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EDUCATION

Ph.D., Expected 05/2006, Electrical Engineering

University of Southern California (USC), Los Angeles, California

Dissertation Advisor: Asst. Prof. Chongwu Zhou

Dissertation: "Synthesis, Devices and Applications of Carbon Nanotubes"

M. S., 05/2004, Electrical Engineering

University of Southern California (USC), Los Angeles, California

M. S., 07/2000, Physics

Tsinghua University, Beijing, China

Thesis Advisor: Prof. Bing-Lin Gu

Thesis: "Electron's Transport Through Quantum Dot Under Dynamic External Field"

B. E., 07/1997, Electrical Engineering

Tsinghua University, Beijing, China

RESEARCH EXPERIENCE

NanoLab, Dept. of Electrical Engineering – Electrophysics, University of Southern California,

Research Assistant, 01/2001 ~ present

Carbon nanotubes

Synthesis:

- Discovered oriented CNT arrays on crystalline insulating surface, due to the tube/surface interactions with controllable density. It paves a way toward large scaled integration of nanotubes-on-insulator (NOI) devices as a mimic to SOI, which is adopted by semiconductor industry.
- Investigate upon diameter dependence of the alignment of the CNT arrays on crystalline surfaces.
- CVD growth of ultralong CNTs up to centimeter long, which provides an ideal template for the studies of CNTs' physical properties and also the opportunities of intratube integrated circuits.
- CNT dense networks and thin films, which has applications in transparent electrodes and flexible electronic devices.

Simulations:

- van der Waals interactions between carbon nanotubes and crystalline surfaces

Device studies:

- Demonstrated that the performance CNT-FET devices can be tailored by partially doping the CNT devices. The optimized performance was achieved without complications of fabricating split gates.
- Demonstrated different types of high performance NOI devices, including NOI transistors with top gate, and polymer electrolyte gate. The aligned nanotubes

arrays were also transferred to flexible substrate and the devices based on it were tested.

- High transconductance devices and power transistors based on surface aligned nanotubes arrays are under investigation.
- High performance nanotube devices on insulator working in RF regime are under investigation.

Applications:

- Inverter based on individual CNTs was achieved, and we are one of the first who demonstrated integrated circuits based on CNTs.
- CNT/OLED optical devices were demonstrated with CNTs as transparent electrodes.
- CNT-FETs were demonstrated to be used as biosensors to low-density lipoprotein via chemical gating effect.
- CNT/polymer composite devices that can be used as NO₂/NH₃/alcohol/pH value/biomolecule sensors.

Nanowires

Synthesis:

- Led/participated the efforts of synthesizing various nanowires including CdO, In₂O₃, ZnO, Ge, GaN, SnO₂, MgO/transition metal oxide core/shell structures via CVD and/or laser ablation methods, which provide the building blocks for nano-scaled devices and circuits, meanwhile also provide templates to study the novel physical properties of low-dimensional systems.

Applications:

- Field effect transistors, chemical/bio sensors, photodetectors were fabricated based on those nanowires.

Molecule electronics

- NW/molecule/NW heterostructures were fabricated. NDR was found on certain molecules.
- Break junctions were fabricated and used to study the transport properties of organic molecules.
- Molecule gating multilevel memory was achieved by self-assembly attaching organic molecules onto nanowires.

The Photonic Center, USC, Lab member 01/2001 ~ present

Conduct micro/nano-fabrications and characterizations of electronic devices

Stanford Nanofabrication Facilities, Stanford University, Lab member 05/2001 ~ present

Conduct micro/nano-fabrications and characterizations of electronic devices

Condensed Matter Theory Group and Material Design Lab, Department of Physics, Tsinghua University, Research Assistant 09/1997 ~ 06/2000

- Numeric simulations on electron's transport through of low dimensional quantum system under dynamic external field
- Numeric simulations on the electronic structure of high-pressure alumina polymorphs

Lab Coordinator and Network Administrator, Department of Physics & Center for Advanced Studies, Tsinghua University, 1998~2000

Plan and setup the network system and computational environment. Administrate the network including the maintenance of the lab supplies, computers, hardware equipments, and softwares.

EXPERTISE

Micro/Nano Fabrications:

Photolithography: aligners and steppers

E-beam lithography: Hitachi, Raith, JEOL and home-made SEM converted systems, have converted a SEM into a EBEAM system

Dry etching: RIE, ECR and ICP

Metallization systems: Ebeam/thermal evaporator and Sputtering systems

Other fabrication systems/tools: LPCVD, PECVD, Oxidation/Annealing/doping, RTA, Wet bench processes, Wafer dicing and cutting, Ellipsometer, Surface profilometer, Spectrophotometer

Photo-Mask Design: have designed more than 30 masks.

