

LETTER OF NOTIFICATION – 3 NEW OPTION, CONCENTRATION, EMPHASIS

- 1. Institution submitting request:** University of Arkansas – Fayetteville
- 2. Contact person/title:** Sharon L. Gaber
Provost and Vice Chancellor for Academic Affairs
- 3. Phone number/e-mail address:** 479-575-5459 / sgaber@uark.edu
- 4. Proposed effective date:** Fall 2013
- 5. Title of existing degree program:**
- There is no nanotechnology degree program at the University of Arkansas currently.
- 6. CIP Code:** 14.1801
- 7. Degree Code:** N/A
- 8. Proposed name of new option/concentration/emphasis:** Nanotechnology Minor

9. Reason for proposed action:

Nanotechnology is a rapidly developing interdisciplinary field that holds great promise for new applications in a wide range of industries that have large societal impact, including consumer goods, electronics, computers, energy, biotechnology, and medicine. It is projected that 2 million workers are needed in nanotechnology-based businesses by 2020 in the United States alone ([Roco, Mirkin, and Hersam, 2010](#)). This field is expected to continue to grow and increasingly in need of trained scientists and engineers. While there are strong research and education activities and courses at the graduate level at the University of Arkansas (UA), most UA undergraduate students never experience any formal classroom education in nanotechnology. We proposed to establish an interdisciplinary minor program of undergraduate study in nanotechnology that will help participating students prepare for a career in this emerging growing field.

This Nanotechnology Minor Program is built upon the considerable existing level of faculty expertise and facilities in nanoscience and engineering within the College of Engineering (COE), the J. William Fulbright College of Arts and Sciences (CAS), and the Institute for Nanoscience and Engineering (INSE). Initial funding of \$200K from the National Science Foundation (NSF) Nanotechnology Undergraduate Education (NUE) in Engineering Program served as a catalyst for preparing for establishing this new minor program and an additional \$25K was obtained from UA Honors College to supplement the cost of developing an interdisciplinary Nanotechnology Laboratory course as a required course for this minor program.

Nanotechnology involves a broad field of study with a number of different major directions, such as synthesis of nanomaterials, fabrication and integration of nanostructures for device and

sensing applications, utilization of novel optical, electrical, and mechanical properties for a wide range of application, and integration of bio/abio systems. Nanotechnology Minor is an interdisciplinary program that is designed to provide students with foundational knowledge and skills related to the emerging field of nanotechnology, including hands-on experience in several major areas of nanotechnology, such as synthesis of nanomaterials, nanoscale imaging, nanostructure assembly and manipulation, device and system integration, and performance evaluation. Nanotechnology Minor curriculum provides students with a coherent field of study that not only covers the basic skills in nanotechnology, but also emphasizes different areas of interest of students from participating departments. We have assembled model programs for students from each participating department. These model programs are presented in section 10.

10. Provide the following:

a. Curriculum outline - List of courses in new option/concentration/emphasis – Underline required courses

The Nanotechnology Minor draws faculty expertise and course work from the COE and the CAS and utilizes the state-of-the-art equipment and facilities at the INSE. The Nanotechnology Minor is intended to prepare participating students for careers in which nanotechnology is playing an increasingly important role, and to increase students' research competitiveness for graduate studies. The Nanotechnology Minor is designed to be accessible to students majoring in Engineering, Physics, or Chemistry & Biochemistry. It is open to all students who have the necessary prerequisites to enroll in the courses that constitute the minor.

Students wishing to participate in the Nanotechnology Minor must declare participation formally. The students are required to meet with the faculty coordinator of individual department who will help the student to develop a list of courses suitable for the minor and a schedule for taking those courses. Examples of model programs for each participating department are given below.

Students need to take a total of 15 credit hours, which includes 6 credit hours of required courses and 9 credit hours of elective courses and must earn a grade of 'C' or better for all courses used to fulfill the requirements of the Nanotechnology Minor.

