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EDUCATION

Ph. D., Materials Science and Engineering, Georgia Institute of Technology, Atlanta, GA, Aug., 2008.
Thesis advisors: Dr. Zhong L. Wang
Thesis Title: "Nanogenerators"
Minor: Electrical Engineering focused applied optics.

M.S., School of Physics, Georgia Institute of Technology, Atlanta, GA, Dec., 2003.

B.S., School of Physics, Nankai University, Tianjin, China, Jul., 1998.

QUALIFICATIONS PROFILE

- Extensive knowledge and exceptionally skilled in applying piezoelectric nanomaterials for power generation and sensor applications.
- Extensive knowledge and exceptionally skilled in nanostructure characterization, especially in mechanical property measurement by using atomic force microscopy(AFM).
- Extensive knowledge and exceptionally skilled in fabricating electronic nanomaterials with controlled morphologies through vapor-liquid-solid, vapor-solid, and wet-chemical processes.
- Exceptionally experienced in nanodevice assembly from electronic nanostructure building blocks and assessing corresponding mechanical, electronic, optoelectronic and biological applications.
- Exceptionally skilled in various characterization methods, including AFM, TEM, SEM, EDS, XRD, PL, UV absorption and reflection, FIB, photolithography, and e-beam lithography.
- Experienced on biological/biomedical applications of nanostructures, including cell manipulation and biological sensing.
- Skilled in assembling, operating, and maintaining vacuum systems, including physical/chemical vapor deposition system, laser ablation deposition system, atomic layer deposition system, and thermal evaporation system.
- Extensive and solid knowledge of classic physics, modern physics, crystallography and semiconductor theories, including solid state physics, optics, classic mechanics, electrodynamics, quantum mechanics, and thermal dynamics.
- Experienced on coaching new graduate students to initiate and conduct research projects.
- Substantial experience on writing proposals, peer-reviewed papers, and presentations.

RESEARCH ACHIEVEMENTS

Research results have been published on **Science**, **Nano Letters**, **Advanced Materials, JACS**, **Applied Physics Letters**, **Nanotechnology, J. Phys. Chem. B, Small**, etc.

- ***Invented the First Nanogenerator in the World.*** I invented the first nanogenerator in the world with my advisor (**Science**, 2006, 14, 242-246). By using conductive AFM scanning on ZnO nanowire arrays, mechanical energy has been converted to electricity in nanometer scale devices for the first time. This invention opens a new field of nanometer scale power generation, which is the pioneer and landmark work for self-powered nanotechnology. The discovery has profound impaction on the application of nanotechnology, which promises self-powered independent nanosystems.
- ***Direct Current Nanogenerator.*** Based on the AFM based nanogenerator, I developed the nanogenerator using aligned piezoelectric ZnO nanowire arrays with my colleagues, which is able to convert wave/vibration energy into electricity(**Science**, 2007, 316, 102-105). This discovery sets the foundation for eliminating batteries in nano- and small electronic devices and realizing an alternative power source that is small, clean, efficient, long life time, integratable and bio-implantable.
- ***Applying Statistics Theory and Methods in Experimental Parameters Design.*** In order to improve the power output of nanogenerator, I employed statistical model to optimize the parameters, which could extensively affect the output, and significantly improve the output of nanogenerators by 3 times. This work sets a model in disciplinary collaboration to overcome the uncertainty of nano-related experimental results.
- ***Cell Traction Force Measurement.*** I applied the atomic force microscopy (AFM) system for measuring the traction force of living normal cells as well as the cancer cells. Well aligned Si nanowire arrays were made by etching process. The elastic modulus of Si nanowire arrays was characterized by AFM. Normal and cancer cells were cultured on the top of the nanowire arrays. The traction force of the live cells was calculated by the bending angles of Si nanowires. This research is potentially useful for oncology, disease diagnosis, drug developing, and tissue engineering.
- ***Piezoelectric Field Effect Transistor (PE-FET).*** I developed the PE-FET based on a single piezoelectric ZnO nanowire with my colleagues. Instead of using traditional gate potential, the PE-FET uses piezoelectric potential generated inside the nanowire to control its current flow. It has been demonstrated as a force sensor for measuring forces in nano-Newton range and even smaller with the use of smaller nanowires.
- ***Mechanical Property Measurement of Aligned.*** I developed an innovative technique to measure the elastic modulus of individual nanowire without manipulating or destroying the sample. For the first time, I measured the elastic modulus of aligned ZnO nanowire arrays by scanning AFM in contact mode. The elastic modulus of each individual nanowire could be obtained from topography and lateral force images. This technique has become a versatile elastic modulus measurement for aligned nanostructures.
- ***Patterned and Aligned Nanowire Arrays.*** I developed a "Phase Diagram" like road map to guide the growth of nanowire arrays on various substrates, such as sapphire, GaN, AlN, and $Al_xGa_{1-x}N$. A synthesis "Phase Diagram" was first time fully developed by varying total pressure and oxygen partial pressure. This landmark work set the foundation for synthesizing aligned nanowire arrays and the morphology has become a versatile building block for sensor arrays, optoelectronic devices and nanogenerators.

