The University of Western Ontario

NanoWestern

Research Western

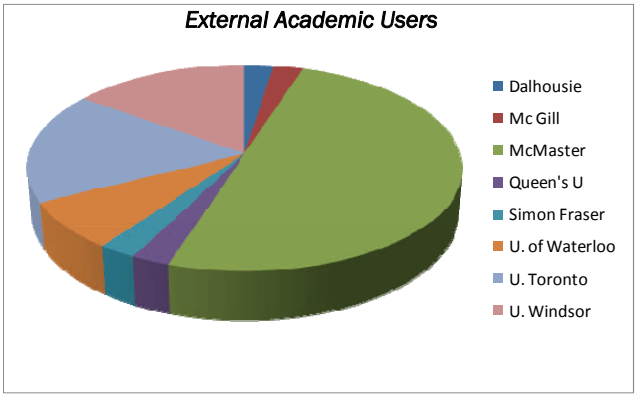
Volume 4, Issue 1 Winter 2008

WELCOME TO 2008!

THIS ISSUE

So here we are! We've started our fourth year of publication with a little makeover but each issue will still contain informative articles about research, equipment , and people relating to The Nanofabrication Laboratory at the University of Western Ontario. Here are some interesting facts about The Nanofab:

- State-of-the-art clean room facility of 2300 square feet.
- Open user facility and service provider with three full time specialists.
- Over 250 facility users since 2005.
- Over 35 pieces of equipment to support R&D in materials synthesis, surface patterning and functionalization down to sub-micron dimensions in many different material classes.
- Publish NanoWestern, a quarterly newsletter in its fourth year, with almost 500 subscribers worldwide.



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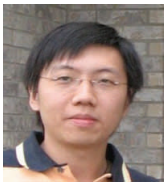
FABRICATION OF MICROFLUIDIC DEVICES TO STUDY BACTERIAL NANOWIRES



Kar Man (Edmond) Leung
Department of Mechanical and Materials Engineering
Faculty of Engineering
University of Western Ontario

The field of micro- and/or nanofabrication has already started to impact on microbiology because its scale of size is well matched to the physical dimensions of most microorganisms. Systems and structures constructed at micron or submicron scales enable the manipulation of individual cells, the control of their extracellular environments (micro- or nanoenvironments) and the study of microbial physiology and behaviour. This article briefly discusses concepts for constructing microfluidic devices to facilitate the study of bacterial nanowires through coaxing Shewanella oneidensis MR-1 into producing nanowires between the cell and a mineral phase through well-defined nanochannels. A major strength in the microfluidic methods is the ability to create devices in almost any configuration. By utilizing microfluidic techniques, experiments can be done on individual cells or microcolonies.

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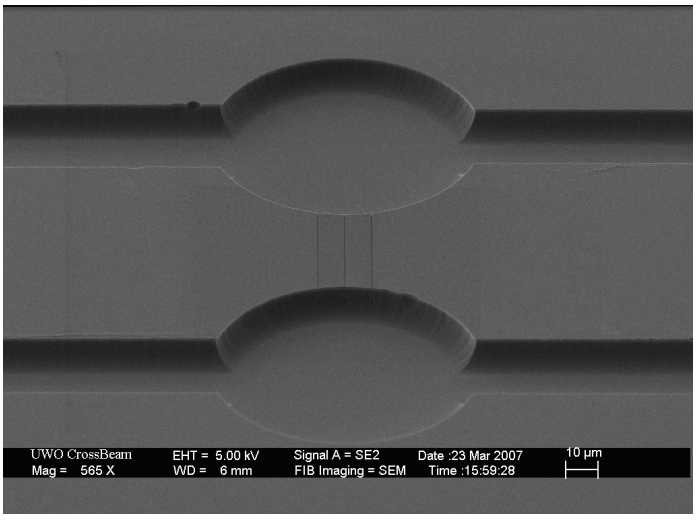

Figure 1. SEM micrograph of a microfluidic device containing two microchambers connected by three nanochannels.