6 hours of required courses:

(1) BENG 4753/BENG 4753H/BMEG 4103/BMEG 4103H/CHEM 4153/CHEM 4153H/MEEG 4323/MEEG 4323H/PHYS 4793/PHYS 4793H Nanotechnology Laboratory (3 credit hours. This is a 4000 level new course submitted for approval together with this minor)

(2) Nanotechnology Research (Independent Study or Honors Thesis in nanotechnology) (3 credit hours)

Students can choose one from the following listed courses to fulfill the Nanotechnology Research requirement:

1) BENG 450V Special Problems

- 2) BENG 451VH Honors Thesis
- 3) BMEG 450VH Honors Thesis
- 4) BMEG 460V Individual Study
- 5) CHEG 488V Special Problems – Nanotechnology Research
- 6) CHEM 400V Chemistry Research
- 7) CHEM 498V Senior Thesis
- 8) ELEG 488V Special Problems
- 9) ELEG 488VH Honors Special Problems
- 10) MEEG 492V Individual Studies
- 11) MEEG 4903H Honors Mechanical Engineering Research
- 12) PHYS 498V Senior Thesis
- 13) PHYS 306V Projects
- 14) PHYS 399VH Honors Physics Research

A minimum of 9 hours of elective courses selected from the following list:

- (1) BENG 3733 Transport Phenomena in Biological Systems
- (2) BENG 3743 Food and Bioproducts Systems Engineering
- (3) BENG 4103 or 4103H Measurement and Control for Biological Systems
- (4) BENG 4123 Biosensors & Bioinstrumentation
- (5) BMEG 3633 Biomaterials
- (6) BMEG 3823 Biomolecular Engineering
- (7) BMEG 4243 Advanced Biomaterials and Biocompatibility
- (8) CHEG 3713 Chemical Engineering Materials Technology
- (9) CHEG 5023 Nano Bio Photonics (will be a co-listed 4000 level course in the future)
- (10) CHEG 4043 Colloids and Surfaces (course number has been submitted to curriculum committee, but not formally approved at present)
- (11) CHEM 4123 Advanced Inorganic Chemistry
- (12) CHEM 4213 Instrumental Analysis
- (13) CHEM 4283 Energy Conversion and Storage
- (14) ELEG 4253 Nanotechnology
- (15) ELEG 4203 Semiconductor Devices
- (16) ELEG 4303 Introduction to Nanomaterials and Devices
- (17) ELEG 4213 MEMS and Microsensors
- (18) MEEG 491V Introduction to Micro and Nanosystems
- (19) MEEG 4313 Introduction to Tribology
- (20) MEEG 491V Intermediate Materials
- (21) MEEG 4303 Materials Laboratory
- (22) PHYS 3213 Electronics in Experimental Physics
- (23) PHYS 3614 Modern Physics
- (24) PHYS 4073 Introduction to Quantum Mechanics
- (25) PHYS 4213 Physics of Devices
- (26) PHYS 4713 Solid State Physics
- (27) PHYS 4774 Introduction to Optical Properties of Materials

or from other appropriate courses not on this list if approved first by the Nanotechnology Minor Curriculum Committee and by the course instructor. Below are model programs for students from different participating department. Students also have the flexibility to design their own programs according to the stated requirements above. The prerequisites for most of the courses listed above can be found from the university catalogue of studies.

Model program 1: for a student with a major in Biological Engineering

6 hours of required courses:

- BENG 4753/BENG 4753H Nanotechnology Laboratory
- BENG 450V Special Problems or BENG451VH Honors Thesis

9 hours of elective courses:

- BENG 3743 Food and Bio-products Systems Engineering
- BENG 4103 or 4103H Measurement and Control for Biological Systems
- BENG 4123 Biosensors & Bioinstrumentation

Model program 2: for a student with a major in Biomedical Engineering

6 hours of required courses:

- BMEG 4103/BMEG 4103H Nanotechnology Laboratory
- BMEG 450VH Honors Thesis or BMEG 460V Individual Study

