# Proposal:
# Interdisciplinary Graduate Certificate in Nanotechnology

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## 1. General Description

This proposal recommends the establishment of a Graduate Certificate in Nanotechnology. This interdisciplinary certificate would be available to all degree-seeking as well as non-degree-seeking students enrolled in the Graduate School at Michigan Technological University.

**Title of Certificate: Graduate Certificate in Nanotechnology**

**Catalog Description**

> The Graduate Certificate in Nanotechnology recognizes advanced study of scientific, technological, and engineering topics in nanotechnology, including aspects of (i) characterization, (ii) micro- to nano-scale fabrication and control, and (iii) devices, systems and integration. The certificate also requires study of the societal and ethical implications of emerging technologies.

## 2. Rationale

Nanotechnology is a rapidly developing field that seeks to understand, control, and exploit new physical properties that arise in systems at length scales between atoms and bulk materials. Applications of nanotechnology, which already are emerging, are highly interdisciplinary and include virtually all fields and disciplines in engineering and the natural sciences. Some enthusiasts are calling nanotechnology the next "industrial revolution."

Michigan Tech has strong and growing research thrusts that deal with a broad range nanoscale science and engineering. Likewise, MTU has been moving to develop appropriate educational program in nanotechnology. While the National Academy of Sciences has advised against rushing to start new engineering and science undergraduate degree programs in nanotechnology [1], Michigan Tech has successfully developed and started an interdisciplinary minor in Nanoscale Science and Technology in fall 2005, and is planning to start a new Nanotechnology Enterprise in January 2008 with NSF funding. The new Multi-Scale Technologies Institute (MuSTI), under the direction of Craig Friedrich, serves as an umbrella organization to assist in

the coordination and development of these and related research and educational efforts (http://www.me.mtu.edu/Institutes/MuSTI/). In this context, we believe that the Graduate Certificate in Nanotechnology is a necessary and appropriate educational opportunity for postgraduate students that will offer them an attractive supplement to their graduate degrees in this era of rapid paced technological change. In addition to a required course on nanotechnology's societal implications, students will choose elective courses to broaden their exposure to the science and applications of nanotechnology in other disciplines, as well as to deepen their understanding in their primary areas of interest.

The Graduate Certificate in Nanotechnology is designed to:

(1) deepen students' understanding of technical aspects of nanoscale science, technology, and engineering;
(2) encourage students to pursue related interdisciplinary coursework outside their major;
(3) be flexible to allow for participation by students in diverse majors;
(4) familiarize students with the real and perceived societal implications of nanotechnology and other emerging technologies, which span from economics to ethics to politics.

## 3. Related Programs

Graduate certificates in nanotechnology or closely related fields exist at a few other institutions, including Lehigh University, Drexel University, the University of Pennsylvania, University of Massachusetts Lowell, Stanford University, and George Mason University. A small number of universities offer M.S. and Ph.D. degrees in nanotechnology [2]. This proposal is modeled in part on the graduate certificate program at University of Pennsylvania [3]. Two primary differences between this proposal and the U. Penn program are (i) U. Penn requires attendance at 6 seminars related to Nanoscale Science and Technology which this proposal does not, however (ii) this proposal requires all certificate seekers to take SS 5820 Societal Implications of Nanotechnology.

## 4. Projected Enrollment

Based on likely faculty participants and current graduate enrollments, we estimate that approximately 20 students may be enrolled at any time. In time we anticipate that this program would become available to students via Distance Learning.

## 5. Scheduling Plans

This graduate certificate program is primarily a regular (daytime) program.

## 6. Curriculum Design

A total of 15 credits are required for this certificate. Students must earn a grade of B or higher in each of the courses counting toward the certificate. As an interdisciplinary certificate, a maximum of 6 credits is allowed in courses at the 3000- and 4000- levels.

Required Courses:

(A) SS5820 Graduate Seminar in Societal Implications of Nanotechnology (2 credits)
This would be a new graduate-level version of SS 3820 Societal Implications of Nanotechnology, and has been proposed in the 2007 curriculum binder-process. (See the new course description below.)

(B) At least one course must be selected from the following list:
BE/MY 5750 Bioapplications of Nanotechnologies[†]
BL 5040/BL 5050 Electron Optical Methods of Analysis I and II:
Principles and Techniques for Biologists (must be selected as a pair to count toward the requirement)
MEEM 5640 - Micromanufacturing Processes
EE/MY 5430 - Electronic Materials
EE/MY 5460 - Solid State Devices
MY 4710 - Photonic Materials and Devices
MY 5550 - Solid Surfaces
PH 5530 - Selected Topics in Nanoscale Science and Technology

For convenience, relevant course descriptions are given below:

BE/MY 5750 - Bioapplications of Nanotechnologies[†]
The prospect of bioapplications of nanotechnologies, selected topics including nanodevices for biosensor and drug delivery, biocompatibility and toxicity of nanomaterials, nanostructured polymers for tissue engineering, design and operation of medical nanorobots, ethics and societal impacts of nanobiotechnology, etc.
Credits: 2.0 Lec-Rec-Lab: (2-0-0)
Semesters Offered: Fall - Offered alternate years beginning with the 2005-2006 academic year
Restrictions: Must be enrolled in one of the following Level(s): Graduate

BL 5040 - Electron Optical Methods of Analysis I: Principles and Techniques for Biologists
Hands-on course focusing on use of transmission electron microscopes. Topics include sample preparation for biology, transmission electron optics, specimen-beam interactions, operating parameter choices, image formation and processing. Successful completion of course is the prerequisite to

[†] Next offering of this course is uncertain.

becoming a certified operator, MTU Electron Optics Facility. (This is a half semester course.)
Credits: 2.0 Lec-Rec-Lab: (0-3-3)
Semesters Offered: Fall - Offered alternate years beginning with the 2002-2003 academic year
Restrictions: Must be enrolled in one of the following Level(s): Graduate

BL 5050 - Electron Optical Methods of Analysis II: Principles and Techniques for Biologists
Hands-on focusing on the use of transmission electron microscopes. Topics: sample preparation for biology, transmission electron optics, specimen-beam interactions, operating parameter choices, image formation and processing. Successful completion of course is the prerequisite to becoming a certified operator in the MTU Electron Optics Facility. (This is a half semester course)
Credits: 2.0 Lec-Rec-Lab: (0-3-3)
Semesters Offered: Fall - Offered alternate years beginning with the 2002-2003 academic year
Restrictions: Must be enrolled in one of the following Level(s): Graduate