RESEARCH EXPERIENCE

Post Doctoral Fellow, Aug. 2008—present. Georgia Institute of Technology, Atlanta, GA.

Supervisor: Dr. Zhong L. Wang

Main responsibilities:

- Developing high output piezoelectric nanogenerators with various configurations and compositions.
- Developing radio frequency nanodevices based on ZnO nanostructures to harvest radio frequency energy.
- Developing hybrid energy harvesting cell composing nanoscale mechanical nanogenerator, biofuel cell, and solar cell.

- Initiating biological research and exploring novel applications of semiconducting nanostructures in biological systems
- Developing nanosensors (force/pressure/gas) using aligned piezoelectric/semiconducting nanowires.
- Leading and training junior students/researchers to initiate different projects.
- Writing research proposals for government funding.

External Collaborations:

- Developing nanoscale energy chip with Dr. Muhammad Mustafa Hussain, King Abdullah University of Science and Technology.
- Investigating the best parameters for high output nanogenerator targeted maximizing the power output of nanogenerator base on ZnO nanowire arrays — collaborate with Dr. Jeff Wu, School of Industrial and Systems Engineering, Georgia Institute of Technology.
- Piezoelectric property measurements of nitrides — collaborate with Dr. Zheng Hu, Key Laboratory of Mesoscopic Chemistry of MOE, School of Chemistry and Chemical Engineering, Nanjing University, Nanjing, China.
- Developing nanogenerator on p-type ZnO nanowire arrays — collaborate with Dr. Lih-Juann Chen, Department of Materials Science and Engineering, National Tsing Hua University, Hsinchu, Taiwan, R.O.C.

Graduate Research Assistant, July. 2004—Aug. 2008. Georgia Institute of Technology, Atlanta, GA.

Advisors: Dr. Zhong L. Wang

- Developed an efficient and economic technique for fabricating aligned and patterned ZnO nanowires on sapphire, GaN, AlN, and $Al_xGa_{1-x}N$ substrates for sensor arrays and light-emitting devices.
- Intensively studied and analyzed the effects of experimental parameters for growing aligned ZnO nanowires, including pressure, oxygen concentration, substrate and catalyst.
- Developed an efficient and economic technique for characterizing elastic modulus of aligned nanostructures.
- Invented nanogenerator based on conductive AFM scanning on piezoelectric ZnO nanowire arrays. For the first time, mechanical energy has been converted into electricity in nanometer scale.
- Fabricated direct current nanogenerator driven by ultrasonic wave. Demonstrated the first prototype nanoscale power source that could harvest vibrating energy into electricity.
- Carried out principle study on elastic deformation of piezoelectric materials.

