NANO-DEVICES FOR ENHANCED THERMAL ENERGY STORAGE, COOLING AND SENSING

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Air Force Research Lab. (AFRL) '06,'07;

ASEE/ONR (Office of Naval Research):

Space & Naval Warfare Center (SPAWAR) '09

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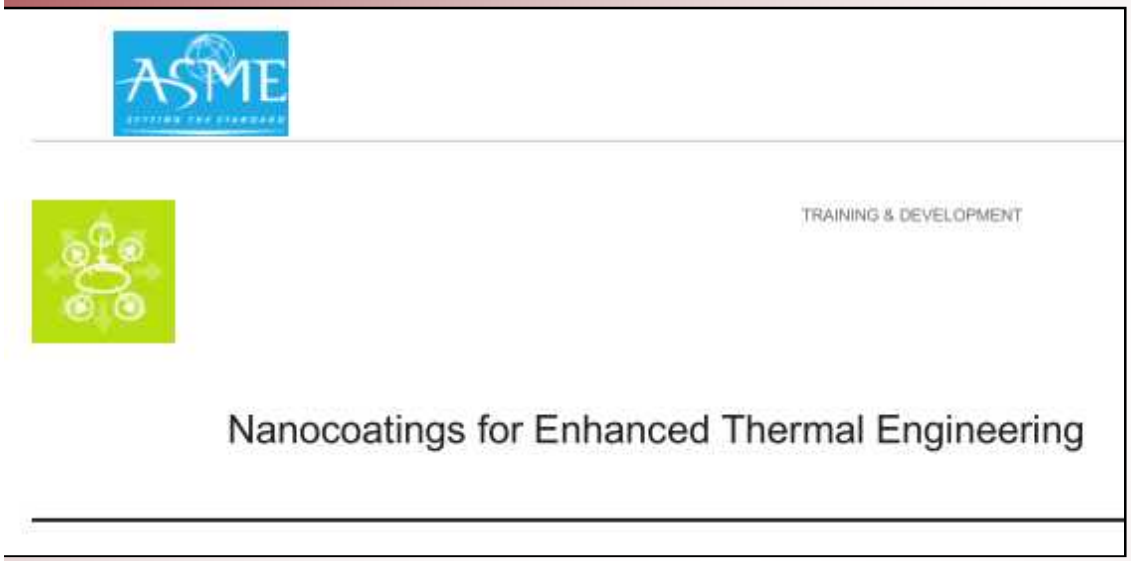
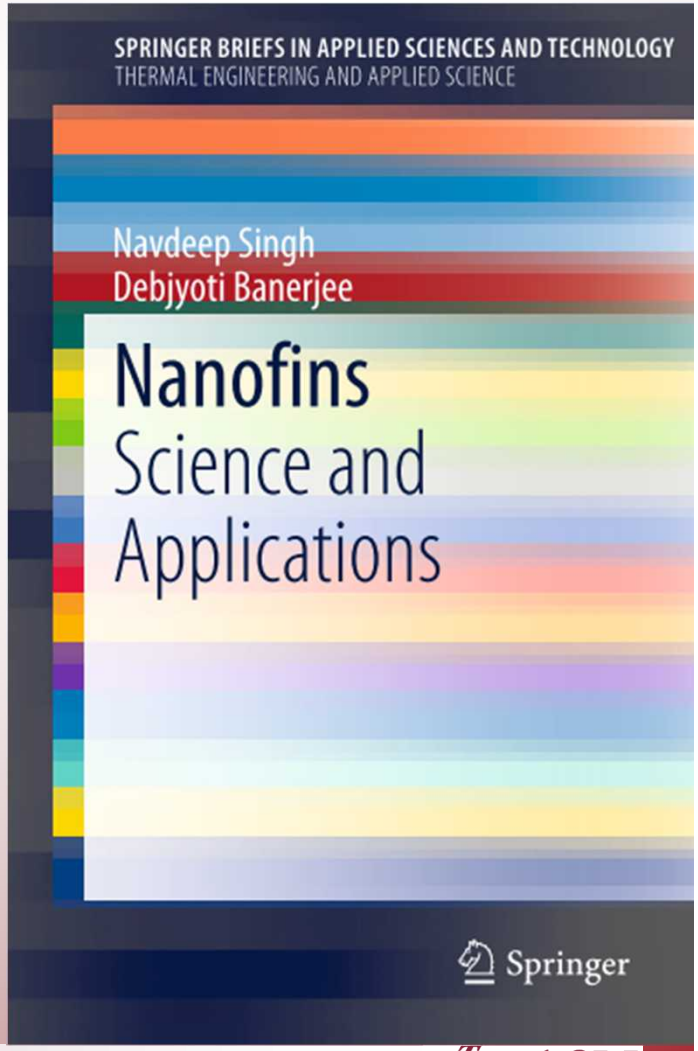
Book & Online Short Course for ASME (MOOC)