MEEM 5640 - Micromanufacturing Processes
Introduces the processes and equipment for fabricating microsystems and the methods for measuring component size and system performance. Fabrication processes include microscale milling, drilling, diamond machining, and lithography. Measurement methods include interferometry and scanning electron microscopy. No credit for both MEEM4640 MEEM5640.
Credits: 3.0 Lec-Rec-Lab: (0-2-2) Semesters Offered: Spring
Restrictions: Must be enrolled in one of the following Level(s): Graduate
Pre-Requisite(s): MEEM 3502(C)

EE/MY 5430 - Electronic Materials
A study of the physical principles, operational characteristics, models, and basic applications of selected solid-state devices.
Credits: 3.0 Lec-Rec-Lab: (3-0-0)
Semesters Offered: Spring
Restrictions: Must be enrolled in one of the following Level(s): Graduate

EE/MY 5460 - Solid State Devices
A study of the physical principles, operational characteristics and models and basic applications of solid state devices such as p-n junctions, metalsemiconductor junctions and transistors.
Credits: 3.0 Lec-Rec-Lab: (3-0-0)
Semesters Offered: Fall

MY 4710 - Photonic Materials and Devices
The use of materials science and engineering principles in the design and processing of electronic materials and devices. Topics include operating principles of solid-state

electronic devices, electronic materials structure-processing-properties relationships, and materials issues in electronic device fabrication and performance.
Credits: 3.0 Lec-Rec-Lab: (3-0-0)
Semesters Offered: Spring

MY 5550 - Solid Surfaces
The performance, durability, and stability of composites, coatings, films, advanced ceramics, implants, and nano-technological products rely on the understanding, control and manipulation of surfaces and interfaces. This course provides both a fundamental and practical introduction to the concepts and theories of solid surfaces and solid-liquid interfaces. The capillary effects, electrical aspects of interfaces, and adsorption at materials surfaces, with their practical applications and consequences, are emphasized.
Credits: 3.0 Lec-Rec-Lab: (3-0-0)
Semesters Offered: Spring
Restrictions: Must be enrolled in one of the following Level(s): Graduate

PH 5530 - Selected Topics in Nanoscale Science and Technology
Presentation and discussion of selected topics in nanoscale science and engineering. Topics include growth, properties, applications, and societal implication of nanoscale materials. Evaluation: attendance and assignment.
Credits: 2.0 Lec-Rec-Lab: (2-0-0)
Semesters Offered: On Demand

Elective Courses:
Students must take from the following list of approved courses at least one course from each of the three topical groups: Characterization; Fabrication and Control; and Devices, Systems, and Integration [3]. Remaining credits may be taken from any of the topical groups or the "Other Electives" group. At least 6 credits in this graduate certificate program, not counting SS 5820, must be from outside of the student's home department. Students in interdisciplinary graduate degree programs and students not seeking a graduate degree must have their selection of elective courses approved by the MuSTI Associate Director for Education and Outreach, or in the absence of such an office, by a faculty member appointed by the Dean of the Graduate School. Underlined courses listed below satisfy part (B) of the "Required Courses" stipulation outlined above.

*1. Characterization*
BL 5040 - Electron Optical Methods of Analysis I: Principles and Techniques for Biologists (2)
BL 5050 - Electron Optical Methods of Analysis II: Principles and Techniques for Biologists (2)
BL 5060 - Biological Ultrastructure (4)
FW 5080 - Gene Profiling Analysis (2)
MY 4200 - Introduction to Scanning Electron Microscopy (2)
MY 5200 - Advanced Scanning Electron Microscopy (3)
MY 5250 - Transmission Electron Microscopy (3)

MY 5580 - Introduction to Scanning Probe Microscopy (2)

*2. Fabrication and Control*

BE 4700 - Biosensors: Fabrication and Applications (3)
EE 5470 - Semiconductor Fabrication (3) [co-listed with MY 5470]
EE 6480 - Thin Films (3) [co-listed with MY 6480]
MEEM 5640 - Micromanufacturing Processes (3)
MY 5470 - Semiconductor Fabrication (3) [co-listed with EE 5470]
MY 6480 - Thin Films (3) [co-listed with EE 6480]

*3. Devices, Systems, and Integration*

BE 5300 - Advanced Polymeric Biomaterials (3)
BE 5660 - Active Implantable Devices (3)
BE 5700 - Biosensors (3)
BE 5800 - Advanced Biomaterials Interfaces (3)
BE 5750 - Bioapplications of Nanotechnologies (2) [co-listed with MY 5750]
BL 5020 - Enzymology (3)
EE 5460 - Solid State Devices (3) [co-listed with MY 5460]
EE 5480 - Advanced MEMS (4) [co-listed with MY 5480]
MY 4240 - Introduction to MEMS (4)
MY 4240D - Introduction to MEMS (4)
MY 5480 - Advanced MEMS (4) [co-listed with EE 5480]
MY 4710 - Photonic Materials and Devices (3)
MY 5460 - Solid State Devices (3) [co-listed with EE 5460]
MY 5750 - Bioapplications of Nanotechnologies (2) [co-listed with BE 5750]

Other Electives:

BE 5440 - Genetic Engineering (3)
BL 5030 – Molecular Biology (3)
*CH 5310 - Advanced Inorganic Chemistry (3)
*CH 5410 - Advanced Organic Chemistry I (3)
*CH 5420 - Advanced Organic Chemistry II (3)
CH 5509 - Environmental Organic Chemistry (3)
CH 5570 - Advanced Biophysical Chemistry (3)
EE 5430 - Electronic Materials (3) [co-listed with MY5430]
FW 4089 - Bioinformatics (3)
FW 5085 - Functional Genomics and Biotechnology (3)
FW 5089 - Tools of Bioinformatics (4)
*MY 3700 - Electronic, Optical, and Magnetic Properties of Materials (4)
MY 5430 - Electronic Materials (3) [co-listed with EE5430]
MY 5550 - Solid Surfaces (3)
MY 6100 - Computational Materials Science and Engineering (3)
*PH 3410 – Quantum Mechanics I (3)
*PH 3411 – Quantum Mechanics II (3)
*PH 5410 – Quantum Mechanics I (3)
*PH 5411 – Quantum Mechanics II (2)

PH 5510 – Theory of Solids (3)
PH 5520 – Materials Physics (3)
PH 5530 - Selected Topics in Nanotechnology (2)

Due to the rapid developments in the field of nanotechnology, other appropriate electives may be substituted upon approval of the Multi-Scale Technologies Institute's Associate Director for Education and Outreach (or in the absence of such an office, by a faculty member appointed by the Dean of the Graduate School).

