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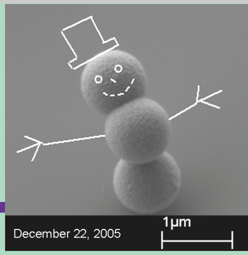


# NANOWESTERN

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**THIS ISSUE**

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## A NANOFAB YEAR IN REVIEW

Over the last 12 months, we have seen a steady increase in the number of NanoUsers (students, researchers and faculty) from Science and Engineering using the facility. Growing interest has also been demonstrated from other universities and industrial establishments. This increase in activity has led to a boost in revenues as well.

It is a pleasure to see up to 50 individuals coming to the Nanofab, more or less regularly, for sample and probe preparation or measurements and characterizations done by themselves or by the Nanofab personnel. According to the academic calendar we also see small waves of new students showing interest in the Nanofab. The new NanoUsers are trained first on general clean room rules before being trained on individual equipment.

It turns out that one of the most popular tools in the Nanofab is the FIB or dual beam integrated in a SEM and e-beam lithography, also integrated in a SEM environment. These two pieces are also the largest source of revenue thus far. The deposition tools are a close second in popularity. Less time is consumed on the milling machines and on the inspection instrumentation.

I would like to introduce to you the availability of the Nanofab's highly sophisticated confocal microscope. It is able to operate in the 2-photon mode and features a high precision sample stage. Some of its capabilities are demonstrated in Dr. Zhifeng Ding's article on page 2 and 3 of this issue.

But it is not only the large, highly sophisticated equipment that is drawing the attention of users and clients. A tool as simple as the dicing saw has recently been busy and helpful in solving our client's problems.

Leica TCS SP2 Confocal Microscope

The users and clients of the Nanofab facility are already wide spread over the Faculties of Science and Engineering. Additionally, the subscription and distribution of the NanoWestern newsletter demonstrates the increasing interest in Nanotechnology and Nanoscience, in Canada and internationally. Our partner universities, through the Ontario-Baden-Württemberg Program are becoming aware of the unique opportunities Western's Nanofab and have started to show interest as well.

My particular aim throughout the new year will be to introduce the Nanofab to researchers in the Life Sciences, both in Biology and Medical, and demonstrate that nanotechnology is an interesting field for exploration and research, but also for developing methods of diagnosis and treatment.

Director,

Silvia Mittler

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- Examples of work
- Contact Information
- Facilities Information
- How to become a NanoUser.
- Find out about services provided
- To subscribe or unsubscribe to NanoWestern

**NEXT ISSUE**

- *More Principal Investigator Profiles*
- *NanoUser Student Project Profile*
- *Manufacturing Fiducial Markings*


- The Nanofabrication Laboratory is a state of the art "hands-on" facility in The Physics and Astronomy Building. It combines class 10,000 and class 100 cleanroom environments where users are trained in cleanroom protocol, the use of the tools and performing various processes.
- If you wish to become a NanoUser, visit the website www.uwo.ca/fab where you'll find forms and instructions.
- To discuss your processing, material and project requirements contact Rick Glew, the Laboratory Manager.

# Toward Electrochemistry in the NanoScale

By Zhifeng Ding
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All natural materials and systems such as live cells establish their foundation at the nanometer-length (nm) scale. We found that when human-made materials are intermediate in extent between isolated atoms and bulk materials, in the range of 1 to 100 nm, the objects often display physical attributes substantially different from those displayed by either atoms or bulk materials. It is therefore challenging for us to fully understand and then to tailor the fundamental properties, phenomena, and processes exactly at the scale where the basic properties are determined. Progress is being made in establishing nanoscale tools - such as the scanning tunneling microscope (STM), the atomic force microscope (AFM) and near-field scanning optical microscopy (NSOM) -for the observation, characterization and analysis of nanostructures. The goals in our Laboratory of Electrochemistry, Spectroscopy and Microscopy (http://publish.uwo.ca/%7Ezfding/) are to develop and apply these improved and integrated tools to investigate single live cells and semiconductor nanostructures and bring insights into their relationships between structure and property and or function.