Material Synthesis:

CVD systems for Carbon nanotubes and various nanowires, Laser ablation system for various nanowires and core-shell nanostructures

Material Analysis:

SEM, TEM, AFM, XRD, EDX, Absorption spectroscopy, Raman spectroscopy

Electrical Characterizations:

Wire bonding, HP/Agilent Semiconductor analyzer, Keithley instruments, Lock-in Amplifier, Network analyzer, Oscilloscopes, Cryogenic system for electrical and optical testing, Probe stations, etc

Selected Software Skills:

LabView, L-Edit, Magic, AutoCAD, C/C++, Igor, Origin, Cadence, SPICE

TEACHING EXPERIENCE

My work include preparing and delivering lectures in the lab sections, guiding students through experiment procedures, designing quizzes, grading lab reports, homework, leading discuss sections and holding weekly office hours. The classes include:

Solid State Physics (undergraduate), Dept. of Physics, Tsinghua University, 02/1999 ~ 07/1999

Linear Circuits (EE202L), Dept. of EE, USC, 08/2000 ~ 06/2001

Physical Electronics (EE338), Dept. of EE, USC, 08/2001 ~ 11/2001

Essentials of Electrical Engineering (EE326), Dept. of EE, USC, 01/2005 ~ 06/2005

PUBLICATIONS

32 Journal Articles, **1** Book chapter

Journal Articles:

[1] "Transparent Conducting Thin Films of Carbon Nanotubes and their Applications for Organic Light Emitting Diodes", D. Zhang, **X. Liu**, K. Ryu, J. Ly, M. E. Thompson and C. Zhou, in preparation.

- [2] "Investigations on interactions between Self-Aligned Carbon Nanotubes and Sapphire Substrates", **X. Liu**, K. Ryu, and C. Zhou, in preparation.
- [3] "Diameter Dependence of Carbon Nanotubes' self-alignment on a-plane Sapphire substrates", **X. Liu**, K. Ryu, S. Han, and C. Zhou, submitted.
- [4] "A Novel Nanotube-on-Insulator (NOI) Approach toward Nanotube Devices", **X. Liu**, S. Han, and C. Zhou, Nano Lett. **6**, 34 (2006).
- [5] "Determination of the Small Band Gap of Carbon Nanotubes Using the Ambipolar Random Telegraph Signal", F. Liu, M. Bao, K. L. Wang, **X. Liu**, C. Li, and C. Zhou, Nano Lett. **5**, 1333 (2005).
- [6] "Synthesis and Electronic Properties of Individual Carbon Nanotube / Polypyrrole Nanocables", **X. Liu**, J. Ly, S. Han, D. Zhang, A. Requicha, M. E. Thompson, C. Zhou, Adv. Mater. **17**, 2727 (2005).
- [7] "Template-Free Directional Growth of Single-Walled Carbon Nanotubes on a- and r-Plane Sapphire", S. Han, **X. Liu**, C. Zhou, J. Am. Chem. Soc. **127**, 5294 (2005).
- [8] "Band Engineering of Carbon Nanotube Field-Effect Transistors via Selected Area Chemical Gating", **X. Liu**, Z. Luo, S. Han, T. Tang, D. Zhang, and C. Zhou, Appl. Phys. Lett. **86**, 243501(2005).
- [9] "Giant random telegraph signals in the carbon nanotubes as a single defect probe", F. Liu, M. Bao, H. Kim, K. L. Wang, C. Li, **X. Liu**, and C. Zhou, Appl. Phys. Lett. **86**, 163102 (2005).
- [10] "Complementary Response of In₂O₃ Nanowires and Carbon Nanotubes to Low-Density Lipoprotein Chemical Gating", T. Tang, **X. Liu**, C. Li, B. Lei, D. Zhang, M. Rouhanizadeh, Tzung Hsiai and C. Zhou, Appl. Phys. Lett. **86**, 103903 (2005).
- [11] "Noise enhanced detection of subthreshold signals with carbon nanotubes", I. Lee, **X. Liu**, C. Zhou, B. Kosko, IEEE Transactions on Nanotechnology, accepted (2005).
- [12] "Detection of NO₂ down to ppb levels using individual and multiple In₂O₃ nanowire devices", D. Zhang, Z. Liu, C. Li, T. Tang, **X. Liu**, S. Han, B. Lei, C. Zhou, Nano Lett. **4**, 1919 (2004).
- [13] "Transition Metal Oxide Core-Shell Nanowires: Generic Synthesis and Transport Studies", S. Han, C. Li, Z. Liu, B. Lei, D. Zhang, W. Jin, **X. Liu**, T. Tang, and C. Zhou, Nano Lett. **4**, 1241 (2004).
- [14] "Photoconduction studies on GaN nanowire transistors under UV and polarized UV illumination", S. Han, W. Jin, D. Zhang, T. Tang, C. Li, **X. Liu**, Z. Liu, B. Lei and C. Zhou, Chemical Physics Letters **389**, 176 (2004).