*These courses may count as electives only for students not enrolled in graduate degree programs in the respective home departments for these courses; e.g. Physics M.S. and Ph.D. candidates may not count PH3410, 3411, 5410 or 5411 toward the Graduate Certificate in Nanotechnology.

## 7. New Course Descriptions

SS 5820 Graduate Seminar in Societal Implications of Nanotechnology (2 credits)
This would be a new graduate-level version of SS 3820 Societal Implications of Nanotechnology, to be proposed in the curriculum binder-process in 2007. SS 3820 is currently being taught by visiting assistant professor Dr. Michael Bennett, and has been taught in the past by Dr. Bruce Seely. SS 5820 could be taught as soon as spring 2008.

Tentative catalog description:
Nanotechnology, which involves understanding and exploiting phenomena in materials or systems where at least one dimension is at the nanometer scale, spans virtually all scientific and engineering disciplines. This graduate course examines in a seminar format some of the likely implications of these developments for society. Attention will be given to the economic, social, ethical and moral, and political consequences of the unfolding development of science and engineering fields at the nanoscale.

Prior to the approval of this new course, students can satisfy the requirements of this certificate by taking SS 3820 plus one-credit independent study in SS 6500 - Independent Study/Directed Reading under the direction of the instructor of SS 3820.

## 8. Library and other Learning Resources.

No additional library or learning resources are required.

## 9. Computing Access Fees

No computing access fees are required beyond those normally incurred by enrolled graduate students.

## 10. Faculty Resumes

Key faculty for this graduate certificate program include the following, whose vitae are attached at the end of this proposal:

Michael Bennett, Ph.D., J.D. (Visiting Assistant Professor, Department of Social Sciences).
Paul Bergstrom, Ph.D. (Associate Professor, Department of Electrical and Computer Engineering; Associate Director for Research, Multi-Scale Technologies Institute).
John A. Jaszczak, Ph.D. (Professor, Department of Physics; Associate Director for Education and Outreach, Multi-Scale Technologies Institute; Adjunct Professor, Department of Materials Science and Engineering, Adjunct Professor, Department of Education).
Craig R. Friedrich, Ph.D. (Professor, Department of Mechanical Engineering-Engineering Mechanics; Director, Multi-Scale Technologies Institute).
Bruce E. Seely, Ph.D. (Professor and Chair, Department of Social Sciences).

Additional faculty and staff that are important to this program are those associated with the Multi-Scale Technologies Institute and the Engineering Physics Ph.D. program. Biographical information and additional details for these personnel may be found at:
http://www.me.mtu.edu/Institutes/MuSTI/research.htm and
http://www.phy.mtu.edu/Engphys/faculty.html .

## 11. Description of available/needed equipment.

No additional equipment is required beyond that currently available on campus.
On campus facilities are extensive, and include:
Hitachi S-4700 field emission scanning electron microscope
Hitachi FB-200A focused ion beam system
JEOL JSM-6400 scanning electron microscope
JEOL JEM-4000FX transmission electron microscope
Philips XL40 environmental scanning electron microscope
Scintag XDS-2000 powder x-ray diffractometer
Scintag XDS-2000 pole figure x-ray diffractometer.
Philips Electronic Instruments x-ray generator and Laue method diffractometer
Siemens D500 powder x-ray diffractometer
Molecular Beam Epitaxy system
Wave Guide Testing Optics Bench
Micromanipulator
Microtome and polishing machine
Dual-RF-plasma Chemical Vapor Deposition (CVD) System
Thermal Chemical Vapor Deposition (CVD) System
Dual-RF-plasma Pulsed-Laser Deposition (PLD) System
Microfabrication laboratory, etching, lithography, sputtering, evaporation and etching
Micromechanical machining laboratory

These and other facilities are described in more detail under http://www.nano.mtu.edu/nanofacilities.htm, http://mcff.mtu.edu/acmal/instrumentation.htm, and http://www.me.mtu.edu/Institutes/MuSTI/facilities.htm; however, these lists are by no means exhaustive.

## 12. Program Costs

There are no additional direct costs associated with establishing this graduate certificate program at this time. The sustainability of offering SS 5820 in the longer term may depend upon additional resources or continuation/conversion of a temporary faculty line.

## 13. Space

No additional space is required.

## 14. Policies Regulations and Rules

All policies, regulations and rules are described in Section 6 and follow University Senate policy for Graduate Certificates.

The Associate Director for Education and Outreach of the Multi-Scale Technologies Institute (MuSTI) shall assist the Graduate School in the administration of this certificate.

Recommendations for modification of the curricular requirements of this certificate shall be made through the MuSTI to the Dean of the Graduate School.

**15. Accreditation** (Not applicable)

**16. Internal Status of the Proposal**

On April 3, 2007, the Graduate Faculty Council approved that this proposal be forwarded to the University Senate. This draft includes suggested modifications made by the Graduate Faculty Council and the Senate Curricular Policy Committee.

Revised version submitted October 8, 2007 to the Provost office, Dean of the Graduate School and President of the Graduate Faculty Council, and the University Senate for advice and approval.

**17. Planned Implementation**

This program could begin starting in spring semester, 2008.

**Citations:**

[1] Committee for the Review of the National Nanotechnology Initiative, Division of Engineering and Physical Sciences, National Research Council. "Small Wonders, Endless Frontiers: A Review of the National Nanotechnology Initiative." National Academy Press, Washington, D. C., pp. 17-19 (2002).

[2] <http://www.nano.gov/html/edu/eduunder.html> National Nanotechnology Initiative, University Education. Listed March 1, 2007.

