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 Shiraz, 2008)
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"Controlling Field-Directed Assembly of Nanowires: Towards Nanomanufacturing for Biosensors and Transparent Electrodes"

Department of Mechanical Engineering

Friday, January 15, 2016
10:00 A.M.
Engineering Office Wing
Room 106

Supervisory Committee:
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Dr. Sandra Hundza, School or Exercise, Science, Physical & Health Education, UVic

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Abstract

The remarkable mechanical, optical, thermal and electronic properties of one-dimensional structures such as nanotubes or nanowires (NWs) have enabled the construction of devices of extraordinary capability. Nanotube resonators, for example, were recently used to demonstrate response to single-proton mass. However, such landmark demonstrations are limited to a small number of devices in research laboratories, since the cost of making them by traditional top-down methods is prohibitive, being proportional to the number of devices. This thesis makes contributions towards a new family of methods, field-directed assembly, to enable reliable and cost-effective fabrication of large numbers of nanodevices. This provides a path towards nanomanufacturing, to help bring the extraordinary capabilities of nanodevices into widespread commercial and scientific use.

Field-directed assembly is a cost-effective technique in which NWs are first synthesized, suspended in a fluid medium and then directed by fields, to predetermined positions between electrodes patterned on a substrate. When the gap size between electrode pairs is comparable to the length of NWs, a single NW can be positioned between each pair of electrodes. This technique enables individually addressable NW devices. This is essential in device applications of mass sensing, but cannot be provided through existing cost-effective techniques such as self-assembly of NWs.

Field-directed assembly has been used for positioning single NWs and fabricating cantilevered nanosensors. However, finding the best parameter values enabling high yield of devices on a substrate has so far been possible only through time consuming and costly trial-and-error experimental efforts. In this work, a framework is introduced that enables choosing parameter values through systematic steps to increase the device yield. Different physical parameters and forces that disrupt NW assembly are discussed here and guidelines to reduce the disruptors are provided. Understanding of the competition between forces serving as disruptors and directors enabled the definition and use of a single dimensionless parameter, the yield index, which provides a rational guide to the selection of parameter values, replacing costly trial-and-error efforts in experimental work. Biosensors enabling molecular diagnosis for early detection of disease and response to treatment are one of the promising applications.

In addition to single NW positioning, in this work, we demonstrate that field directed assembly can be used to create multiple long NW chains between electrodes when the electrode gap size is much larger than length of a single NW. In this method, we have shown how NW connectivity and configuration of the NW chains can be controlled through dipole-dipole interaction between NWs. This level of control cannot be achieved by using other low-cost techniques such as drop casting or spray of NWs. With such ordered chains made on a low-cost transparent substrate, the resulting transparent conductive substrate can be used in optoelectronic devices, such as solar cells and displays, where a low cost fabrication technique is required to create ordered NW arrays with end-to-end registry.

In this work, for the first time, field directed NW chaining is examined as a versatile and inexpensive fabrication method for transparent conductive substrates. Since no corrosive chemical and elevated temperature are involved in electric field assisted NW chaining, this method shows potential for creating NW network on rigid as well as polymeric substrates as demonstrated here. Chained NWs on a flexible substrate can combine electrical or thermal conductivity, optical transparency and flexibility which open new avenues for fabricating light-weight and flexible transparent electrodes for foldable displays, organic solar cells and several other devices.