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Microbiologists recently found that bacterial nanowires play an important role in the transport of electrons in microbial systems both between individual cells and between cells and mineral phases. Bacterial nanowires have been directly observed using scanning tunnelling microscopy (STM) and conducting probe atomic force microscopy (AFM) in several species of bacteria.[1,2] Some of these nanowires appear to be electrical conductive. Thus, bacterial nanowires may represent a common strategy for efficient electron transfer and energy distribution. To date bacterial nanowires have only been analyzed in dehydrated forms, and their true conductivity and other electrical properties remain unknown. In a hydrated form or when the bacteria are bathed in a conducting fluid (e.g. media or natural waters), these nanowires might function differently. By applying microfluidic technology, our research team would like to unravel these essential microbiology questions.

In our design, the microfluidic device contains two microchambers, which are etched on a glass substrate using a mixture of buffered hydrofluoric (HF) and hydrochloric (HCl) acids after standard optical lithographic procedures. One microchamber serves as a reservoir for bacteria and the other one for the mineral. The microchambers are connected by nanochannels, which are about 300 nm deep and wide. The nanochannels are precisely carved using the focused ion beam (FIB) method at a milling current of 50 pA. Poly(dimethysiloxane) (PDMS) is chosen to be the cover material to seal the device. The PDMS is oxygen plasma treated before bonding onto the glass substrate to promote better adhesion and sealing.

The mineral used in this study is uranyl acetate [U(VI)], which is water-soluble and is diluted to 1 M. *S. oneidensis* is bathed in a defined minimal medium, which contains only chemicals necessary for cell survival and lactate as an electron donor. Oxygen is usually the best electron acceptor for many microorganisms due to its high reduction potential. In the presence of oxygen, bacteria do not produce nanowires to save metabolic costs. The functions of bacterial nanowires are believed to be searching for alternative electron acceptors and attaching to them for direct electron transfer under electron acceptor (O_2) limitation. The experimental condition is kept anaerobic and our device is designed to isolate the cells from the only available electron acceptor, U(VI). Provided the cells sense the presence of electron acceptor in the opposite chamber through diffusion through the nanochannels, they are not able to swim across the nanochannels due to their bigger size. The only possible way in order for them to survive would be producing nanowires to the mineral side and getting electrons dumped. The existence of nanowires in the nanochannels would prove these hypotheses. In the future, sensors can be fitted into the device to measure the conductivity and other electrical properties of these wires.

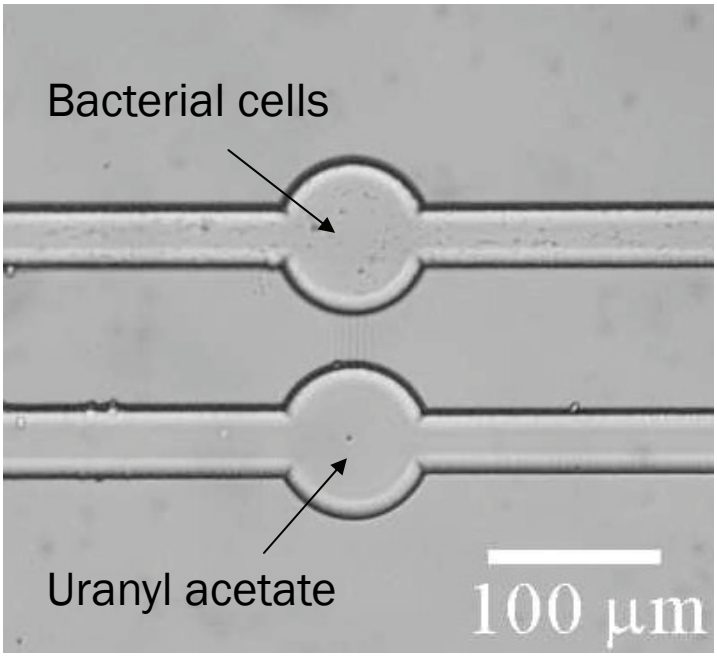

Figure 2. Optical micrograph of a device after loaded with bacterial cells and mineral.

The applications of microfluidics to microbiology can be enormous and limited only by the imagination of researchers.

The author would like to thank Mr. Gregory Wanger (PhD candidate, Earth Sciences, UWO), Prof. Gordon Southam (Earth Sciences, UWO), Prof. Jun Yang (Mechanical and Materials Engineering, UWO) and Prof. Leo Lau (Director, SSW) for discussions and support. He would also like to thank the Nanofabrication team for its support and advice.