[3] K. Cowan and Y. Gogotsi, *Journal of Materials Education* **26** (2004) 147-152.

## Listing of Prerequisites to Required and Elective Courses

| | Prerequisites and/or Restrictions |
|---|---|
| BE 4700 | many not be freshman or sophomore |
| BE 5300 | graduate enrollment |
| BE 5440 | graduate enrollment |
| BE 5660 | graduate enrollment |
| BE 5700 | graduate enrollment |
| BE 5750 | graduate enrollment |
| BE 5800 | graduate enrollment |
| BE 5940 | graduate enrollment and instructor permission |
| BL 5020 | graduate enrollment |
| BL 5030 | graduate enrollment |
| BL 5040 | graduate enrollment |
| BL 5050 | graduate enrollment |
| BL 5060 | BL 5040 or BL 5050 |
| CH 5310 | CH 4320 |
| CH 5410 | graduate enrollment |
| CH 5420 | graduate enrollment |
| CH 5509 | CE 4501 or CH 3510 |
| CH 5570 | CH 3520 |
| EE 5430 | graduate enrollment |
| EE 5460 | none |
| EE 5470 | senior or graduate enrollment |
| EE 5480 | EE 4240 or MY 4240 and senior or graduate enrollment |
| EE 6480 | graduate enrollment |
| FW 4089 | may not be freshmen or sophomore |
| FW 5080 | graduate enrollment and instructor permission |
| FW 5085 | senior or graduate enrollment |
| FW 5089 | graduate enrollment |
| MEEM 5640 | MEEM 3502(C) |
| MY 3700 | (PH 2200 or PH 2260) and MA 3160 and (MA 3520 or MA 3530) or (MA 2321 and MA 3521) |
| MY 4200 | none |
| MY 4240 | senior or graduate enrollment |
| MY 4240D | senior or graduate enrollment |
| MY 4710 | none |
| MY 5200 | graduate enrollment |
| MY 5250 | graduate enrollment |
| MY 5430 | graduate enrollment |
| MY 5460 | none |
| MY 5470 | senior or graduate enrollment |
| MY 5480 | EE 4240 or MY 4240 and senior or graduate enrollment |
| MY 5550 | graduate enrollment |
| MY 5580 | graduate enrollment |
| MY 5750 | graduate enrollment |
| MY 6100 | graduate enrollment |
| MY 6480 | graduate enrollment |

| | |
|---|---|
| PH 3410 | PH2400 and MA3530 |
| PH 3411 | PH3410 |
| PH 5410 | graduate enrollment |
| PH 5411 | PH5410 |
| PH 5530 | senior or graduate enrollment |
| SS 5820 | graduate enrollment |

## BIOGRAPHICAL SKETCH

**MICHAEL G. BENNETT**
Social Sciences department
Michigan Technological University
1400 Townsend Drive
Houghton, MI 49931-1295
1.906.487.2413 (o)
1.906.487.2468 (f)
mbennett@mtu.edu

**EDUCATION**

**Rensselaer Polytechnic**, Ph.D., Science & Technology Studies — August 2006
Honors: DeWitt-Wallace Foundation Fellow;
Rensselaer Graduate Fellow; Alger Research Fellow
Activities: Graduate Committee, member;
Tennis Club, member

**Harvard Law School**, J.D. — June 1998
Activities: Harvard Law Record, Columnist
Campus Calendar Newspaper, Food Critic
Black American Law Student Association, Section Rep.
Asian Law Society, Member
Harvard Shao Lin Kung Fu Club, Member

**Florida A&M University,** B.S. Applied Physics — June 1995
Mathematics Minor
Honors: Summa Cum Laude; Dean's List;
Florida Undergraduate Scholar; Conn Memorial Scholar
Activities: National Society of Physics Students, Member

**APPOINTMENTS**

**Michigan Technological University**, Houghton, MI — 2006-Present
Visiting Assistant Professor teaching and performing research on the ethical, legal and societal implications of emerging nanotechnoscience.

**University of Virginia**, Charlottesville, VA — 2004-2005
Worked as a research and teaching fellow.

**Conduit Technology Partners/The Tiptree Group**, Chicago, IL — 2001-Present
Co-founder and managing director of an intellectual property consultancy specializing in patent law, copyright law and technology transfer.

**Polytechnic University**, New York, NY — Spring 2001
Worked as a lecturing adjunct professor of intellectual property and management studies.

**Florida A&M University**, Tallahassee, FL — 2000-2001
Worked as a lecturing adjunct professor of Physics and Physical Science.

**Brinks, Hofer, Gilson, Lione**, Chicago, IL — 1998-2000
Worked as an intellectual property law firm associate, focused on patent, trademark and copyright law.

**Federal Deposit Insurance Corporation**, New York, NY Summer 1997
Worked as a law clerk researching and writing on issues concerning banking laws and regulations.

**Brinks, Hofer, Gilson, Lione**, Chicago, IL Summer 1996
Worked as a law clerk researching and writing on intellectual property issues ranging from trademark protection to a draft of the Illinois Digital Signature Act.

**Florida A&M University, Physics Dept.**, Tallahassee, FL 1990-1994
Worked as a research assistant studying the partial differential equations that govern collisions between atoms and molecules.

**Lawrence Livermore Natl. Laboratory**, Livermore, CA Summer 1994
Worked in the Advanced Lasers Division and studied the thermally sensitive regions of several types of laser crystals.

**Lawrence Livermore Natl. Laboratory**, Livermore, CA Summer 1993
Worked in the Advanced Lasers Division researching the thermal depolarization of Helium-Neon laser components.

**Argonne Natl. Laboratory**, Argonne, IL Summer 1992
Worked as a research assistant studying the Bismuth-Germanium-Oxide detectors of the ATLAS linear accelerator.

**PUBLICATIONS**

**"Does Existing Law Fail to Address Nanotechnoscience?"** *IEEE/Technology and Society Magazine*, Winter 2004.

**"The Adoxic Adventures of John Henry in the 21st Century,"** *Socialism & Democracy*, Special Issue on Race and Science Fiction, Winter 2006.

**COLLABORATORS IN THE PAST 48 MONTHS**

Ron Eglash, Rensselaer Polytechnic Institute.
Steven Maynard, Conduit Technology Partners.

