NanoWestern

Western Science

Issue 1 2013

## Microbial Acceleration of Carbon Mineralization in Mine Waste

**Jenine McCutcheon** (M.Sc. Geology Candidate, Department of Earth Sciences, Western University, London, ON, Canada)
Supervisor: Dr. Gordon Southam (Department of Earth Sciences, University of Queensland, Brisbane, QL, Australia)
Collaborators: Dr. Ian Power, Anna Harrison, and Dr. Greg Dipple (Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, BC, Canada)

Carbonate minerals offer a stable, long term method of carbon storage, and can be generated through a range of active and passive processes. This study examines an active biogeochemical process of storing carbon in magnesium carbonate minerals in ultramafic mine tailings. Magnesium released from mine waste rock through leaching can react with atmospheric carbon dioxide ($CO_2$) to produce carbonate minerals including magnesite [$MgCO_3$] and hydromagnesite [$Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$]. These reactions occur slowly in abiotic conditions, but have the potential for enhanced carbon storage rates if accelerated by phototrophic microorganisms. A naturally occurring microbial community dominated by cyanobacteria was used in a model 'wetland' to characterize the aqueous geochemical environment in which biogenic magnesium carbonate formation occurs. The microbes induce the alkaline (pH>9.2) water chemistry conditions required to generate mineral supersaturation, and provide extracellular structures which act as nucleation sites for mineral precipitation. Dissolved oxygen, pH, dissolved inorganic carbon, and major ion concentrations were monitored in the wetland. Carbonate formation was identified using X-ray diffraction. Scanning electron microscopy and energy dispersive spectroscopy were used to characterize the micron-scale microbe-mineral relationships taking place in the system (Figure A and B). Mineralization occurred as both coatings on cells and as individual crystals. The aqueous geochemistry data was used to quantify the rate of carbon storage that could be achieved at a field-scale carbonation plant at a mine site. If this process can be optimized, it has potential as a strategy for mining operations to reduce their net carbon emissions.

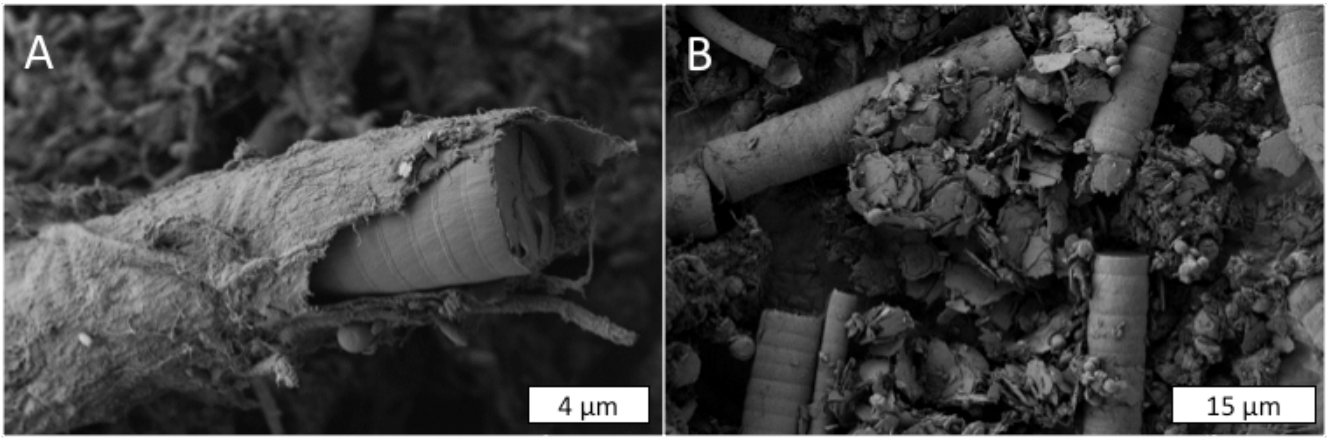
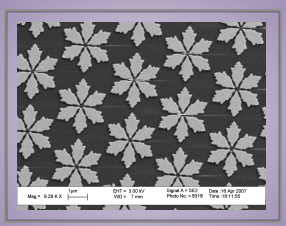
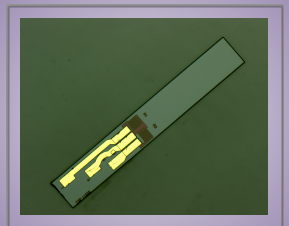



Figure: A) A cyanobacteria filament encrusted in fine grained magnesium carbonate. B) Cyanobacteria filaments surrounded by platy hydromagnesite crystals.







# Vapor-Liquid-Solid Growth of Si Wires on Si

**Sergey Dedyulin** (Supervisor: Lyudmila Goncharova) *Western University, Physics and Astronomy Department, London, ON, Canada*

The vapor-liquid-solid (VLS) growth, first discovered in the 1960s, is the most investigated process for Si wire synthesis. The name vapor-liquid-solid reflects the pathway of Si. First, Si comes from the vapor phase to the substrate covered with liquid silicon-gold nanoparticles that act as a preferred sink for arriving silicon atoms. Then silicon diffuses through the liquid "droplet", and when its concentration exceeds saturation point, the excess Si precipitates as a solid wire at the gold/substrate interface.