https://www.asme.org/products/courses/nanocoatings-for-enhanced-thermal-engineering



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Guest Editorial

Guest Editorial for the Special Issue on Micro/Nanoscale Transport Phenomena

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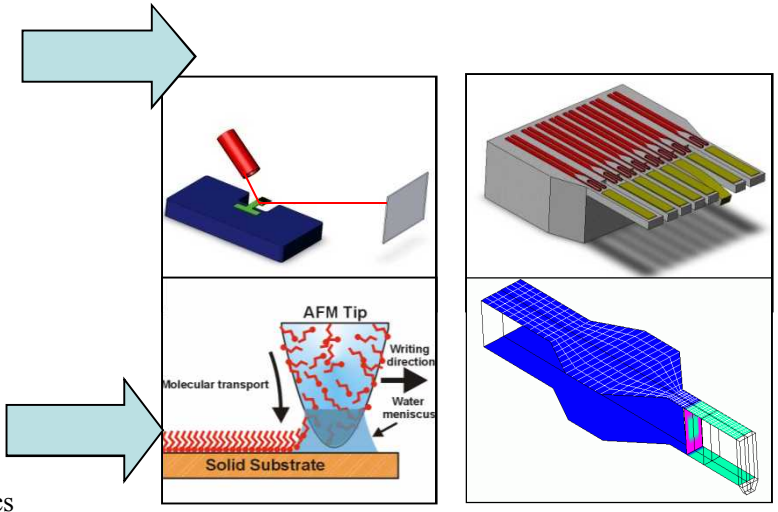
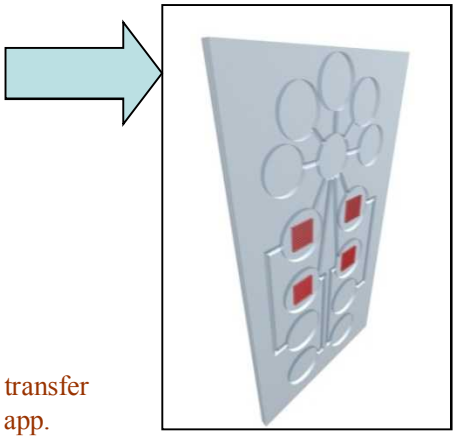
ARTICLE

Multiphase Flows & Heat Transfer Lab.

(Since Jan. 2005, 45 Extra-Mural Funded Projects in 11 years)

- **Nano-Sensors** (3 Ph.D., 1 M.S.)
  - **MEMS:**
    - **TEES**: Nano-calorimeter (**EXPLOSIVES SENSOR**)
    - **Nano-MEMS Research/NSF SBIR**: RF-MEMS,RF-Tuner
  - **DPN** (Dip Pen Nanolithography):
    - **DARPA/MTO:** chirality control, low temp. synthesis of CNT
    - **ONR STTR/ ADA Tech.: Ultra-Capacitors**
    - SPAWAR: low temp. synthesis of Graphene (ONR/ASEE)
    - **TSGC**: Nanolithography+Microfluidics, CFD
    - **GE Research**: Silicon Nanofins
  - **Bio-Microfluidics, Lab-On-Chip:**
    - **AFRL**: Portable water quality monitor
    - **DARPA/MF^3**: Micro-Chamber Filling
      - » (1) Vaccine Storage/ Paper microfluidics,
      - » (2) Anthrax Detection using CD Microfluidics
    - **NASA**: Lipid bi-layer sensors for studying protein/peptide kinetics
    - **Energy Institute**: Micro/nano-fluidics, thermodynamic properties in shale rocks/ reservoirs
    - **Crisman Institute**: Micro/nano-fluidics, thermodynamic properties in shale rocks/ reservoirs
    - **AFOSR**: Reconfigurable microfluidic device for nano-optics (**META MATERIALS**)