- [15] "Multilevel memory based on molecular devices", C. Li, W. Fan, B. Lei, D. Zhang, S. Han, T. Tang, X. Liu, Z. Liu, S. Asano, M. Meyyapan, J. Han, and C. Zhou, Appl. Phys. Lett. 84, 1949 (2004).
- [16] "Synthesis and characterization of single-crystal indium nitride nanowires", T. Tang, S. Han, W. Jin, X. Liu, C. Li, D. Zhang, C. Zhou, B. Chen, J. Han, and M. Meyyapan, J. of Mater. Res. 19, 423 (2004).
- [17] "Synthesis, Electronic Properties and Applications of Indium Oxide Nanowires", C. Li, D. Zhang, S. Han, X. Liu, T. Tang, B. Lei, Z. Liu and C. Zhou, Annals of New York Academy of Sciences 1006, 104(2003).
- [18] "Nanosignal Processing: Stochastic Resonance in Carbon Nanotubes That Detect Subthreshold Signals", I. Y. Lee, X. Liu, B. Kosko, and C. Zhou, Nano Letters 3, 1683 (2003).
- [19] "Chemical Gating of In₂O₃ Nanowires by Organic and Bio Molecules", C. Li, B. Lei, D. Zhang, X. Liu, S. Han, T. Tang, M. Rouhanizadeh, T. Hsiai, and C. Zhou, Appl. Phys. Lett. 83, 4014 (2003).
- [20] "Surface Treatment and Doping Dependence of In₂O₃ Nanowires as Ammonia Sensors", C. Li, D. Zhang, S. Han, X. Liu, and C. Zhou, J. of Phys. Chem. B 107, 12451 (2003).
- [21] "Laser Ablation Synthesis and Electronic Transport Studies of Tin Oxide Nanowires", Z. Liu, D. Zhang, S. Han, C. Li, T. Tang, W. Jin, X. Liu, B. Lei, and C. Zhou, Advanced Materials 15, 1754 (2003).
- [22] "Polymer Thin-Film Transistors with High Dielectric Constant Gate Insulators", S. Han, X. Liu, J. Han, and C. Zhou, Applied Physics A 77, 873 (2003).
- [23] "Doping-dependent Ammonia Sensing of Indium Oxide Nanowires", D. Zhang, C. Li, X. Liu, S. Han, T. Tang, and C. Zhou, Appl. Phys. Lett. 83, 1845 (2003).
- [24] "Fabrication Approach for Molecule Memory Arrays", C. Li, D. Zhang, X. Liu, S. Han, T. Tang, C. Zhou, W. Fan, J. Koehne, J. Han, M. Meyyapan, A. M. Rawlett, D. W. Price, and J. M. Tour Appl. Phys. Lett. 82, 645 (2003).
- [25] "Ultraviolet Photodetection Properties of Indium Oxide Nanowires", D. Zhang, C. Li, S. Han, X. Liu, T. Tang, W. Jin and C. Zhou, Appl. Phys. A 76, 1 (2003).
- [26] "In₂O₃ nanowires as chemical sensors", C. Li, D. Zhang, X. Liu, S. Han, T. Tang, J. Han and C. Zhou, Appl. Phys. Lett. 82, 1613 (2003).
- [27] "Electronic Transport studies of Single-Crystalline In₂O₃ Nanowires", D. Zhang, C. Li, S. Han, X. Liu, T. Tang, W. Jin and C. Zhou, Appl. Phys. Lett. 82, 112 (2003).
- [28] "Controlled Growth of Gallium Nitride Single-Crystal GaN Nanowires Using a Chemical Vapor Deposition Method", S. Han, W. Jin, T. Tang, C. Li, D. Zhang, X. Liu, J. Han, and C. Zhou, J. Mater. Res. 18, 245 (2003).

- [29] "Diameter-Controlled Growth of Single-Crystalline In₂O₃ Nanowires and Their Electronic Properties", C. Li, D. Zhang, S. Han, X. Liu, T. Tang, and C. Zhou, Adv. Mater. 15, 143 (2003).
- [30] "Synthesis and Electronic Transport Studies of CdO Nanoneedles", X. Liu, C. Li, S. Han, J. Han and C. Zhou, Appl. Phys. Lett. 82, 1950 (2003).
- [31] "Carbon Nanotube Field-Effect Inverters", X. Liu, R. Lee, J. Han, C. Zhou, Appl. Phys. Lett. 79, 3329 (2001).
- [32] "Electronic structure of High-pressure Alumina Polymorphs", X. Liu, W. Duan, B. Gu, Chin. Phys. Lett. 17, 441 (2000).

Book Chapter:

"Synthesis and Electronic Properties of Carbon Nanotubes", X. Liu, C. Lee, S. Han, C. Li, and C. Zhou, in Molecular Electronics (eds. M.A. Reed and T. Lee), in press.

PROFESSIONAL ACTIVITIES

Member of Material Research Society (MRS) 2002- present

Member of American Physical Society (APS) 2004 - present

Member of IEEE/EDS 2004 - present