TEACHING EXPERIENCE

- Co-teaching MSE8803 “Nanomaterials & Nanotechnology” with Prof. Z.L. Wang, 2010.
- Co-teaching MSE8803A “Nanomaterials & Nanotechnology” with Prof. Z.L. Wang, 2009.
- Teaching Assistant for several MSE classes, including “Transmission Electron Microscopy”, “Nanomaterials & Nanotechnology”, “X-Ray Analysis”, “Introduction to Engineering”.
- Teaching “Introduction of Modern Physics I” and “Introduction of Modern Physics II” from 2002 to 2004 in School of Physics, Georgia Institute of Technology.
- Teaching Assistant for several classes in School of Physics, Georgia Institute of Technology, such as “Electrodynamics”, “Quantum Physics”.

ACADAMIC ACHIEVEMENTS

- ***Journal Publications*** (**total citation: 2,090 times; h-index: 18**, list ordered by publication time)

1. ***Jinhui Song***, H.Z. Xie, W.Z. Wu, V.R. Joseph, C.F. Jeff Wu, and Z.L. Wang, "Robust Optimization of the Output Voltage of Nanogenerators by Statistical Design of Experiments", Nano Res., 2010, 3(9), 613-619.
2. C.T. Huang, ***Jinhui Song***, C.M. Tsai, W.F. Lee, D.H. Lien, Z.Y. Gao, Y. Hao, L.J. Chen, and Z.L. Wang, "Single-InN-Nanowire Nanogenerator with Upto 1V Output Voltage", Adv. Mater., Oline
3. C.T. Huang, ***Jinhui Song***, W.F. Lee, Y. Ding, Z.Y. Gao, Y. Hao, L.J. Chen, and Z.L. Wang, "GaN Nanowire Arrays for High-Output Nanogenerators ", J. AM. CHEM. SOC., Online.
4. X.B. Wang*, ***Jinhui Song***, F. Zhang*,(* equal authorship), C.Y. He,Z. Hu and Z.L. Wang, "Electricity Generation based on One-Dimensional Group-III Nitride Nanomaterials ", Adv. Mater., Online.
5. Y. Xi, ***Jinhui Song***, S. Xu, R. Yang, Z. Gao, C. Hu and Z. Wang "Growth of ZnO nanotube arrays and nanotube based piezoelectric nanogenerator ", J. Mater. Chem., 2009, 19, 9260-9264
6. S. Lin, J. Hong, ***Jinhui Song***, Y. Zhu, H. He, Z. Xu, Y. Wei, Y. Ding, R. Snyder and Z. Wang "Phosphorus Doped Zn1-xMgxO Nanowire Arrays ", Nano Lett., 2009, 9, 3877-3882
7. P. Fei,P. Yeh,J. Zhou,S. Xu,Y. Gao, ***Jinhui Song***, Y. Gu,Y. Huang and Z. Wang "Piezoelectric Potential Gated Field-Effect Transistor Based on a Free-Standing ZnO Wire", Nano Lett., 2009, 9, 3435-3439.
8. Z. Li, ***Jinhui Song***, G. Mantini, M. Lu, H. Fang, C. Falconi, L. Chen and Z. Wang "Quantifying the Traction Force of a Single Cell by Aligned Silicon Nanowire Array", Nano Lett. 2009, 9, 3575-3580.
9. H. Fang, W. Wu, ***Jinhui Song*** and Z. Wang "Controlled Growth of Aligned Polymer Nanowires", J. Phys. Chem. C., 2009, 113, 16571-16574
10. S. Lin*, ***Jinhui Song***, (* equal authorship), Y. Lu and Z L Wang "Identifying individual n- and p-type ZnO nanowires by the output voltage sign of piezoelectric nanogenerator", *Nanotechnology*, 2009, 20, 365703.
11. M. Lu*, ***Jinhui Song***, (* equal authorship), M. Lu, M. Chen, Y. Gao, L. Chen and Z.L. Wang "Piezoelectric Nanogenerator Using p-Type ZnO Nanowire Arrays ", *Nano Lett.*,9 (2009) 1223-1227.
12. M. Lu, ***Jinhui Song***, M. Lu, C. Lee, L. Chen and Z.L. Wang "ZnO- ZnS Hererojunction and ZnS Nanowire Arrays for Electricity Generation ", *ACS Nano.*, 2009.
13. X. Wang, Y. Ding, Z. Li, ***Jinhui Song*** and Z.L. Wang "Single-Crystal Mesoporous ZnO Thin Films Composed of Nanowalls ", *J. Phys. Chem. C*, 113 (2009) 1791-1794,
14. Y. Lin, ***Jinhui Song***, Y. Ding, S.Y. Liu and Z.L. Wang "lternating the Output of a CdS Nanowire Nanogenerator by a White-Light-Stimulated Optoelectronic Effect ", *Adv. Mater.*, (2008) 0704.
15. Z.L. Wang, X. Wang, ***Jinhui Song***, J. Liu and Y. Gao "Piezoelectric Nanogenerators for Self-Powered Nanodevices", *IEEE Perv. Comp.*, 7 (2008) 49-55..
16. Y. Lin, ***Jinhui Song***, Y. Ding, S. Liu and Z.L. Wang "Piezoelectric nanogenerator using CdS nanowires", *Appl.Phys. Lett.*, 92 (2008) 022105.
17. J. Liu, P. Fei, ***Jinhui Song***, X. Wang, C. Lao, R. Tummala and Z.L. Wang "Carrier Density and Schottky Barrier on the Performance of DC Nanogenerator", *Nano Lett.*, 8(2008) 328-332.
18. ***Jinhui Song***, X. Wang, J. Liu, H. Liu, Y. Li and Z.L. Wang "Piezoelectric Potential Output from ZnO Nanowire Functionalized with p-Type Oligomer", *Nano Lett.*, 8(2008) 203-207.
19. X. Wang, J. Liu, ***Jinhui Song*** and Z.L. Wang "Integrated Nanogenerators in Biofluid", *Nano Lett.*, 7 (2007) 2475-2479.
20. X. Wang, J. Zhou, C. Lao, ***Jinhui Song***, N. Xu, and Z.L. Wang "In Situ Field Emission of Density-Controlled ZnO Nanowire Arrays", *Adv. Mater.*, 19 (2007) 1627–1631.