**THESIS ADVISOR** Langdon Winner, Rensselaer Polytechnic Institute.

**BIOGRAPHICAL SKETCH**

***PAUL L. BERGSTROM***
*Associate Professor, Electrical and Computer Engineering*

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***A. Professional Preparation:***

| | | | |
|---|---|---|---|
| The University of Michigan | Electrical Engineering | Ph.D. | 1996 |
| The University of Michigan | Electrical Engineering | M.S. | 1993 |
| The University of Minnesota | Electrical Engineering | B.S. *summa cum laude* | 1989 |

***B. Appointments:***

| | |
|---|---|
| 9/06–present | Associate Professor, Department of Electrical and Computer Engineering, Michigan Technological University, Houghton, MI |
| 9/00–9/06 | Assistant Professor, Department of Electrical and Computer Engineering, Michigan Technological University, Houghton, MI |
| 4/96–9/00 | Principle Staff Engineer, Motorola Inc., Semiconductor Product Sector, Sensor Products Division, Transportation Systems Group, Tempe, AZ |
| 9/93–4/96 | Semiconductor Research Corp., Graduate Fellow, The University of Michigan, Department of Electrical Engineering and Computer Science, Ann Arbor, MI |
| 9/89–9/90 | Design Engineer, Rosemount, Inc., Aerospace Division, Burnsville, MN, Air Products Group |

***C. Publications:***

***(i) Selected Related Publications:***

- P. S. K. Karre, P. L. Bergstrom, G. Mallick and S. P. Karna, "Effect of tunnel resistance in the strong tunneling regime on the conductance of the Single Electron Transistors fabricated using Focused Ion Beam etching", *The 25th Army Science Conference (Paper # MP-12)*, Orlando, FL, 27 – 30 November 2006, also presented.
- P. S. K. Karre, P. L. Bergstrom, M. Govind, and S. P. Karna, "Single Electron Transistor Fabrication using Focused Ion Beam Direct Write Technique," *Digest 17th Annual SEMI/IEEE Advanced Semiconductor Manufacturing Conference (ASMC 2006),* pp. 257 – 260, Boston, MA, 21 – 24 May 2006.
- J. Z. Wallner, N. Nagar, C. R. Friedrich, and P. L. Bergstrom, "Macro porous silicon as pump media for electro-osmotic pumps," accepted for publication in *physica status solidi a*.
- J. Z. Wallner, K. S. Hunt, H. Obanionwu, M. C. Oborny, P. L. Bergstrom, and E. T. Zellers, "An integrated vapor source with a porous silicon wick," accepted for publication in *physica status solidi a*.
- J. Z. Wallner and P. L. Bergstrom, "A porous silicon based particle filter for microsystems," accepted for publication in *physica status solidi a*.

***(ii) Other Related Publications:***

- P. Santosh Kumar Karre and P. L. Bergstrom, "Fabrication of Quantum Islands for Single Electron Transistors using Focused Ion Beam Technology," *Proc. IWPSD'05: Thirteenth Int'l Workshop on the Physics of Semiconductor Devices*, New Delhi, India, vol. II, pp. 1637–1641, December 2005.
- J. Zheng, M. Christophersen, and P. L. Bergstrom, "Thick Macroporous Membranes Made of P-Type Silicon," *physica status solidi a*, vol. 202(8), pp. 1662–1667, June 2005.
- J. Zheng, M. Christophersen, and P. L. Bergstrom, "Formation Technique for Macroporous Morphology Superlattice," *physica status solidi a*, vol. 202(8), pp. 1402–1406, June 2005.
- T. W. Wallner, A. D. Oliver, and P. L. Bergstrom, "Scribe and Break for Post Release MEMS Die Separation," *Proc. IMECE: 2004 ASME Int'l Mechanical Engineering Congress*, *EPP-Vol. 4 titled Electronic and Photonics Packaging, Electrical Systems Design and Photonics, and Nanotechnology – 2004*, Anaheim, CA, pp. 329–336, November 2004.
- E. T. Zellers, W. H. Steinecker, G. R. Lambertus, M. Agah, C.-J. Lu, H. K. L. Chan, J. A. Potkay, M. C.

Oborny, J. M. Nichols, A. Astle, H. S. Kim, M. P. Rowe, J. Kim, L. W. da Silva, J. Zheng, J. J. Whiting, R. D. Sacks, S. W. Pang, M. Kaviany, P. L. Bergstrom, A. J. Matzger, Ç. Kurdak, L. P. Bernal, K. Najafi, and K. D. Wise, "A Versatile MEMS Gas Chromatograph for Determinations of Environmental Vapor Mixtures," *Digest Solid-State Sensor, Actuator, and Microsystems Workshop (Hilton Head 2004)*, Hilton Head Island, SC, pp. 61–66, June 2004. (Invited)

***D. Synergistic Activities:***

- Associate Director, Multi-Scale Technologies Institute, Michigan Technological University.
- Director, Microsystems Materials and Devices Laboratory, encompassing the semiconductor fabrication facilities at Michigan Technological University
- Co-advisor for Wireless Integrated Microsystems Enterprise Team at Michigan Tech. University, sponsored by the NSF ERC on WIMS
- Reviewer for *IEEE J. Micro Electro Mechanical Systems*, *Trans. Electron Devices* and *Electron Device Letters*, *Sensors and Actuators A: Physical, Sensors and Actuators B: Chemical SME J. Manufacturing Systems*

***E. Collaborators & Other Affiliations:***

***(i) Collaborators:***
Helmut Föll (Christian-Albrechts U.–Kiel), Craig Friedrich (MTU), John Jaszczak (MTU), Shashi Karna (Army Research Laboratory), Miguel Levy (MTU), Joseph Lindgren (Micron Technology, Inc.), Govind Mallick (Army Research Laboratory), Michele Miller (MTU), Andrew Mason (Mich. State U.), Peter Moran (MTU), Khalil Najafi (U. Mich), Ravindra Pandey (MTU), Mikko Ritala (U. Helsinki), Tom Ritzdorf (Semitool, Inc.), Raymond Roop (Freescale Semiconductor, Inc.), Thomas Schuelke (Fraunhofer Soc.–USA), Orhan Soykan (Medtronic, Inc.), Larry Sutter (MTU), Douglas Swenson (MTU), Thomas van Dam (MTU), Kensall Wise (U. Mich.), Yoke Khin Yap (MTU), Edward Zellers (U. Mich.)

