University of Victoria | Graduate Studies

Notice of the Final Oral Examination for the Degree of Master of Applied Science

of

MANYAN XU

BEng (Zhejiang University, 2016)

“Field-Directed Nanowire Chaining Enabling Transparent Electrodes”

Department of Mechanical Engineering

Thursday, December 13, 2018
11:00am
Engineering Office Wing
Room 230

Supervisory Committee:
Dr. Rustom Bhiladvala, Department of Mechanical Engineering, University of Victoria (Supervisor)
Dr. Mohsen Akbari, Department of Mechanical Engineering, UVic (Member)

External Examiner:
Dr. Tao Lu, Department of Electrical and Computer Engineering, UVic

Chair of Oral Examination:
Dr. Peter Wan, Department of Chemistry, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

Transparent electrodes (TEs) require materials that have both transparency and electrical conductivity, a combination not usually found in nature. They are in increasing demand for use in solar cells, touch screens, displays, transparent heating films and several other devices. Most TEs used today are made of indium tin oxide (ITO). However, it has several disadvantages. Many ITO alternatives are being pursued, among which metallic NW networks on transparent substrates such as glass or polmer, have received much attention. This thesis demonstrates ordered silver NW networks on polyimide, fabricated by the field-directed chaining technique. We achieved a sheet resistance of 27 Ω/sq and 95.4% transparency at 550nm, with a Figure of Merit (FOM) $0.023\Omega^{-1}$, which is higher than the FOM of commercial ITO, $0.005\Omega^{-1}$. We have demonstrated that ordered NW networks, directed by AC electric fields, are easy to fabricate over a large area and at low cost, on rigid and flexible substrates.

The AC electric field changes with different experiment setup. In this work, the effect of polymer thickness, frequency, and gap size between electrodes are explored by COMSOL simulation and experiment. By choosing the appropriate frequency and gap size, ordered NW networks were successfully created on a 23μm PET sheet. Fluid motion is one of the disruptors during NW chaining. We demonstrate control of this disruptor by the use of sandwiched channels for the NW suspension.

Post-fabrication treatments are important and necessary for improving the connectivity and conductivity of Ag NW networks. In this work, we explore Joule heating and show its potential to improve the conductivity over other post-treatment. However, Joule heating can also cause failures of NW networks.

Ordered NW networks present better optical-electrical properties than random NW networks. Post-fabrication treatment can improve the properties, but there is a limit. In this work, a mathematical model is built for optical-electrical properties of perfectly ordered NW networks, which sets the upper bound of performance for transparent electrodes made of NW networks. A linear relationship is found between the transmittance and inverse sheet resistance. The model is then modified with factors to account for departure from the ideal.