- **Thermal Management** (3 Ph.D., 1 M.S.)
  - **Nanostructures**
    - **ONR: Flow Boiling on Carbon Nanotubes**
    - **NSF: Pool Boiling on Silicon Nanofins, Molecular Dynamics**
    - **DOE: Nanofluids for Thermal Energy Storage (SOLAR ENERGY)**
    - **ARPA-E (ARID): Energy-water nexus**
    - **Alstom: Nanofluids for Thermal Energy Storage (SOLAR ENERGY)**
    - **AFOSR/AFRL(ASEE-SFFP): Nano-Fluids**
    - **Qatar National Research Foundation (QNRF):** Nanofluids and Nanofins for enhanced heat transfer
    - **Photronics Corp./ Trianja Tech. (Si Values Partners/ B G Group):** Nanofluids for energy app.
    - **Irvine Sensors:** Micropump Design for Electronics Cooling **(AFRL SBIR Phase II)**
    - **Aspen Thermal Systems:** Compact condensers **(ONR SBIR Phase I; Phase II)**
  - **Thermo-Chemical Energy Storage (TCES), Thermal Energy Storage (TES)**
    - **AFRL: Chevron Plate Heat Exchangers (PHE) for rapid thermal management**
  - **Biomedical Device (Surgical Sterilizer)**
    - **Lynntech/ ARO SBIR Phase II**: Portable sterilizer for surgical tools using steam.

Nano-Fluids/ Nano-Coating Research

- Demonstrated 40% enhancement in performance of compact heat exchangers using carbon nanotube (CNT) based nano-fluids in Poly Alpha Olefin (PAO) oils (sponsored by Air Force Research Lab.)
  - **Specific Heat enhanced by ~20%**
  - **Viscosity enhanced by 12.5%**
- Demonstrated 10% enhancement in convective heat transfer in flow loop cooling using ex-foliated graphite nanoparticles in Poly-Alpha-Olefin (PAO) Coolants/ Nanofluids (sponsored by Air Force Research Lab.)
  - **Specific Heat enhanced by ~50%**
  - **Viscosity enhanced by 10X**
- Demonstrated ~20-120% enhancement in specific heat capacity of high temperature nanofluids (molten salt eutectics and solar salts) for applications in Concentrated Solar Power (CSP) – Thermal Energy Storage (TES). (sponsored by the Department of Energy/ DOE Solar Energy Technology Program/ SETP).
- Demonstrated ~60-300 % enhancement in pool boiling using carbon nanotube (CNT) coatings (sponsored by Office of Naval Research, National Science Foundation)
- Demonstrated ~120% enhancement in Critical Heat Flux (CHF) for pool boiling on silicon nano-fins (sponsored by National Science Foundation)
- Demonstrated ~180 % enhancement in flow boiling using carbon nanotube coatings (sponsored by Office of Naval Research)
- Demonstrated 100% enhancement in performance of Compact Condensers using carbon nanotube (CNT) coatings (collaboration with Aspen Thermal Systems; Sponsor: Office of Naval Research/ ONR Thermal Management Program). Leakage issues.
- ~650-850% enhancement in spray cooling (with phase change) using Titania nano-coatings.

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- **Energy Institute**
- **Mary Kay O'Connor Process Safety Center**
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  - **Alstom**
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  - **MRV Systems (ONR SBIR Phase I)**
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DARPA
MICROSYSTEMS TECHNOLOGY OFFICE