***(ii) Graduate and Postdoctoral Advisors:***

| | |
|---|---|
| Dr. Kensall D. Wise | Director, Michigan Engineering Research Center on Wireless Integrated MicroSystems (WIMS), Department of Electrical Engineering and Computer Science, The University of Michigan |

***(iii) Thesis Advisor and Postgraduate-Scholar Sponsor:*** (Current students: 8 PhD, 3 MS)
Doctoral Students: Hui Xia, MSE (expected August 2007); P. Santosh Karre, EE (expected August 2007); Jianlin Liang, EE (expected December 2007); Daw Don Cheam, EE (expected August 2008); L. Kumar Vanga, EE (expected December 2008); Manoranjan Acharya, EE (expected September 2008); Madhusudan Savaikar, Physics (expected December 2008); Ghous Narejo, EE (expected December 2008).
Masters Students: Shwetha Bolagond, EE (expected May 2007); Rodney Snow, EE (expected May 2007); Michael Oisten, EE (expected May 2008).
Graduates: Aditya Kapoor, MS EE, May 2006; Jin Zheng Wallner, Ph.D EE, April 2006; Melissa Trombley, NDSEG Fellow, Ph.D EE, October 2005; Thomas Wallner, MS EE, July 2004; Yan Yang, MS EE, July 2004.

## BIOGRAPHICAL SKETCH

### *CRAIG FRIEDRICH*

### Professor, Department of Mechanical Engineering and Engineering Mechanics

***Office:*** Michigan Technological University, ME-EM Department, 1400 Townsend Drive, Houghton, MI 49931 Phone: 906-487-1922, Fax: 906-487-2822, Email: craig@mtu.edu

***A. Education:***

| | | |
|---|---|---|
| Louisiana Tech University | B.S., Mechanical Engineering | 1978 |
| Louisiana Tech University | M.S., Mechanical Engineering | 1981 |
| Oklahoma State University | Ph.D., Mechanical Engineering | 1987 |

***B. Appointments:***

**Current**: Professor, Department of Mechanical Engineering & Engineering Mechanics, Michigan Technological University, Director - Multi-Scale Technologies Institute

**1995-1997**: Associate Director, Institute for Micromanufacturing, Louisiana Tech University

**1994-1997**: Group Leader, Micromechanical Machining Processes Laboratory, Institute for Micro-manufacturing, Louisiana Tech University, 1994-1997

**1991-1997**: Associate Professor, Department of Mechanical and Industrial Engineering, Louisiana Tech University

**1987-1991**: Assistant Professor, Department of Mechanical and Industrial Engineering, Louisiana Tech University

**1980-1981**: Nuclear Engineer, U.S. Navy, Norfolk Naval Shipyard

**1978-1980**: Senior Design Engineer, Pangborn Division of Carborundum Corp.

***C. Selected Papers:***


- Arcand,B, Butala,N, Shyamsunder,S, Friedrich,C, "A Fluid Actuator for Thin Film Electrodes," *ASME Journal of Medical Devices,* (1) 70-78, 2007.
- Friedrich,C, Avula,R, Gugale,S, "A Fluid Microconnector Seal for Packaging Applications," *Journal of Micromechanics and Microengineering* Vol 15:1115-1124, 2005.
- Friedrich,C and Kulkarni,V, "Effect of Springback on Micromilling Forces," *Microsystems Technology Journal*, 10(6-7), 2004, pp. 472-477.
- Arcand,B, Butala,N, Friedrich,C, "Design and Modeling of an Active Positioning Device for a Perimodular Cochlear Electrode Array," *Microsystems Technology Journal,* 10(6-7), 2004, pp.478-483.
- J.Li, C.R.Friedrich, R.S.Keynton,"Design and Fabrication of a Miniaturized, Integrated, High Frequency Acoustical Lens-Transducer System," *J. of Micromechanics and Microengineering*, 12 (3), pp.219-228, May 2002.
- C.R.Friedrich,"Micromechanical Machining of High Aspect Ratio Prototypes," *Microsystems Technology Journal*, 8 (4/5), pp. 343-347, May 2002.
- C.Friedrich,"Near-Cryogenic Machining of Polymethyl Methacrylate for Micromilling Tool Development," J. *Materials and Manufacturing Processes,* 15(5): 667-678, 2000.
- C.Friedrich, R.Keynton, M.Vasile, and R.Warrington, "Development of a Core Curriculum in Miniaturization Technologies," *ASEE J. of Engineering Education 1998 Supplement*, pp.567-574.
- C.Friedrich, P.Coane, J.Goettert, and N.Gopinathin, "Direct Fabrication of Deep X-ray Lithography Masks by Micromechanical Milling," *J. Precision Engr*., 22(3), pp. 164-173,1998.

- C.R.Friedrich, "Micromechanical Machining of High Aspect Ratio Prototypes," *Proceedings of Conference on High Aspect Ratio Microsystems '01*, Baden-Baden, Germany, pp.99-100, June 2001.

***D. Synergistic Activities:***

- Dr. Friedrich is the founder and Director of the Multi-Scale Technologies Institute (MuSTI) at Michigan Tech www.me.mtu.edu/Institutes/MuSTI/. MuSTI is comprised of more than 30 faculty affiliates who share the vision that devices and systems can have increased functionality by integrating phenomena across many dimensional scales. MuSTI became operational in late 2005 and already has more than $4 million of funded research by 18 faculty, 3 post-doctoral fellows, and 29 PhD students. MuSTI is also home to the Undergraduate Minor Degree in Nanoscale Science and Technology and the Graduate Certificate in Nanotechnology.
- The NSF ERC for Wireless Integrated Microsystems has a particularly strong component in education from K-12 to the Engineering Enterprise in Integrated Microsystems. This outreach has provided training for classroom teachers in the field of microtechnologies, will provide experimental hardware to high school students, and will attempt to attract under-represented minorities into engineering and science. Dr. Friedrich chaired the ERC Science Teacher Workshop in 2003 "*Linking Education with Research*" and the Native American Student Workshop in 2005. These workshops placed high school teachers and under-represented students in the microfabrication laboratories at MTU and gave them hands-on experiences to take back to the classroom, in addition to creating and archiving appropriate lesson plans.
- Dr. Friedrich strongly believes in the integration of research and student learning. Working on a past NSF Combined Research and Curriculum Development grant, he developed courses in micromechanical machining and micrometrology that were the technical focus of the research. Those quarter-term courses were taught multiple times while at Louisiana Tech University and have been integrated into a one-semester course now taught at Michigan Tech. During spring 200 and 2005, the course was taught via distance technologies to the University of Michigan and several companies. In addition to course development, a CD-ROM tutorial and a web site were created to serve as reference materials for students. The web site is located at www.me.mtu.edu/~microweb.

