



University
of Victoria

Graduate Studies

Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

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MSc (University of Barcelona, 2010)
BSc (Sharif University of Technology, 2008)

“Electrochemical Control for Nanoelectromechanical Device Production”

Department of Mechanical Engineering

Monday April 13, 2015
10:00 A.M.
Engineering and Computer Science Building
468

Supervisory Committee:

Dr. Rustom Bhiladvala, Department of Mechanical Engineering, University of Victoria (Supervisor)
Dr. Rodney Herring, Department of Mechanical Engineering, UVic (Member)
Dr. David Harrington, Department of Chemistry, UVic (Outside Member)

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Abstract

Electrochemical synthesis of straight, separable, cylindrical nanowires for use as cantilevered mechanical resonators is the main focus of this dissertation. These types of nanowires are significant for many applications, but particularly so for chip-based sensor arrays made for ultrasensitive mass detection. Directed-assembly of nanowire-based devices has enabled the development of large-area fabrication of sensor devices with new functions such as cancer detection at early stage. Chemically stable noble metals gold and rhodium are interesting materials for making nanowire resonators. Gold makes a well-known, stable and strong bond with the thiol group, which enables a range of surface functionalization chemistries. Rhodium nanowires have desirable mechanical properties for resonant mass sensing as they can retain high quality factor (Q-factor) from high vacuum to near atmospheric pressures. As a versatile and inexpensive tool, electrodeposition provides the most suitable synthesis path for gold and rhodium resonator-grade nanowires in nanoporous templates. In this work, the structural characteristics of nanoporous membranes anodized aluminium oxide and track-etched polycarbonate was explored for use as electrodeposition template. New chemistries for making gold and rhodium nanowires are introduced. Although gold cyanide-based solutions work well for the electrochemical synthesis of separable nanowires. The toxicity of cyanide solutions makes noncyanide alternatives desirable. However, electrochemical synthesis of gold nanowires in templates from non-cyanide solutions suffers from serious drawbacks. These include growth-arresting pellet formation, poor length control and defects such as inclusions. In this dissertation, the first electrochemical synthesis of straight, cylindrical, separable gold nanowires from a sulfite-based solution is presented. This work demonstrates a scheme that suppresses electroless particle growth in the weakly-complexed gold in solution by proper use of additives. The electrochemical nucleation and growth of rhodium nanowires from a sulphatebased solution is also discussed. The effect of pH on the length uniformity and the effect of EDTA and polyethylenimine as additives on the development of the wire nanostructure was studied. This study has shown that the control over hydrogen coreduction on the electrode surface and its bubble transport rate allowed for tailoring the nanostructure of the grown nanowires. The control over electrochemical nucleation and growth of noble metal films for nanowire clamping has also been investigated in this work for making reliable defect free clamps for nanoresonator measurements.