9 hours of elective courses:

- BMEG 3633 Biomaterials
- BMEG 3823 Biomolecular Engineering
- BMEG 4243 Advanced Biomaterials and Biocompatibility

Model program 3: for a student with a major in Chemical Engineering

6 hours of required courses:

- PHYS 4793/PHYS 4793H Nanotechnology Laboratory
- CHEG 488V Special Problems – Nanotechnology Research

9 hours of elective courses:

- CHEG 3713 Chemical Engineering Materials Technology
- CHEG 5023 Nano Bio Photonics (will be a co-listed 4000 level course in the future)
- CHEG 4043 Colloids and Surfaces

Model program 4: for a student with a major in Chemistry

6 hours of required courses:

- CHEM 4153/CHEM 4153H Nanotechnology Laboratory
- CHEM 400V Chemistry Research or CHEM 498V Senior Thesis

9 hours of elective courses:

- CHEM 4123 Advanced Inorganic Chemistry
- CHEM 4213 Instrumental Analysis
- CHEM 4283 Energy Conversion and Storage

Model program 5: for a student with a major in Electrical Engineering

6 hours of required courses:

- PHYS 4793/PHYS 4793H Nanotechnology Laboratory
- ELEG 488V Special Problems or ELEG488VH Honors Special Problems

9 hours of elective courses:

- ELEG 4253 Nanotechnology
- ELEG 4203 Semiconductor Devices
- ELEG 4303 Introduction to Nanomaterials and Devices

Model program 6: for a student with a major in Mechanical Engineering

6 hours of required courses:

- MEEG 4323/MEEG 4323H Nanotechnology Laboratory
- MEEG492V Individual Studies or MEEG4903H Honors Mechanical Engineering Research

9 hours of elective courses:

- MEEG 491V Introduction to Micro and Nanosystems
- MEEG 4313 Introduction to Tribology
- MEEG 491V Intermediate Materials

Model program 7: for a student with a major in Physics

6 hours of required courses:

- PHYS 4793/PHYS 4793H Nanotechnology Laboratory
- PHYS 498V Senior Thesis or PHYS 399VH Honors Physics Research

9 hours of elective courses:

- PHYS 4073 Introduction to Quantum Mechanics
- PHYS 4713 Solid State Physics
- PHYS 4774 Introduction to Optical Properties of Materials

b. Total semester credit hours required for option/concentration/emphasis

15 semester credit hours.

c. New courses and new course descriptions

New course: MEEG 4323 Nanotechnology Laboratory (Cross-list as BENG 4753, BMEG 4103, CHEM 4153, PHYS 4793 and Co-list as honors course)

New course description: Provide students with hands-on experience in several major areas of nanotechnology, including nanoscale imaging, synthesis of nanomaterials, nanostructure assembly and manipulation, device and system integration, and performance evaluation. The emphasis is on the integration of size-dependent properties and surface and interface effects at the nanoscale into devices and systems.

d. Goals and objectives of program option

1. provide and recognize UA undergraduate students' interest with a curriculum that includes the knowledge and skills in nanoscale science and engineering
2. prepare participating UA students for a career in nanoscience and engineering
3. Increase participating UA students' research competitiveness for graduate studies

e. Expected student learning outcomes

Upon completion of the Nanotechnology Minor, students should have achieved the following learning outcomes:

1. Student demonstrates understanding of the fundamentals in nanoscience and nanoscale engineering
2. Student demonstrates experimental skills in several major areas of nanotechnology, including synthesis of nanomaterials, nanoscale imaging, nanostructure assembly and manipulation, device and system integration, and performance evaluation
3. Student demonstrates an understanding of a broad range of nanotechnology applications
4. Student demonstrates understanding and capability in a specific application in an area of nanotechnology
5. Student demonstrates research skills in nanotechnology

f. Documentation that program option meets employer needs

A study supported by the National Science Foundation estimates that, by 2020, 6 million nanotechnology workers will be needed worldwide with 2 million in the United States (Roco, Mirkin, and Hersam, 2010).