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2008 WINS Distinguished Lecture – April 16, 2008

Eli Yablonovitch

The Western Institute for Nanomaterials Science is pleased to announce that the 2008 WINS Distinguished Lecture is Eli Yablonovitch, Professor of Electrical Engineering and Computer Science at UC Berkeley. Professor Yablonovitch is best known as the founding experimentalist of the current world-wide effort in photonic band gap materials. He lists his expertise as being in nonlinear optics, laser-plasma interaction, infrared laser chemistry, photovoltaic energy conversion, strained-quantum-well lasers, and chemical modification of semiconductor surfaces. Currently his main interests are in optoelectronics, high speed optical communications, high efficiency light-emitting diodes and nano-cavity lasers, photonic crystals at optical and microwave frequencies, quantum computing and quantum communication. For many he is a leading candidate to win a Nobel Prize for his photonic crystal work.

Nanostructured Platforms for Surface Enhanced Raman Spectroscopy of Biomolecules.

Betty Galarreta, bgalarre@uwo.ca,
(Sarvesh Varma, Elwood Chan,
François Lagugné-Labarthet),
Department of Chemistry,
University of Western Ontario.

Rapid and accurate identification of trace amounts of chemical species using optical methods has been a challenge for more than 20 years. The discovery of the surface enhanced Raman effects (SERS) from rough surfaces or colloidal solutions has stimulated a desire to further increase the detection limit of Raman signals that intrinsically suffer from weak scattering cross sections.

Our group (Dr. F.Lagugné-Labarthet) is investigating the fabrication and the characterization of very well controlled lithographic structures on glass platforms to quantify local enhancements with the goal to achieve the highest optical enhancement with a high reproducibility.

Such nanoscale structured surfaces composed of noble metals (Ag, Au, Pt) have several advantages. First, their geometries can be controlled by the user. As shown is figure 1, triangles or snowflakes were fabricated with controlled gaps between the different elements. The nanosized individual structures are separated by gaps in the range of 30-50 nm. The control of the inter-structure gap is the key parameter for high optical enhancements and can be well controlled in the e-beam lithography process.

We have started investigating in collaboration with the Robarts Institute (Dr. S. Ferguson) the study of membrane receptors coupled to the intracellular system via a G-protein. Such GPCRs (G protein coupled receptors) are of tremendous importance in life science being responsible of many physiological processes as transducers (light, smell, hormones and other). All information about their insertion into the biological membranes, their structural conformations, or their interactions with surrounding molecules is significant in order to understand some fundamental bioprocesses.

Raman spectra have initially been performed on GTP molecules deposited at the surface of our SERS platforms.

As shown in figure 2 the Raman spectrum of guanosine triphosphate (GTP) measured under a confocal microscope is significantly enhanced when deposited on our platform while it appears very weak on a flat gold surface.

The Raman spectra show a number of bands that can be associated with the functional units of the GTP. Any change of intensity or spectral shift can reveal the inter- or intra- molecular interactions that can possibly be quantified. Due to the complexity of GPCR biological macromolecules (polypeptide chain with up to 1100 residues) our group will focus on specific vibrational bands that are associated either with molecular recognition or molecular structure.

Acknowledgments: We wish to thank Surface Science Western (M-.J.Walzak) and the Nanofabrication Laboratory (Dr. T.Simpson) for their interest and suggestions for the nanofabrication processes. Group contact: flagugne@uwo.ca