21. J. Zhou, J. Liu, X. Wang, ***Jinhui Song*** R. Tummala, N. Xu and Z.L. Wang "Vertically Aligned Zn2SiO4 Nanotube/ZnO Nanowire Heterojunction Arrays", *Small*, 3 (2007) 622-626.
22. X. Wang, ***Jinhui Song***, J. Liu and Z.L. Wang "Direct-Current Nanogenerator Driven by Ultrasonic Waves", *Science*, 316 (2007) 102-105.
23. Y. Chueh, L. Chou, ***Jinhui Song*** and Z.L. Wang "Mechanical and magnetic properties of Ni-doped metallic TaSi2 nanowires", *Nanotechnology*, 18 (2007) 145604.
24. X. Wang, ***Jinhui Song*** and Z.L. Wang "Nanowire and nanobelt arrays of zinc oxide from synthesis to properties and to novel devices", *J. Mater. Chem.*, 17 (2007) 711-720.
25. Y. Chueh, C. Hsieh, M. Chang, L. Chou, C. Lao, ***Jinhui Song***, J. Gan and Z.L. Wang "RuO2 nanowires and RuO2-TiO2 core-shelled nanowires: from synthesis to mechanical, optical, electrical and photoconductive properties", *Adv. Mater.*, 19 (2007) 143-149.
26. P. Gao, ***Jinhui Song***, J. Liu and Z.L. Wang "Nanowire Piezoelectric Nanogenerators on Plastic Substrates as Flexible Power Sources for Nanodevices", *Adv. Mater.*, 19 (2007) 67-72.
27. X. Wang, J. Zhou, ***Jinhui Song***, J. Liu, N.S. Xu and Z.L. Wang "Piezoelectric Field Effect Transistor and Nanoforce Sensor Based on a Single ZnO Nanowire", *Nano Lett.*, 6 (2006) 2768-2772.
28. ***Jinhui Song***, J. Zhou and Z.L. Wang "Piezoelectric and Semiconducting Coupled Power Generating Process of a Single ZnO Belt/Wire. A Technology for Harvesting Electricity from the Environment", *Nano Letters*, 6 (2006) 1656-1662.
29. X. Wang, ***Jinhui Song*** and Z.L. Wang "Single-crystal nanocastles of ZnO", *Chem. Phys. Lett.*, 424 (2006) 86-90.
30. Z.L. Wang and ***Jinhui Song*** "Piezoelectric Nanogenerators Based on Zinc Oxide Nanowire Arrays", *Science*, 14 April 2006: 242-246.
31. X. Wang, ***Jinhui Song***, C.J. Summers, J.H. Ryou, P. Li, R.D. Dupuis and Z.L. Wang "Density-Controlled Growth of Aligned ZnO Nanowires Sharing a Common Contact: A Simple, Low-Cost, and Mask-Free Technique for Large-Scale Applications", *J. Phys. Chem. B*, 110 (2006) 7720-7724.
32. ***Jinhui Song***, X. Wang, E. Riedo and Z.L. Wang "Elastic Property of Vertically Aligned Nanowires", *Nano Lett.*, 5 (2005) 1954-1958.
33. ***Jinhui Song***, X. Wang, E. Riedo and Z. L.Wang "Systematic Study on Experimental Conditions for Large-Scale Growth of Aligned ZnO Nanwires on Nitrides", *J. Phys. Chem. B*, 109 (2005) 9869-9872.
34. X. Wang, ***Jinhui Song***, P Li, J. H. Ryou, R. D. Dupuis, C. J. Summers and Z. L.Wang "Growth of Uniformly Aligned ZnO Nanowire Heterojunction Arrays on GaN, AlN, and $Al_{0.5}Ga_{0.5}N$ Substrates", *J. Am. Chem. Soc.*, 127 (2005) 7920-7923.