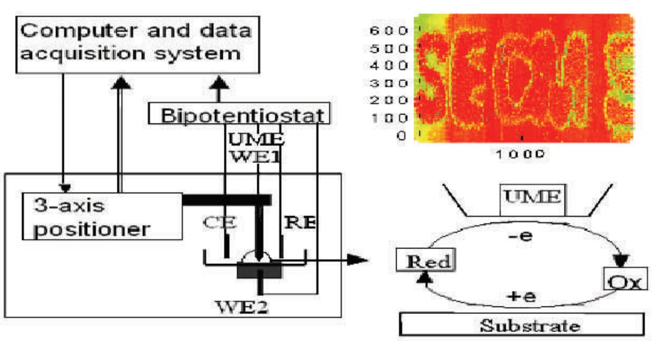


Fig. 1

Our research lab has recently built a Scanning Electrochemical Microscope (SECM) combining electrochemistry with AFM and NSOM. In fact, SECM measures the rate of faradic reactions at an ultramicroelectrode (tip) during its movement in a solution above a substrate (Fig. 1). As measured by the electrode current, the electrochemical reaction rate of the species contained in the solution gap between the tip and the substrate is a function of the gap spacing and the reactivity nature of the substrate. SECM is useful in a wide range of applications, including fast heterogeneous kinetics, imaging of biological molecules, characterization and fabrication of interdigitated arrays. For instance, Fig. 1 shows SECM image of letters “SECM” printed in bold font Courier New and font size 2 on a transparency. From the electrochemical current, the height of the letters was measured as 1 mm. Of particular interest is the use of SECM to perform “chemical images” observing differences in reaction rates at different locations. Fig. 2 illustrates SECM images of two COS 7 live cells. Information about the cell metabolism is anticipated.

The same kind of live cells were labeled with a fluorescent molecule and were then imaged on the Leica fluorescence microscope in the Nanofab (Fig. 3). While the fluorescence image gave the intracellular structure information, SECM image supplied rich information on extracellular chemical reactions. Both techniques are complementary.