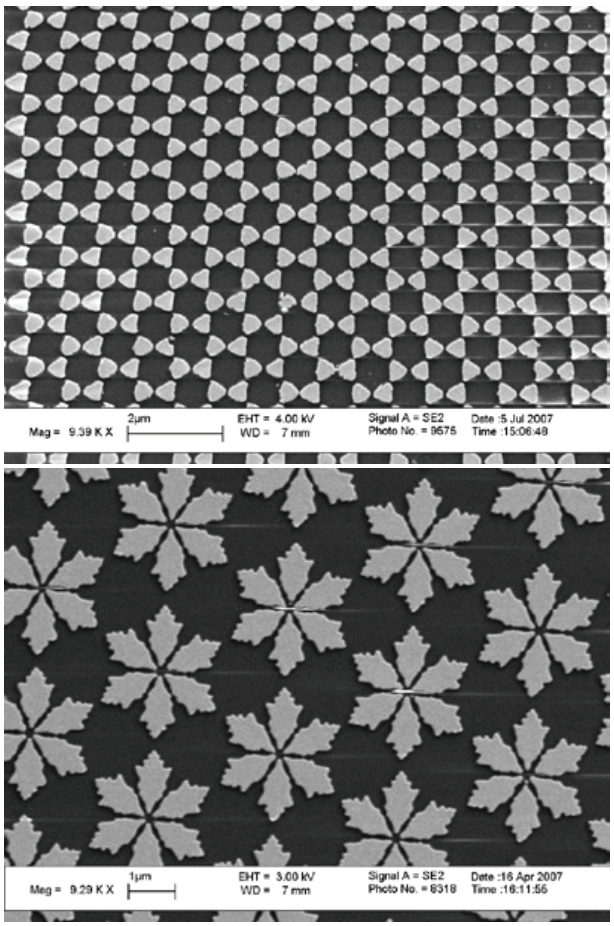

Figure 1: Examples of plasmonic devices made using the e-beam lithography technique. The triangles have a side of 400 nm and a 20 nm gold thickness. The sharp structures of the nano-snowflakes have gaps in the 50-100 nm range.

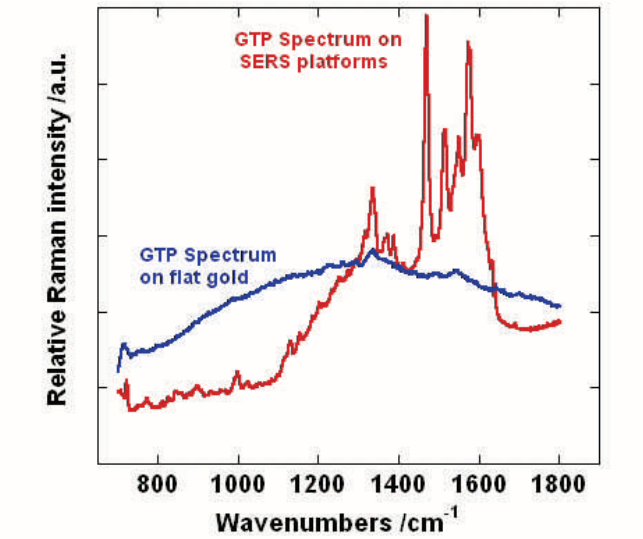

Figure 2: Raman spectra of a monolayer of GTP deposited on flat gold and on SERS platforms. The laser power is similar in both experiments.

How to Become a NANOUSER

The Nanofabrication laboratory is operated as an open facility. Users can receive access and training to perform their own fabrication and analysis. Alternatively, work can be performed by a Nanofab staff member as a service.

Access to the Nanofab:

1. All users must submit a completed information form. Forms can be downloaded from our website at http://www.uwo.ca/fab/newuser.htm
2. The NanoUser Orientation Course will introduce you to proper cleanroom protocol and give you a tour of the facility. Once the Orientation is successfully completed, you will receive your keycard granting access to the Nanofab.
3. You will be trained by a Nanofab staff member on the operation of each equipment item required for your project.

Service Work:

Users who wish to have work performed as a service by Nanofab staff can contact us directly to discuss their requirements. A cost estimate or quote will be provided.

Commonly provided services:

- Scanning Electron Microscopy (SEM) imaging.
- Preparation of Transmission Electron Microscopy (TEM) samples by Focused Ion Beam (FIB).
- Materials deposition.
- Wafer dicing.

Western Institute for Nanomaterials Science
4th Annual Workshop
Friday May 16, 2008

This year the opening address at the Workshop will be given by Professor Sajeev John of the University of Toronto, who along with Eli Yablonovitch (our 2008 WINS Distinguished Lecturer) and his experimental work, was the driving force behind laying down the theoretical underpinnings of photonic band gap materials.

For more information, please contact Prof. Rob Lipson: rlipson@uwo.ca

The Nanofabrication Laboratory

University of Western Ontario
Physics & Astronomy Building Rm 14
London, Ontario N6A 3K7

Phone: 519-661-2111
Fax : 519-661-2033

Silvia Mittler, Laboratory Director
Ext. 88592 Email: smittler@uwo.ca

Todd Simpson, Research Scientist
Ext. 86977 Email: tsimpson@uwo.ca

Rick Glew, Lab Manager
Ext. 81458 Email: rglew@uwo.ca

General Inquires Email: nanofab@uwo.ca