In this project, we have been using molecular beam epitaxy (MBE) to grow silicon wires on Si (001) and Si (111) substrates. Scanning electron microscopy (SEM) images obtained at the Western Nanofabrication Facility (LEO 1540XB FIB/SEM) for silicon grown on Si(001) substrate are very intriguing. Si wires are growing epitaxially along in-plane Si <110> crystallographic directions (Fig. 1a), the liquid-solid interface of the growing wire is oriented along Si <111> direction to minimize the surface energy contribution to the total energy (Fig. 1b).

The results obtained in our work suggest that commonly accepted VLS growth model still needs to be refined. In particular, our results indicate that surface diffusion of Si ad-atoms on the substrate plays a significant role in the wire growth and has to be incorporated in the model.

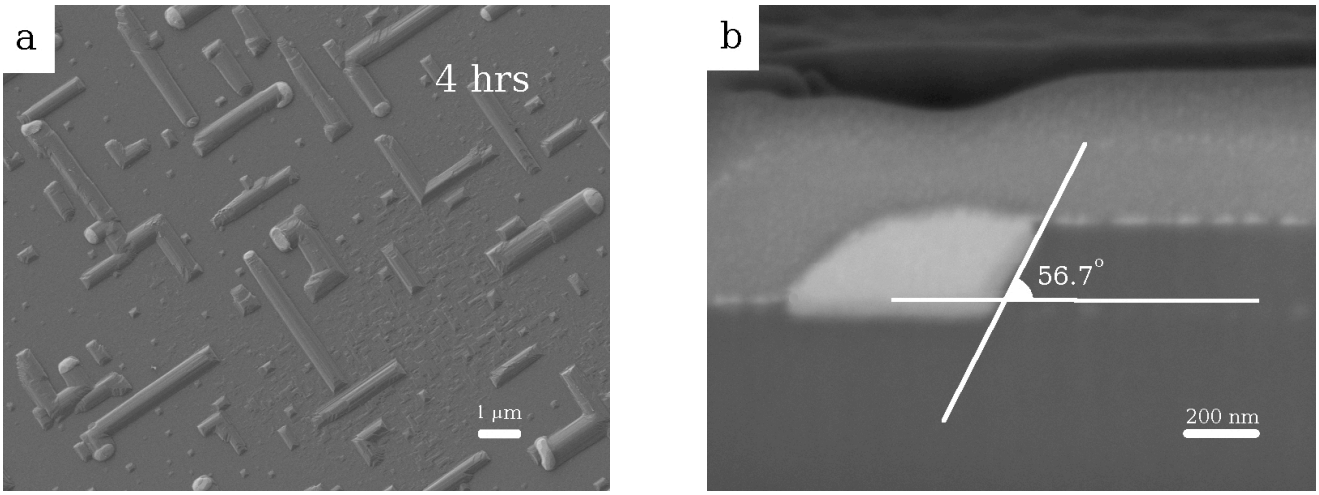



***Figure 1.*** *a) SEM planar views of Si wires obtained on Si(100) substrate at T = 650 °C using 1nm Au film annealed at 600 °C for 30 min. The Si deposition time is indicated on the figure. b) High resolution SEM image of the Si wire cross-section performed with focused ion beam along the growth direction. The theoretical value for the liquid-solid interface oriented along Si (111) direction is 54.7°*

# Western Nanofabrication Facility Opens New Fluidics and Sensors Laboratory

Dear Nanofabrication Users,

I am delighted to announce the opening of additional laboratory space at the Western Nanofabrication Facility. This space offers new capabilities for your nanofabrication projects, device conception as well as surface preparation. The Fluidics and Sensors Laboratory offers a variety of solutions for those who want to test new materials that are not necessarily compatible with our class 100 level clean room facility. The new laboratory will include a spin-coater along with a vacuum oven that can be utilized for the preparation, spinning and curing of polydimethylsiloxane (PDMS) materials. These materials are generally used for micro and nano fluidic applications, however, other materials can also be used under our guidance and supervision. The addition of an 8-foot laminar flow bench provides ideal conditions for sample preparation. A UV-Ozone cleaner is also available for cleaning surfaces and interfaces. This versatile tool can be used for improving the binding of PDMS stamps or to simply regenerate AFM tips that have been contaminated with organic materials.