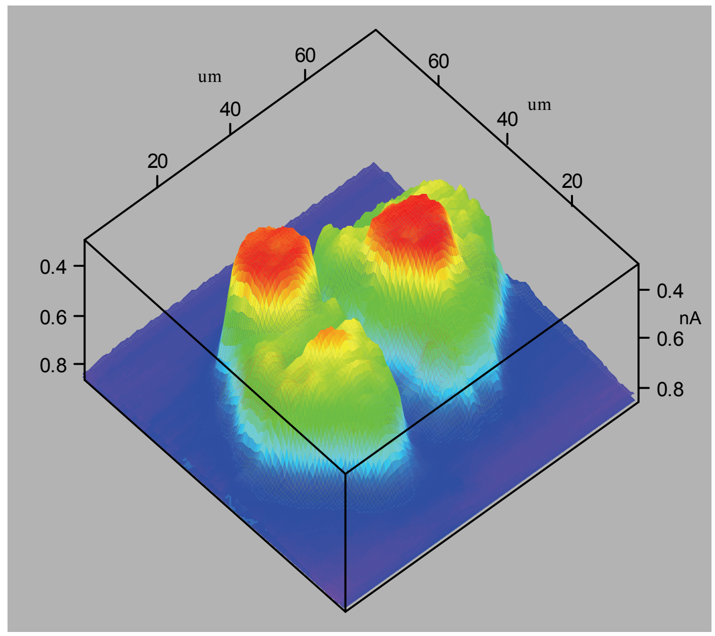


Fig. 2

The SECM electrode is insulated in glass to expose only the disk shape at the end of the electrode. The electrode is normally several microns in diameter, which limits the resolution to the same scale. Results obtained so far have not tested the theoretical limits. We are using Focus Ion Beam (FIB) in the Nanofab in order to push this limit to 50-100 nm and improve the resolution. This nanofabrication allows the probe to approach the substrate more closely and therefore enhance the sensitivity and the resolution. SECM with this kind of nanoelectrodes will be used to map out the concentration profiles of important chemical substances such as oxygen, hydrogen peroxide, ascorbic acid, uric acid, dopamine, noradrenaline, menadion etc, in the vicinity of the live cells. We have been successful in making Pt nanoelectrodes embedded in glass as small as 15 nm in diameter using a micropipette laser puller. The challenge was how to reduce the diameter of shield glass outside the electrode and prevent the glass end touching the sample as the probe approaches to a cell during SECM experiments. This was realized by fine milling using FIB facility In the Nanofab. Fig.4 demonstrates a voltammogram of a 30 nm dimeter electrode in a solution (Fig. 4A) and an in-situ SEM picture (Fig. 4B) when the electrode was machined. A steady-state current as low as 0.8 pA was measured. The preliminary results are very promising and inspiring for the realm of electrochemistry in nanoscale.

On the other hand, in collaboration with Dr. Xueliang Sun at Western engineering, we were able to trim down carbon nanotubes (Fig. 5A) to smaller nanostructures (Fig. 5B), using electrochemistry. The scanning electron microscope in the Nanofab has been used to monitor the processes.

Based on our work in the last two years, we plan to prepare monodispersed CdSe nanocrystals (NCs) capped with proper ligands so that the NCs can be transfected into live cells. The long-term stability and brightness of nanostructures make NCs ideal candidates for live animal targeting and imaging. However, little research has been done on the toxicity of manufactured nanoparticles and nanotubes. Cytotoxicity and the potential interference of labeling with cellular processes are primary issues in any live-cell or animal experiment. We will first use confocal microscopy (reflection, transmission and fluorescence) to see the morphology changes in the cells after the addition of NCs. We will then perform AFM, NSOM as well as SECM to monitor the cell topography, cell respiration of oxygen etc, with higher resolution to determine if NCs play a role.