Nano-related materials and applications have been identified as the strengths of Arkansas in a recent Battelle study for developing a knowledge-based economy. Nanotechnology is one of the State's key strategic areas of development. For example, UA recently created INSE and dedicated a \$50 million Nanoscale Material Science and Engineering building as its home. The new building houses state-of-the-art nanofabrication and characterization facilities as well as faculty members from 7 departments across the COE and the CAS, creating an environment that promotes and encourages cross-disciplinary partnership in nanotechnology research and education. While there are strong research and education activity and courses at the graduate level at the UA, nanotechnology education at the undergraduate level is nearly nonexistent. Most science and engineering undergraduate students never experience any formal classroom education or training in nanotechnology. Given the role that new nanomaterials and corresponding new devices are anticipated to play in future technology developments in multiple fields, there is a great need to provide opportunities for nanotechnology education in the undergraduate curriculum to support our undergraduates in preparing for future nanotechnology challenges.

Parallel to nanotechnology research, the State has also seen several success stories from nanotechnology start-up companies, such as NanoMech, LLC, NNLabs, LLC, and Ocean NanoTech, LLC, using technologies developed by faculty and students at the UA. These companies are now bringing products to market with very significant economic and performance advantages. With the continued growth of nanotechnology-based companies in the State, there is a growing need for offering nanotechnology coursework in undergraduate education to prepare a skilled workforce to promote competitiveness of local and regional companies. Increased nanotechnology literacy and a trained workforce in Arkansas will also continue to encourage home-grown companies, the incorporation of nanotechnology in existing Arkansas industry, and opportunities for engineering graduates to find employment in the State.

Despite the rapid growth of nanotechnology, little has been done to “bridge” traditional disciplines to this dynamic new field within the undergraduate educational experience. Given the interdisciplinary nature of nanotechnology, a university-wide coordinated effort is needed to effectively integrate nanotechnology into the undergraduate curriculum to prepare our undergraduates to be innovative at the nanoscale.

g. Student demand (projected enrollment) for program option

This minor program is expected to attract a large number of UA undergraduates, especially students in Honors College. UA currently has more than 2400 high-achieving honors students of whom the majority are from COE (~ 600 students) and CAS (~ 1000 students). These students have tremendous intellectual capacity waiting to be developed and many of them are required to complete an honors research project or thesis. We should provide them with fertile ground to

grow their natural curiosity and obtain the necessary skills through formal classroom education as well as research at the forefront of the technology development. This century has been inaugurated with striking new developments in nanotechnology. Since nanotechnology encompasses knowledge from many disciplines such as physics, chemistry, and engineering, it is inherently interdisciplinary and challenging to learn. A solid introduction to fundamental concepts in nanotechnology, including theory and hands-on practice, will provide honors students with the higher level of learning that they desire. In addition, through engaging in undergraduate research, honors students are more likely to fully realize their potential and become more competitive in winning national research fellowships and more successful in their future careers.

h. Name of institutions offering similar program or program option and the institution(s) used as a model to develop the proposed program option

Only a few universities in the US have minors in nanotechnology. These minor programs are unique to individual institutions. The following is an incomplete list of universities that have Undergraduate Nanotechnology Minor programs:

1. The University of Pennsylvania
Minor in Nanotechnology
http://www.nanotech.upenn.edu/minor_nanotech.html
2. The Pennsylvania State University
Undergraduate Nanotechnology Minor
<http://www.esm.psu.edu/programs/undergraduate/nano/>
3. University of Maryland
The Interdisciplinary Minor for Undergraduates in Nanoscale Science and Technology
<http://www.mse.umd.edu/undergrad/ug-nanominor.html>
4. Lehigh University
Minor in Nanotechnology
http://www.lehigh.edu/~inmatsci/under/minor_nano.htm
5. SUNY at Stony Brook
Minor in Nanotechnology Studies (NTS)
<http://www.stonybrook.edu/est/underg/nano.shtml>
6. University of Connecticut
Nanotechnology Minor
<http://www.engr.uconn.edu/nanotechminor.php>
7. Michigan Technological University
Interdisciplinary Minor in Nanoscale Science and Engineering (Nanotechnology)
<http://nano.mtu.edu/nanominor.htm>
8. The University of Texas at Dallas
Minor in Nanoscience and Technology
<http://mse.utdallas.edu/about/degrees.html>