- ***Invited Book Chapters***

1. **First author** for chapter "ZnO Nanowires and Nanobelts: Growth, Properties and Applications in Nanopiezotronics" for the forthcoming book series on "Metal Oxide Nanostructures and Their Applications" to be published by American Scientific Publishers.
2. Z.L. Wang, ***Jinhui Song***, P. Gao and X. Wang "Nanogenerator as nano-scale power source for biomedical devices" in "Nanomaterials and Their Applications in Biomedicine", Springer, (in preparation).
3. ***Jinhui Song***, Z.L. Wang "Piezoelectric Nanogenerator for Self-powered Nanodevices" for the forthcoming book series on "Piezoelectric Nanomaterials for Biomedical Applications", Springer, (in preparation)
4. Book chapter invitation for a book or edit a review volume on "Nanogenerator" for World Scientific (2009).
5. Book writing invitation for Artech House Publisher from London (2007)

- ***Patents***

1. ***Jinhui Song***, Z.L. Wang, X.D. Wang "Piezoelectric and Semiconducting Coupled Nanogenerators" European patent. Application No./Patent No. 06846573.1-1235 PCT/US2006061933 (Jul. 2008)
2. Z. L. Wang, X. Wang, ***Jinhui Song*** J. Zhou, J.-H. He "Nanopiezotronics" US patent filed, US Application No. 11/760,002. (July. 2007).
3. Z. L. Wang, X. Wang, ***Jinhui Song*** "Nanowire Piezo-Electric Generators for Converting Mechanical Movement Energy, Vibration and/or Hydraulic Energy Into Electricity For Self-Powering of Wireless Nano-Bio-devices and Systems" US patent filed, US Application No. 11/608,865 (Dec. 2006).

