Ziqi Yu

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Education

2014	B.S. in Mechanical Engineering	Rensselaer Polytechnic Institute
2014	M.S. in Mechanical Engineering	Rensselaer Polytechnic Institute
2015 - Present	PhD in Mechanical Engineering	University of California, Irvine

Appointments

2015 - Present	Graduate Research Assistant, University of California, Irvine
2015 - 2017	Teaching Assistant, University of California, Irvine

Research Interests

Micro/nano scale heat transfer; microfabrication; semiconductor physics; nanoscale electron and phonon transport; phononics; photonics; metamaterials; topological insulators; neural networks

Skills & Trained Equipment/Software

1. **Microfabrication**: **photolithography** (*Karl Suss MA6 mask aligner, Laurell spin coater*); **mask design** (*L-edit*); **thin film deposition** (*Temescal CV-8 and Angstrom Engineering EVOVAC electron beam evaporator*); **deep reactive ion etching** (*STS System DRIE*); **wet processing** (*HF and NaOH/KOH etching benches*)
2. **Optical Characterization**: **characterization of optical properties** (*Cary-7000 Universal Measurement spectrophotometer, Thermo Scientific Nicolet 6700 FT-IR spectrometer, FLIR A655sc IR camera*)
3. **Thermal Science**: **thermal metrology** (*Janis Research vacuum cryostat, Lake Shore PWP6 cryogenic probe station, TestEquity 107 temperature chamber, WestBond 4500B/747677E wire bonder*); **thermal analysis** (*ANSYS 18.1, COMSOL Multiphysics 5.3a*); **thin film characterization** (*Quanta 3D FEG Dual Beam scanning electron microscopy, FEI Magellan 400 XHR scanning electron microscopy*)

On-Going Research Experience

1. **Investigation of Holey Silicon-based Thermal Cloaking (on-going)**
   - The thermal cloaking effect can be effectively achieved due to the contrast thermal conductivities of bulk silicon and holey silicon with the optimized geometry.
     a. Designed and studied the holey silicon-based thermal cloaking devices by finite-element-analysis simulations (ordered or staggered distribution of squared holes with pitch sizes ranging from 10 to 25 μm and neck sizes ranging from 2 to 8 μm)

b. Developed the fabrication flow for the thermal cloaking devices and designed the photo/shadow masks for microfabrication

c. Currently working on fabricating the thermal cloaking devices using lithography and deep-reactive-ion etching

2. **Investigation of Optical and Thermal Properties of Textured Silicon-based Photonic Metamaterials for Potential Thermophotovoltaic Applications (on-going)**

- By tailoring the surface of the silicon wafer to construct high-density of microscale pyramidal structures, the surface of the resulted black silicon turns into anti-reflective. The anti-reflection level can be further improved by having a hierarchical structure of Si nanowires on the pyramidal structures through metal-assisted etching. The dimensions of the pyramids and nanowires can be tuned by modifying the fabrication parameters which provides the flexibility of optimizing the optical and thus thermal performance of the metamaterial.

a. Fabricated the microscale pyramidal structures by anisotropic Si etching using NaOH as the etchant and Na_2SiO_3 particles as the nanomask

b. Achieved the hierarchical structure of nanowires on the pyramidal structures by metal-assisted etching

c. Preliminarily characterized the optical property (e.g., absorptivity and reflectivity) of the textured silicon with pyramidal structures and hierarchical structures

d. Currently working on the optimization of the fabrication recipe to achieve more precise morphological control on the silicon wafer surface

3. **Investigation of Light Scattering and Absorption in Polymer-encapsulated-dielectric Microspherical Structures and Applications for Efficient Radiative Cooling (on-going)**

- By encapsulating microscale dielectric (e.g., glass) microspherical structures into polymer matrices whose refractive indices have weak wavelength dependence, the optical properties of the resulting composites can be optimally tuned by varying the size, distribution, and volume fraction of the microspheres. The optimized design can enable efficient radiative cooling with limited absorption in the solar wavelengths and enhanced emission in the infrared range. Both theoretical and numerical tools are employed. Mie and generalized Mie theories are used for modeling light propagation in single and a cluster of microspheres; finite-domain-time-domain (FDTD) simulations are used to provide numerical understanding and supports for the theoretical approach and experimental findings.

a. Theoretically compute the optical properties and light propagation for single glass microspheres using MATLAB based on Mie theory and Maxwell-Garnett effective medium theory

b. Numerically calculated the optical properties of and light propagation for single and multiple microspheres using Lumerical FDTD simulator

4. **Investigation of Energy Harvesting Devices based on Nano-textured Metallic Surface using Metal Electrodeposition (on-going)**
    - The absorption of solar energy can be effectively enhanced by hierarchically textured metallic surface
    - The Si wafer is anisotropically etched by $NaOH/Na_2SiO_4$/IPA solution followed by a secondary HF etching to form nanowire forests over micropyramids. Ni thin film is then electrodeposited and peeled off. The device is sturdy and flexible. The target is to co-electrodeposit Nitinol (Ni/Ti) to enable more efficient energy harvesting application by responding to external temperature actuation