The proposed Nanotechnology Minor is also uniquely developed based on the UA's existing infrastructure and courses. This minor will provide our participating students a competitive edge in finding nanotechnology jobs given the increasing need in trained nanotechnology workforce.

11. Institutional curriculum committee review/approval date:

12. Will the new option be offered via distance delivery? Indicate mode of distance delivery:

No.

13. Explain in detail the distance delivery methods/procedures to be used:

N/A.

14. Specify the amount of additional costs required for program implementation, the source of funds, and how funds will be used.

The courses constitute the proposed Nanotechnology Minor Program are mostly *existing courses or courses participating departments already planned to offer* with the exception of the Nanotechnology Laboratory course, which will be discussed below. Based on an estimated total participation of about 30 - 40 students (about 7 - 10 each year), we expect there should be no additional resources or costs associated with participation of the minor students. It is also most likely that the minor students will take most of the elective courses offered by their own department. Initially, the total number of students might be capped at a level consistent with the available seats in existing courses. If the program proves extremely popular and participating departments agree, the cap might be lifted and additional costs will be distributed among participating departments.

Nanotechnology Laboratory: This is *a new laboratory course* that will be cross-listed by the participating departments and co-listed as an honors course. Initially, this course will be co-taught by the following faculty members from five departments in COE and CAS. The participating departments are requested to support faculty teaching of this lab course.

Name	Department	Rank	Office	Phone	Email Address
Min Zou	Mechanical Engineering	Associate Professor	NANO 212	5-6671	mzou@uark.edu
Gregory Salamo	Physics	Distinguished Professor	NANO 205	5-5931	salamo@uark.edu
Steve Tung	Mechanical Engineering	Associate Professor	MEEG 214	5-5557	chstung@uark.edu
D. Keith Roper	Chemical Engineering	Associate Professor	NANO 206	5-6691	dkroper@uark.edu
Jin-Woo Kim	Biological Engineering	Professor	NANO 203	5-3402	jwkim@uark.edu
Jingyi Chen	Chemistry & Biochemistry	Assistant Professor	CHEM 242	5-6203	chenj@uark.edu
Adam Huang	Mechanical Engineering	Assistant Professor	MEEG 105	5-4054	phuang@uark.edu

Initial funding of \$200K from the National Science Foundation Nanotechnology Undergraduate Education in Engineering Program was obtained for supporting the development of the Nanotechnology Laboratory course, the purchase of the needed equipment, materials and supplies, and a teaching assistant for the first offering of the lab course. An additional \$25K was obtained from UA Honors College to supplement the cost of materials and equipment for the lab course development. The INSE has committed to offer the 800 – 1000 ft² of lab space for the course. The COE has committed to provide funds needed for laboratory improvements, teaching assistants, and materials to support the NSF NUE project. The CAS is expected to make similar commitment if students from CAS participate in the Nanotechnology Minor program.

In addition, the Nanotechnology Minor is estimated to have a total participation of about 30 - 40 students (about 7 - 10 each year), which will generate corresponding tuition and fees for supporting the operation of the program. We expect the number of students enrolled in the program steadily increase every year. With increase in the number of students, we expect colleges involved in this minor program to allocate proportional Tele fee to support the lab course that is the core of this minor program. Other courses are all existing courses offered by participating departments. With this combination plan, we are confident that the program will self-sustain.

15. Provide additional program information if requested by ADHE staff.

President/Chancellor Approval Date:

Board of Trustees Notification Date:

Chief Academic Officer