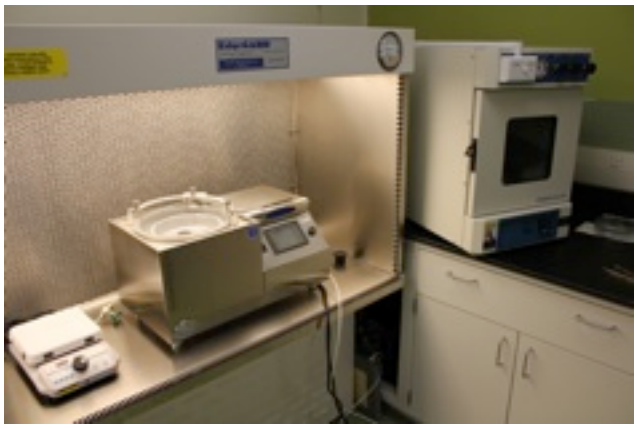
Within the cleanroom, we have acquired an electroplating system that is capable of elecrtodepositing pristine thin copper films on a 4" wafer. Another addition to the cleanroom, is an optical microscope equipped with a Zeiss CCD colour camera with powerful image analysis software to examine structures and surfaces of various substrates. With thanks to an NSERC-RTI grant, we will soon receive a new profilometer, with the capability of providing 3D mapping of your surfaces and structures with high resolution over a 6" diameter.

All of our improvements were made possible with your constant support over the years. This support has allowed us not only to maintain our instruments in the best conditions, but to enable new solutions for exciting and stimulating fabrication projects. Please do not hesitate to contact us if you are interested in training on any of our new equipment or want to explore the new possibilities offered.

We are always eager to discuss new projects or your particular need for instrumentation. Your feedback is always appreciated.

Sincerely yours,

François Lagugné-Labarthet



Laminar Flow Bench with Spinner and Vacuum Oven

ECSI FIBRotools-Model IKO Classic Electroplating System

SAMCO UV-1 UV-Ozone Cleaner

# High-Performance Nanohole Array Sensors Fabricated by Template Transfer

**Peipei Jia**, Ph.D. candidate, supervisor: Prof. Jun Yang
Biomedical Engineering Program,
Faculty of Engineering,
Western University
London, ON, Canada

Nanoplasmonics has been developing fast because of recent nanofabrication advancement. Traditional methods include focused ion beam (FIB) milling, electron beam lithography (EBL) and deep UV lithography. They are either time-consuming or require complex and expensive systems. Template approaches involving soft lithography, nanoimprint lithography and so on, can make nano-structures in a more efficient and cost-effective way due to the use of templates with relief patterns.

Solid objects of different size, shape and composition have been transferred to various substrates by controlling adhesion between different interfaces. Here we demonstrate a template transfer method for fabrication of nanohole array sensors using a high resolution template formed by EBL. The Si template of the nanohole array was patterned using EBL followed by deep ion etching. An e-beam lithography system (LEO 1530) was used to pattern square arrays of circular nanoholes with 200 nm diameter and 600 nm pitch on the PMMA resist spin-coated on a Si wafer. The features were then transferred to the Si substrate using a deep reactive ion etching machine (Alcatel 601E). After removing the PMMA mask in piranha solution, the template was thoroughly rinsed with ultrapure water and dried with $N_2$. A 100 nm thick Au film was then deposited onto it without adhesion layer. Gold nanohole arrays formed on the top surface of the template were then transferred to PDMS (Sylgard 184, Dow Corning) substrates by means of conformal contact to and removal from the template.

A major merit is that the template can be repeatedly used, therefore reducing the cost and time consumption of nanofabrication. In addition, this process does not require any additional resist processing, etching, or liftoff. This advantage is of great benefit, especially in biological applications, compared to conventional nanofabrication techniques based on chemistry processing. Sensors fabricated by the template transfer approach are featured with high sensitivity 522 nm/RIU. Although our current work is focused on subwavelength holes in continuous Au films, the template transfer technique is equally applicable to fabrication of other nanoplasmonic architectures such as nanoparticles and nanorings.

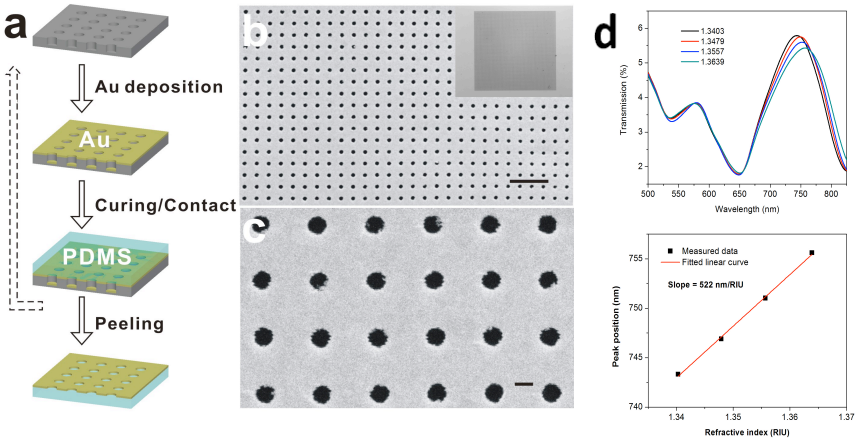



Figure (a) Schematic for transfer of Au nanohole arrays from the Si template to PDMS substrates. (b,c) SEM and optical images of the nanohole array transferred to PDMS. (d) Transmission spectra and sensitivity of the fabricated nanohole array sensor.