AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
CAIRO-EGYPT
Electronics and Communications Engineering Department

Nanowire Laser

A thesis
Submitted in partial fulfillment for the requirements of the degree of
Master of Science in Electrical Engineering

by

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STATEMENT

This thesis is submitted to Ain Shams University in partial fulfillment of the degree of Master of Science in Electrical Engineering.

The work included in this thesis was carried out by the author in the department of Electronics and Communications Engineering, Ain Shams University.

No part of this thesis has been submitted for a degree or a qualification at any other university or institute.

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To my parents

for their unconditional love, constant support,

and unyielding encouragement.

To Richard Feynman

for letting me take pleasure in nature's strangeness.

To Eugene Hecht

for letting me delightfully appreciate light's beauty.

Abstract

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Keywords: Electroluminescence; CdS/Si Heterostructure; Nanowire Laser; Optoelectronic Simulation.

A coupled and self-consistent optoelectronic simulation for studying electrically pumped CdS nanowire (NW) laser is presented. A specific electrically pumped Hybrid Nanowire Laser structure (EP-Hybrid-NWL) which was demonstrated experimentally by Prof. Lieber research group at Harvard University (i.e. published by DUAN, X. et al in Nature, v. 421, p. 241-245, 2003) is chosen for simulation. The simulation is based on semiclassical electronic and photonic principles and was implemented using ATLAS part of SILVACO TCAD® and MATLAB® software packages.

The simulation results are comparable to the experimental data given by the Prof. Lieber research group; the device I-V relation showing current rectification with a forward-bias turn-on voltage of 2–5 V, the emission intensity versus injection current relation showing the onset of lasing, and the electroluminescence spectrum for the device along with its peak emission wavelength.

This thesis comprises six chapters which have the chief objective of analyzing, modeling, and simulating electrical and optical processes within the EP-Hybrid-NWL device under equilibrium and forward-bias; both under and above the threshold current necessary for lasing action. Firstly, Chapter one discusses the topic of nanowire lasers beginning with a panoramic view of the field of Nanophotonics and ending with an explanation of semiconductor lasers' operation. A basic description of the device structure to be studied in the thesis is given in Chapter two. Chapter three examines different device parameters under thermal equilibrium conditions. Chapters four and five investigate primarily the I-V, the emission intensity versus injection current, and the electroluminescence spectrum characteristics for the device, respectively. In the end, Chapter six presents a conclusion for the thesis topic, summarizing important observations and suggesting future directions that hopefully would improve our understanding of nanowire lasers. Finally, for the sake of completeness, an appendix is supplemented to this thesis which points out different relevant parameters and their cited values for the materials used in the EP-Hybrid-NWL device.

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In addition, I greatly appreciate the help of Professor Dr. Charles M. Lieber from Harvard University, who –through electronic mail correspondence– elaborated on the origin of an apparently n-type doping for the CdS nanowire, clarifying that it is mainly due to the non-stoichiometry of the nanowire compound material.

I am much obliged to Dr. Ivan Pesic, for without his generous SILVACO TCAD license offer; I would not have been able to simulate the majority of the optoelectronic processes taking place inside the CdS nanowire. Furthermore, thanks are due to several sales and technical personnel at SILVACO Europe, especially Mr. Chris Marnoch, Mr. Andrew (Boris) Samalionis, and Dr. Ahmed Nejim, for their constant assistance and support during my work using the software.

Finally, I would like to thank my colleagues and friends for their consideration and support. To each one of them, I extend my genuine appreciation.

Hany Mohsen AbdelRahman AbuShall

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