AZ), and the Department of Chemical Engineering at the University of Washington.
# Workshop 2007 Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Email</th>
<th>Current College/University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleecker</td>
<td>joan@<a href="mailto:bleecj@gmail.com">bleecj@gmail.com</a></td>
<td>University of Washington</td>
</tr>
<tr>
<td>Chen</td>
<td><a href="mailto:yuchun@u.washington.edu">yuchun@u.washington.edu</a></td>
<td>University of Washington</td>
</tr>
<tr>
<td>Christin</td>
<td><a href="mailto:BRChristin@hotmail.com">BRChristin@hotmail.com</a></td>
<td>University of Washington</td>
</tr>
<tr>
<td>Deleo</td>
<td><a href="mailto:deleof@aa.washington.edu">deleof@aa.washington.edu</a></td>
<td>University of Washington</td>
</tr>
<tr>
<td>Gill</td>
<td><a href="mailto:korynn@kyriani.org">korynn@kyriani.org</a></td>
<td>North Seattle Community College</td>
</tr>
<tr>
<td>Jaramillo</td>
<td><a href="mailto:chavallaneous@hotmail.com">chavallaneous@hotmail.com</a></td>
<td>University of Washington</td>
</tr>
<tr>
<td>Koniges</td>
<td><a href="mailto:koniges@washington.edu">koniges@washington.edu</a></td>
<td>University of Washington</td>
</tr>
<tr>
<td>Marciniak</td>
<td><a href="mailto:monik956@u.washington.edu">monik956@u.washington.edu</a></td>
<td>University of Washington</td>
</tr>
<tr>
<td>Nair</td>
<td><a href="mailto:nairt@seattleu.edu">nairt@seattleu.edu</a></td>
<td>Seattle University</td>
</tr>
<tr>
<td>Quarfoth</td>
<td><a href="mailto:rquarfoth@hmc.edu">rquarfoth@hmc.edu</a></td>
<td>Harvey Mudd College</td>
</tr>
<tr>
<td>Schneider</td>
<td><a href="mailto:ars7@u.washington.edu">ars7@u.washington.edu</a></td>
<td>University of Washington</td>
</tr>
<tr>
<td>Smith</td>
<td><a href="mailto:smit1105@seattleu.edu">smit1105@seattleu.edu</a></td>
<td>Seattle University</td>
</tr>
<tr>
<td>Stapleton</td>
<td><a href="mailto:staples@u.washington.edu">staples@u.washington.edu</a></td>
<td>University of Washington</td>
</tr>
<tr>
<td>Stephen</td>
<td><a href="mailto:zrs420@u.washington.edu">zrs420@u.washington.edu</a></td>
<td>University of Washington</td>
</tr>
<tr>
<td>Tey</td>
<td><a href="mailto:johnson.tey@gmail.com">johnson.tey@gmail.com</a></td>
<td>University of Washington</td>
</tr>
<tr>
<td>Yaghoobi</td>
<td><a href="mailto:pyaghoobi@gmail.com">pyaghoobi@gmail.com</a></td>
<td>University of British Columbia</td>
</tr>
</tbody>
</table>