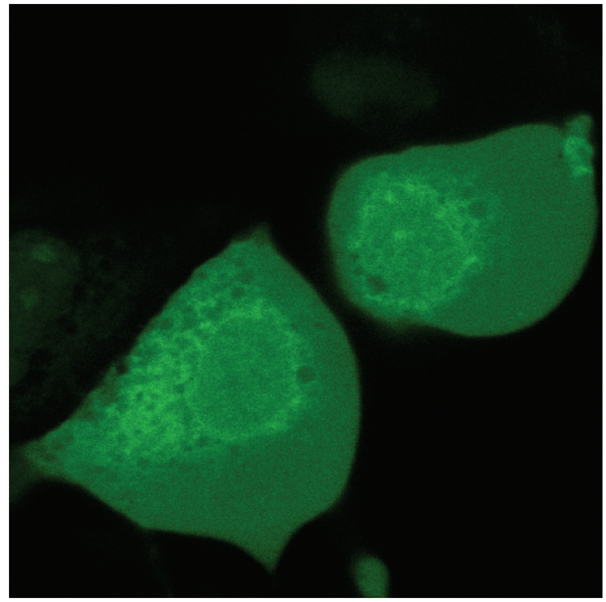

Fig.3

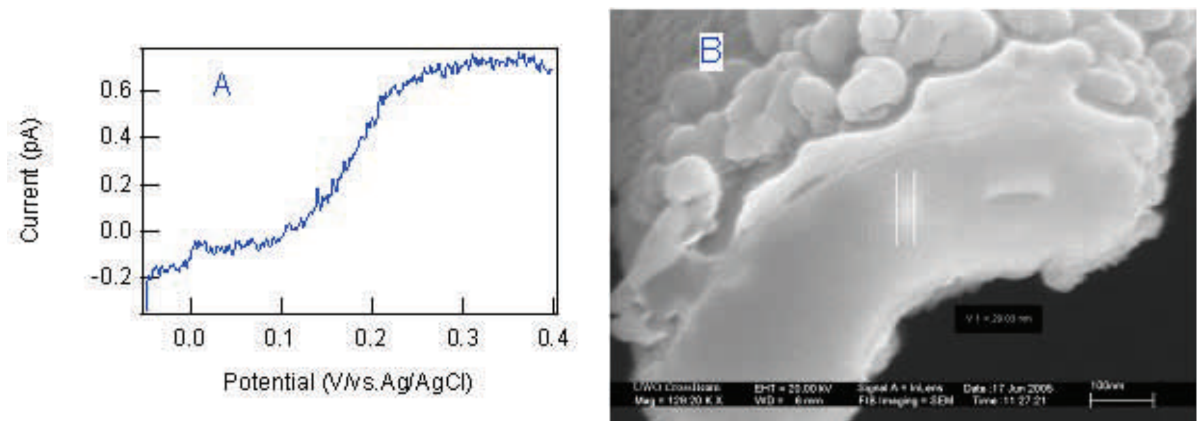


Fig. 4

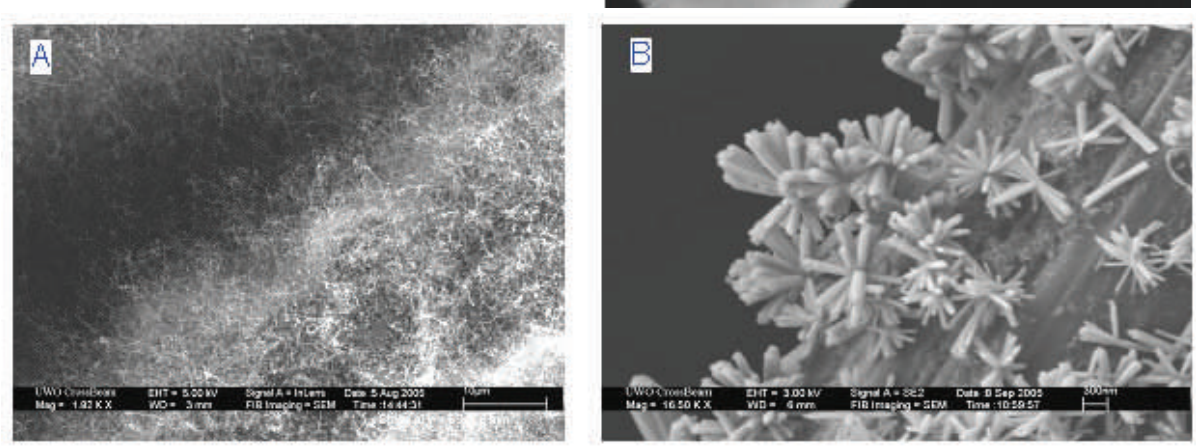


Fig. 5

*We appreciate the financial support for this research from Ontario Photonics Consortium, the Canadian Institute for Photonic Innovations, the Natural Science and Engineering Research Council of Canada, Canada Foundation for Innovation, Ontario Innovation Trust, the Premier's Research Excellence Award and the University of Western Ontario. The Laboratory of Electrochemistry, Spectroscopy and Microscopy is part of WINS and CCP at Western. The research team consists of two research scientists; Dr. Fengping Wang and Dr. Yingzhi Sun, two postdoctoral fellows; Dr. Shah Nawaz Lanjwani and Dr. Piotr Diakowski, three graduate students; Renkang Zhu, Jigang Zhou and Xiaocui Zhao and two undergraduate students; Catherine Nowierski and Nahla Mohamed. Thanks are owed to Dr. Rob Lipson, Dr. Nils Petersen, Dr. Maxim Anikovskiy, Dr. Peter Norton, Dr. David Shoesmith, Dr. Todd Simpson and Dr. Mark Workentin. Technical assistance from John Vanstone, John Aukema, Sherrie McPhee, Mary Lou Hart and Marty Scheiring is also gratefully acknowledged.*

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# Fabrication of 2D Planar Photonic Crystal Slab Waveguides for Optimized Coupling & Sensor Applications

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Photonic crystals (PCs) are periodic structures with alternating high and low refractive indices and periodicity on the order of the wavelength of light, which show interesting characteristics due to the existence of photonic bandgap. Manipulating and guiding light on planar photonic circuits with very small foot-print area is one of the main applications in which 2D PC waveguides can play an important role. Even though PCs offer exciting possibility to guide light in two (and three dimensions), the practical use of PC waveguides is limited due to the poor coupling efficiency between the PC waveguides and other optical components such as conventional index guided waveguides. Coupling poses a challenge because PC waveguides exhibit a significantly different mode profile and propagation mechanism compared to traditional waveguides that use index confinement. In order to successfully implement planar PC waveguides in practical applications such as sensors, it is essential to accurately analyze and improve the coupling mechanism and transmission in these waveguides.