Other Research Experience

1. **Numerical Investigation of Thermal Transport in Nanoporous Structures**
    a. Developed the program for Monte-Carlo Ray Tracing and simulated phonon transport in Si nanoporous structures with varying pore configurations
    b. Calculated the thermal conductivity for Si nanoporous structures using Boltzmann Transport Equation
2. **Experimental Characterization of Thermoelectric Properties of SbTe Thin Films**
    a. Fabricated measurement devices using lithography, metal deposition and lift-off
    b. Measured the cross-plane thermal conductivity of electrodeposited SbTe thin films (1~2 μm thick) under varying annealing conditions using the 3ω method
    c. Determined the thermoelectric figure-of-merit zT for electrodeposited SbTe thin films under varying annealing conditions
3. **Numerical Investigation of Elastic Wave Propagation in Si Nanoporous Structures to Achieve Topological Insulators at GHz Range**
    a. Developed the six-petal holey silicon nanoporous structures to achieve the phononic phase transition
    b. Numerically demonstrated the robust topologically protected elastic wave propagation against geometrical defects and potential fabrication-induced errors using COMSOL Multiphysics

Working Experience

Jun. 2019 – Sep. 2019 Co-op Researcher, Toyota Research Institute of North America

a. Experimentally investigated topology-optimized micro heat sinks in single- and two-phase regimes
b. Designed a thermal metamaterial using bi-objective topology-optimization
c. Investigated the unitary transformation to realize Si photonic-based optical neural networks (deep learning) for potential in-vehicle applications including image and voice recognition

Publications

Journal Papers

1. **Z. Yu**, L. Ferrer-Argemi, and J. Lee, Investigation of thermal conduction in symmetric and asymmetric nanoporous structures, *Journal of Applied Physics*, **122** (24), 244305, 2017.
2. **Z. Yu**, L. Ferrer-Argemi, J. Kim, JH. Lim, NV. Myung, and J. Lee, Phase-dependent thermal conductivity of electrodeposited antimony telluride films, *Journal of Materials Chemistry C*, **6** (13), 3410, 2018.
3. **Z. Yu**, Z. Ren, and J. Lee, Phononic topological insulators based on six-petal holey silicon structures, *Scientific Reports* **9**(1), 1805, 2019.
4. Z. Ren, **Z. Yu**, J.C. Kim, and J. Lee, TSV-integrated thermoelectric cooling by holey silicon for hot spot thermal management, *Nanotechnology* **30**(3), 035201, 2018.
5. M. Sala-Casanovas, A. Krishna, **Z. Yu**, and J. Lee, Bio-inspired stretchable selective emitters based on corrugated nickel for personal thermal management, *Nanoscale and Microscale Thermophysical Engineering*, **23**(3), 173, 2019.
6. L. Ferrer-Argemi, **Z. Yu**, J. Kim, N.V. Myung, J.H. Lee, and J. Lee, Silver content dependent thermal conductivity and thermoelectric properties of electrodeposited antimony telluride thin films, Scientific Reports, **9**(1), 9294, 2019.
7. L. Ferrer-Argemi, **Z. Yu**, and J. Lee, Effects of metal silicide inclusion interface and shape on thermal transport in silicon nanocomposites, Journal of Applied Physics, **126**(3), 035106, 2019.
8. H. Yu, J. Wang, B. Deng, X. Wei, Y.K. Wong, W.L. Chan, K.M. Tsang, and **Z. Yu**, Chaotic phase synchronization in small-world networks of bursting neurons, *Chaos: an interdisciplinary journal of nonlinear science* **21**(1), 013127, 2011.

Conference Proceedings

1. **Z. Yu**, L. Ferrer-Argemi, and J. Lee, Temperature-dependent thermoelectric properties of electrodeposited antimony telluride films. In: *Proceedings of the IEEE 17th Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems*. San Diego, CA, 2018.
2. **Z. Yu**, Z. Ren, and J. Lee, Investigation of thermal metamaterials based on nanoporous silicon using ray tracing and finite element simulations. In: *Proceedings of the IEEE 18th Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems*. Las Vegas, NV, 2019.
3. Z. Ren, **Z. Yu**, and J. Lee, Hotspot management by holey silicon-metal composites for 1 kW/cm^2 and beyond. In: *Proceedings of the IEEE 18th Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems*. Las Vegas, NV, 2019.
4. J. Sullivan, L. Ferrer-Argemi, **Z. Yu**, and J. Lee, Wafer-scale hierarchically textured silicon for surface cooling. In: *Proceedings of the IEEE 18th Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems*. Las Vegas, NV, 2019.

Conference Presentations

1. **Z. Yu** and J. Lee, Thermal transport modeling of asymmetric nanostructures by Monte-Carlo ray tracing. In: *The 36th International Conference on Thermoelectrics*. Pasadena, CA, 2017.

2. **Z. Yu** and J. Lee, Temperature-dependent thermoelectric properties of electrodeposited antimony telluride films. In: *IEEE 17th Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems*. San Diego, CA, 2018.
3. **Z. Yu**, L. Ferrer-Argemi, and J. Lee, Thermal transport in electrodeposited antimony telluride films with varying silver contents. In: *2019 Spring Materials Research Society Meeting & Exhibit. Phoenix*, AR, 2019.
4. **Z. Yu**, Z. Ren and J. Lee, Investigation of thermal metamaterials based on nanoporous silicon using ray tracing and finite element simulations. In: *Proceedings of the IEEE 18th Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems*. Las Vegas, NV, 2019.

Awards and Honors

1. Best Paper Award in the *Emerging Technologies and Fundamental* Track, ITHERM 2019

Professional Affiliations

Institute of Electrical and Electronic Engineers (IEEE); Materials Research Society (MRS).

Other Skills

Thermoelectrics, thermal management, device characterization, MEMS, X-ray Diffraction analysis, MATLAB, SolidWorks, Lumerical FDTD