***E. Collaborators & Other Affiliations:***

***(i) Collaborators:***
Dr. Tim Ameel (University of Utah), Mr. Philip Coane (Louisiana Tech University), Dr. Rob Keynton (University of Louisville), Dr. Mike Vasile (Sandia National Lab). There are numerous ERC collaborators at the University of Michigan (Richard Brown, Carlos Mastrangelo, Leo McAfee, Khalil Najafi, Clark Nguyen, Ken Wise, Ted Zellars, and others) and Michigan State University (Dean Aslam, Percy Pierre).

***(ii) Dissertation Advisor:***
James K. Good, Oklahoma State University.

***(iii) Graduate students in last 5 years:***

N. Nagar 2006 (Pi Technologies), E. Burns 2005 (US Steel), S. Thomas 2005 (Intel), S. Gugale 2005 (Cummins Engine), B. Arcand 2005 (Boston Scientific), S. Shyamsunder 2004, Y. Zhan 2003, C. Kulkarni 2003 (Cummins Engine), N. Butala 2003, R. Avula 2002, V. Kulkarni 2001 (Norman Noble, Inc.).

53 total graduate students graduated with 6 additional in progress.

## JOHN A. JASZCZAK

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***Education***

Ph.D. (Physics), The Ohio State University, 1989. Advisor: Professor W. F. Saam.
Dissertation: "Facets and Roughening in Crystals and Quasicrystals."
M.S. (Physics), The Ohio State University, 1985.
B.S. *with Highest Honors* (Physics), Case Western Reserve University, 1983.

**Professional Experience**

| | | |
|---|---|---|
| Michigan Technological University<br>Houghton, Michigan | Professor<br>Associate Professor<br>Assistant Professor<br>Department of Physics | 9/2006-present<br>9/1997-present<br>9/1991-8/1997 |
| | Associate Director for Education and Outreach, MTU Multiscale Technologies Institute | 4/2006-present |
| | Adjunct Professor<br>Materials Science and Engineering | 6/2006-present |
| | Adjunct Associate Professor<br>Department of Education | 10/2004-present |
| | Adjunct Curator<br>Seaman Mineral Museum | 8/1992-present |
| United States Air Force<br>Office of Scientific Research | Summer Faculty<br>Research Associate | 7/1/93-8/25/93 |
| Argonne National Laboratory<br>Argonne, Illinois | Postdoctoral Appointee<br>Materials Science Division<br>Interface Group | 6/1989-8/1991 |

## Selected Publications:

1. "Micro- and nano-scale graphite cones and tubes from Hackman Valley, Kola Peninsula, Russia." J. A. Jaszczak, S. Dimovski, S. A. Hackney, G. W. Robinson, and Y. Gogotsi. (Letter submitted to *American Mineralogist*, 10/4/2005).
2. "Developing Nano Education at a Technological University: Science, Technology and Societal Implications of Nano." J. A. Jaszczak and B. E. Seely. In: *Nanoscale Science and Engineering Education: Issues, Trends and Future Directions,* A. E. Sweeney and S. Seal, Eds. American Scientific Publishers. (In press.)
3. "A mechanism for spatial organization in quantum dot self-assembly." D. Gao*, A. Kaczynski‡, and J. Jaszczak. *Applied Physics Letters* 86, 133102 1-3 (2005). Also published in *Virtual Journal of Nanoscale Science & Technology* (http://www.vjnano.org) 11(13), April 4, 2005.
4. "Naturally occurring graphite cones." J. A. Jaszczak, G. W. Robinson, S. Dimovski, and Y. Gogotsi. *Carbon* 42, 2085-2092 (2003). This work was also selected for featuring on the cover of *Carbon* in 2004 and 2005.
5. "Monte Carlo simulations of surface phase transitions in a modulated layered structure." D. Gao* and J. A. Jaszczak, *Physical Review B* **67**, 155420 1-7 (2003).

6. "Multiple length scale growth spirals in metamorphic graphite {001} surfaces studied by atomic force microscopy." J. Rakovan and J. A. Jaszczak. *American Mineralogist* **87** 17-24 (2002).
7. "Disclinations in unusual graphite crystals from anorthosites of Ukraine." V. N. Kvasnitsa, V. G. Yatsenko, and J. A. Jaszczak. *Canadian Mineralogist* **37**, 951-960 (1999).
8. "Roughening and Preroughening of Diamond-Cubic {111} Surfaces." D. L. Woodraska* and J. A. Jaszczak. *Physical Review Letters* **78**, 258-261 (1997).
9. "Graphite: Flat, Fibrous and Spherical." J. A. Jaszczak, In, *Mesomolecules: From Molecules to Materials*, edited by G. D. Mendenhall, J. Liebman and A. Greenberg (Chapman & Hall, New York, 1995) pp. 161-180.
10. "A Monte Carlo Simulation Method for {111} Surfaces of Silicon and Other Diamond-Cubic Materials", D. L. Woodraska* and J. A. Jaszczak.