- ***Conference Presentations and Invited Talks***

1. "Piezoelectric Nanogenerator by Using p-type ZnO Nanowire Arrays", MRS Fall Meeting, Boston, MA, Nov. 30-Dec.4, 2009.
2. "Quantifying the Traction Force of a Single Cell by Aligned Silicon Nanowire Array", MRS Fall Meeting, Boston, MA, Nov.30-Dec.4, 2009.
3. "Nanogenerators for Self-Powered Nanotechnology", DARPA/MTO Workshop on Piezoelectric MEMS, San Francisco, CA, March 12th, 2008 (Invited talk).
4. "Piezoelectric and Semiconducting Coupled Power Generating Process of a Single ZnO Belt/Wire. A Technology for Harvesting Electricity from Environment." MRS Fall Meeting, Boston, MA, Nov. 26-30, 2007.
5. "Nanomaterials & Nano-Sensors" NASA/DoD UAPT Program 2006 Review, Cleveland, OH, Oct. 17th, 2007(invited talk).
6. "Nanogenerator Based on Piezoelectric Nanowires" 6th International Workshop on Micro and Nanotechnology for Power Generation and Energy Conversion Applications, Berkeley, CA. Nov. 29-Dec.1, 2006 (invited talk).
7. "Elastic Property of Vertically Aligned Nanowires", MRS Fall Meeting, Boston, MA, Nov., 2006.
8. "Piezoelectric Nanogenerators Based on ZnO Nanowire Arrays", MRS Fall Meeting, Boston, MA, Nov., 2006.
9. "Elastic Property of Vertically Aligned Nanowires", 231st ACS National Meeting, Atlanta, GA, March 26-30, 2006.
10. "Systematic Study on Experimental Conditions for Large-Scale Growth of Aligned ZnO Nanowires on Nitrides", 231st ACS National Meeting, Atlanta, GA, March 26-30, 2006.

GRANT APPLICATION EXPERIENCE

- "Development of Large-Scale ZnO Nanowire Piezoelectric Energy Harversting Devices","ARPA-E, concept paper (2009).
- "High Power Nanogenerators", KAUST Global Research Partnership(GRP) Research Fellows Program. **Funded ($300,000 fellowship for 3 years starting from 2009).**
- "Three-Dimensional Architectured Nanogenerators for Self-Powered Nanosensors and Nanosystems" DARPA, full proposal (2007).

MEDIA REPORTS OF MY RESEARCH

- The invention of direct current Nanogenerator driven by ultrasonic wave (Science, 316 (2007) 102-105) was reported by ***New York Times*** newspaper in Science Times section, April 10, 2007.

- The discovery of direct current nanogenerator driven by ultrasonic wave was reported by ***AJC, Cox, Daily India, Dallas News, EE Times, Nanotech Web, News Wise, NextGen Log, NSF, Photonics, Science Blog***, et al. medias and institutes.
- The invention of Nanogenerator was
- The invention of first Nanogenerator (Science, 312 (2006) 242-246) was reported by ***CBC News, Fox News, China Daily Oversea, Chinese Science Daily, Nature Report, Scientific Watch, Semiconductor International, Technology Review***, et al..
- The invention of Nanogenerator (Science, 312 (2006) 242-246) was highlighted as a example of research benefits the interest of nation in the **NSF 2008 Budget Request to Congress**.
- The invention of Nanogenerator was elected as the **4th of the top 10 most important science discoveries worldwide** in 2006 by Members of Chinese Academic of Science and Chinese Academy of Engineering.
- The discovery of Nanogenerator was elected as one of the **10 the new immerging techniques in future 20 years** comparable with the invention of mobile phone by Science Watch.

AWARDS

- KAUST GRP Research Fellow for three years, starting from 2009 (top 0.0076%).
- MRS Graduate Student Silver Award (2007, top 0.46%)
- Chinese Government Award for Outstanding Self-financed Student Abroad (2006, top 0.07%)
- School of Materials Science & Engineering Research Initiation Award (2006)
- School of Materials Science & Engineering Advanced Publication Award (2005)
- School of Materials Science & Engineering Research Initiation Award (2005)
- 2nd Class Award in the National College Student Mathematics Modeling Contest (1997)

OTHER ACTIVITIES

- Reviewer for ***Nano Letters, Applied Physics Letters, Journal of Alloys and Compounds, Journal of Chemical Physical Chemistry C, and Benthan Science Publishers***, etc.
- Member of Materials Research Society.

PROFESSIONAL REFERENCES:

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