Nanouser Surabhi Mittal (M.E.Sc. student in Electrical and Computer Engineering, UWO supervised by Prof. J. Sabarinathan) has been researching better 2D PC waveguide designs using commercial FDTD and photonic bandgap solvers to optimize the coupling and transmission through the waveguides. The calculations involve 3D FDTD simulations which allow us to factor in vertical losses (as opposed to 2D simulations) as shown in Figure 1a. A maximum transmission of 78% has been obtained for this design including any vertical losses and coupling losses. With these designs, Surabhi Mittal and Dr. Todd Simpson in the Nanofab lab have been able to successfully fabricate SOI photonic crystal slab waveguides integrated with conventional slab waveguides as shown in Figure 1b.

The fabrication process involves patterning an SOI wafer with 0.3um Silicon epilayer and 1um oxide, coated with PMMA, using Electron beam lithography. On development the E-beam pattern is transferred to the PMMA layer. The PMMA pattered layer is then used as an etch mask for reactive ion etching. Using the Alcatel 601E Deep RIE tool, the pattern is then etched into the Silicon epi-layer. Figure 2 shows the top view profile and angled view cross section of the fabricated waveguide structure that has been recently fabricated in the UWO Nanofab. The Focused Ion Beam system available in the lab also allows us to characterize the etch process by providing the ability to slice through the cross section of the device providing detailed images of the air-hole profile. The vertically of the air-hole will affect the actual transmission through the waveguides and the Alcatel Deep RIE process provides almost vertical sidewalls for the PC air-holes.

Future work involves fabricating air-bridge waveguide structures which will increase the vertical confinement of light as well as allow us to fabricate the waveguides for mechanical sensor applications which are currently being designed. For this, the underlying oxide has to be removed by buffered HF to create the air-bridge. A critical point dryer which is being purchased by the Nanofab and will be installed shortly will help in the stability of these air-bridge devices during fabrication. These waveguides will then be characterized using optical waveguide measurement setup in the near future to compare to the designed values.

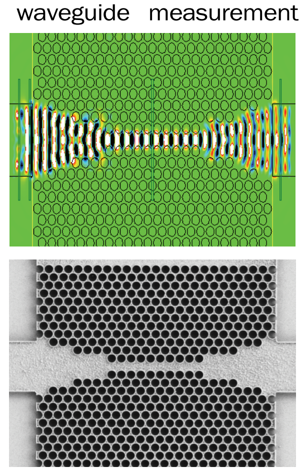

Figure 1: (top) 3D FDTD simulation of 2D PC slab waveguide design with 78% transmission (bottom) Top view SEM micrograph of fabricated PC waveguide.

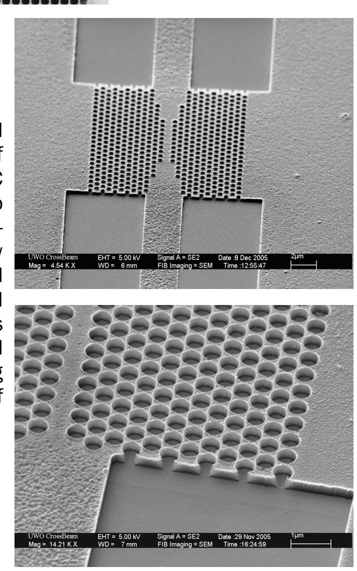

Figure 2: SEM micrographs of fabricated 2D PC planar slab waveguides showing (top) Top View with integrated conventional waveguides (bottom) Angled Section showing vertical profile of structure.