**Ph.D. student advisee.* [‡]*Undergraduate student advisee.*

***Synergistic Activities:***

1. "NUE: Undergraduate Exploration of Nano-Science, Applications and Societal Implications at Michigan Tech" PI for NSF-funded project (~$100k) in 2003-2005 leading a group of approximately 20 faculty participating in introducing various aspects of nano-scale science, technology and implications into MTU's undergraduate curriculum. Proposed a new interdisciplinary minor in "Nanoscale Science and Engineering (Nanotechnology)", now offered starting fall 2005. PI for NSF grant"NUE: Michigan Technological University Nanotechnology Enterprise" ($200k) starting January 2008.
2. Lead development of the Engineering Physics Ph.D. program at MTU that began in 2002. Serve as Engineering Physics Ph.D. graduate studies committee chair, 2002-present. Served as Physics Graduate Studies Committee chair 1997-2002. Currently serves as Undergraduate Studies Committee chair.
3. As adjunct curator of the A. E. Seaman Mineral Museum, the Mineralogical Museum of the State of Michigan, help to develop the academic role of the museum for the Michigan Tech community and surrounding communities. As chair of the Seaman Mineral Museum Society, help to promote the museum nationally and internationally and promote the museum's mission.
4. Chair, Physics Department Graduate Studies Committee: 1997-2002. Work with all aspects of program development, student advising, recruiting and program assessment. Helped to lead the effort to develop and implement the new Ph.D. in Engineering Physics at MTU, which was State Academic Board and the MTU Board of Control in December, 2001. Continuing role as department assessment coordinator for physics graduate programs.
5. Present lectures and workshops, "Exploring Nanotechnology through Carbon Nanotubes", to local high school students and MTU freshmen engineering majors, 2004-present.
6. Work with MTU Education Department to (i) develop new teaching certification programs in Integrated Science and in Physical Science (ii) prepare review materials for review of Physics secondary education certification program

***Collaborators in the past 48 months:***

Yury Gogotsi, Svetland Dimovski (Drexel University)
Da Gao, Bruce Seely, Michele Miller, Gerry Caneba, George Robinson, Steve Hackney (MTU)
John Rakovan (Miami University, Oxford, Ohio)

## *Advisors*

Doctoral thesis advisor: W. F. Saam, Ohio State University
Postdoctoral advisor: D. Wolf, Argonne National Laboratory

# Biographical Sketch: Bruce E. Seely

Department of Social Sciences, Michigan Technological University
1400 Townsend Drive
Houghton, Michigan 49931-1295
email: bseely@mtu.edu ; phone: 906/487-2113

**Professional Preparation**

B.A., *cum laude,* St. Lawrence University, Canton, New York, May 1975
M.A., University of Delaware, Newark, Delaware, June 1977
Ph.D., History of Technology, University of Delaware, Newark, Delaware, June 1982

**Professional Appointments**

Assistant Professor of History, Texas A&M University, 1981-1986.

Professor of History and of Science, Technology and Society, Department of Social Sciences, Michigan Technological University. (Assistant Professor, 1986-1988; Associate Professor, 1988-1997); Department Chair, beginning August 2002

Program Director for Science and Technology Studies, Directorate for Social, Behavioral and Economic Sciences, National Science Foundation, July 2000-August 2002.

**Publications (most closely related to the project)**

John Jaszczak and Bruce E. Seely, "Developing Nano Education at a Technological University: Science, Technology, and Societal Implications of Nanotechnology," in Aldrin E. Sweeney & Sudipta Seal, eds., **Nanoscale Science and Engineering Education: Issues, Trends and Future Directions** (American Scientific Publishers, forthcoming, 2007).

"Societal Implications of Emerging Science and Technologies: A Research Agenda for Science and Technology Studies (STS)," ," **Societal Implications of Nanoscience and Nanotechnology II: Maximizing Human Benefit**: Report of the National Nanotechnology Initiative Workshop, December 3-5, 2004, Arlington, VA, Mihail C. Roco and Williams Sims Bainbridge, eds. (Springer Science and Business Media, 2006), pp. 211-23.

"Education Opportunities related to the Societal Implications of Nanotechnology," **Societal Implications of Nanoscience and Nanotechnology II: Maximizing Human Benefit***:* Report of the National Nanotechnology Initiative Workshop, December 3-5, 2004, Arlington, VA, Mihail C. Roco and Williams Sims Bainbridge, eds. (Springer Science and Business Media, 2006), pp. 327-31.

"Patterns in the History of Engineering Education Reform: A Brief Essay," for National Academy of Engineering**, Engineer of 2020: National Education Summit** (National Academies Press, 2005), pp. 114-130.

"The Other Re-engineering of Engineering Education, 1900-1965," **Journal of Engineering Education** 88, no. 3 (July 1999): 285-94 (William Elgin Wickenden Award, American Society for Engineering Education, for the best article published in the Society's journal in 1999).

**Publications (significant other publications)**

Mark Rose, Bruce Seely, and Paul Barrett**, "The Best Transportation System in the World:" Railroads, Trucks, Airlines, and American Public Policy in the Twentieth Century** (Columbus: Ohio State University Press, 2006).

**Building the America Highway System: Engineers as Policy Makers.** (Philadelphia: Temple University Press, 1987).

"The Scientific Mystique in Engineering: Highway Research in the Bureau of Public Roads, 1918-1940," **Technology and Culture** 25 (October 1984): 798-831; reprinted in Terry S. Reynolds, ed., **The Engineer in America: A Historical Anthology from *Technology and Culture*** (Chicago: University of Chicago Press, 1991), pp. 309-42.

"European Contributions to American Engineering Education: Blending Old and New," **Quaderns d'Histoira del'Enginyeria** III (1999): 25-50. (Published by the Escola Tecnica Superior d'Enginyers Industrial de Barcelona, Spain.)

**Synergistic Activities**

Co-PI with John Jaszczak,, et.al., National Science Foundation, Nanoscale Science and Engineering Competition, " NUE: Undergraduate Exploration of Nano-science, Applications, and Societal Implications at Michigan Tech," 2003 ($100,000).

Founding Co-Editor-in-Chief of **Comparative Technology Transfer and Society**, (Johns Hopkins University Press), April 2003.

## Collaborators:

Paul Barrett, Illinois Institute of Technology
Terry Reynolds, Michigan Technological University
Mark Rose, Florida Atlantic University
Donald Klingner, University of Colorado -Colorado Springs

## Advisors:

Engene S .Ferguson, University of Delaware (deceased)
Glenn Porter, Hagley Museum (retired)

## Advisees:

Teresa Kynell, Northern Michigan University (deceased)
Randall Chafy, Northern Telecom, Ottawa, Canada