MF3
Micro/nano Fluidics
Fundamentals Focus Center

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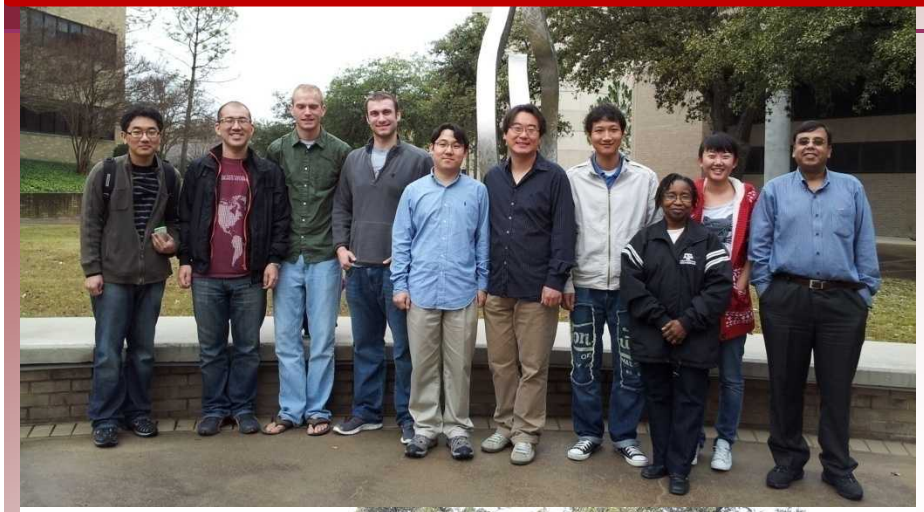
Industry Partners (DARPA-MF^3 Center)

- Douglas Scientific
- Pioneer Hi-Bred International, Inc.
- IDEX Health & Science
- SHRINK Nanotechnologies
- Microfluidic Innovations
- ESI Group
- Symbient Product Development
- Sierra Proto Express
- Lawrence Livermore National Labs.
- NASA Ames Research Center
- Beckman Coulter, Inc.
- BIOCOM

Past Industry Partners (DARPA-MF^3 Center)

- Monsanto Company
- Invitrogen
- Applied Biosystems (Life Technologies)
- Irvine Sensors Corporation

11 Ph.D. and 17 M.S. Students Graduated since 2005
~ 25 Undergraduate Scholars (3 honors thesis, 8 women/ minorities)



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Acknowledgements

- 28 Graduate Students graduated since 2005
  - 17 MS (1 Woman)
  - 11 PHD
- GRADUATE STUDENTS (6)
  - 4 Ph.D., 2 M.S. Students(1 woman)
- UNDERGRADUATE STUDENTS (25)
  - 8 Women/ Minority students
  - 3 UG Honors Thesis
- 3 Labs:
  - Multi-Phase Flows & Heat Transfer Lab.
  - CNT Furnace: Energy Systems Lab.
  - Nano-Manufacturing: Wet Lab. (AggieFab)
  - 7 Shared User Facilities
    - Supercomputing Center, Texas A&M
    - Microscopy and Imaging Center (MIC), Texas A&M
    - Materials Characterization Facility (MCF), Texas A&M
    - Center for Integrated Microchemical Systems (CIMS), Texas A&M
    - INRF, University of California, Irvine (UCI)
    - NSF National Nanotechnology Infrastructure Network (NNIN), University of Texas, Austin
    - SPAWAR (Space and Naval Warfare Center, US Navy)

5 Graduate Students graduated in 2006

5 Graduate Students graduated in 2007

Contact Information

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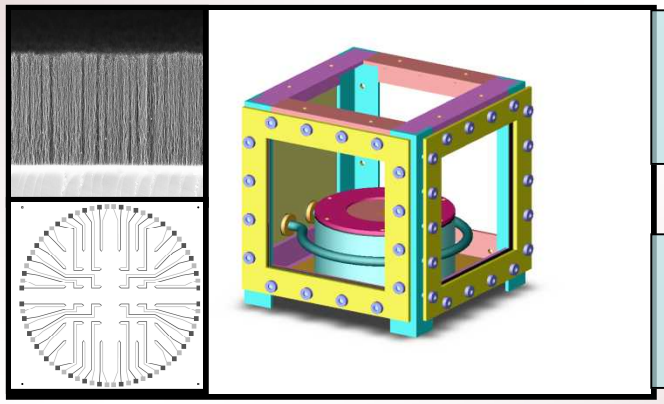

Thermal-Fluids Technologies

Emerging Technologies