SOUTH DAKOTA MINES

An engineering, science and technology university

NANOSCIENCE AND BIOMEDICAL ENGINEERING

Graduate Handbook

2023-2024

NANO-BME Program Director ... S. Smith (Steve.Smith@sdsmt.edu)

NANO-BME Committee … R.B. Anderson (Robert.Anderson@sdsmt.edu)
J. Morrow (Johnica.Morrow@sdsmt.edu)
T. Ozdemir (Tugba.Ozdemir@sdsmt.edu)
D. Salem (David.Salem@sdsmt.edu)
B. Scott (Brandon.Scott@sdsmt.edu)
C. Wang (Congzhou.Wang@sdsmt.edu)
S. Wood (Scott.Wood@sdsmt.edu)
T. Walker (Travis.Walker@sdsmt.edu)
S. Zhou (Shan.Zhou@sdsmt.edu)
Z. Zhu (Zhengtao.Zhu@sdsmt.edu)

Ex-Officio … M. Price (Maribeth.Price@sdsmt.edu)

Note: This handbook is for informational purposes - it provides more detailed explanations than are available in the SDSMT Catalog, as well as specific NANO-BME policies established by the NANO-BME Graduate Committee. This handbook should be used in conjunction with the SDSMT Catalog.

TABLE OF CONTENTS

General information concerning the Graduate School is contained in the South Dakota School of Mines and Technology Catalog. Detailed listings of graduate courses, as well as additional information concerning Nanoscience and Biomedical Engineering graduate programs and university graduate degree requirements, are contained in the catalog. All graduate students should familiarize themselves with pertinent information contained in this catalog.

The following guide relates to specific requirements of the Nanoscience and Nanoengineering and Biomedical Engineering M.S. and Ph.D. programs, and is intended to supplement catalog information. It should be studied carefully by all students in the Nanoscience and Nanoengineering (NANO) and Biomedical Engineering (BME) Programs. A discussion of the various forms that must be filed is included herein. The procedure for completing a degree program including example forms are in Appendix A.

I. ADMISSION

Both the NANO and BME programs requires GRE (Graduate Record Examination) scores of all applicants; applicants must take the Verbal, Quantitative, and Analytical parts. The GRE subject test in the individual's undergraduate degree major is encouraged, but not required. Any exception to the GRE requirement should be approved by the NANO-BME Graduate Committee. In addition to the general admission requirements, the Graduate School requires applicants from foreign countries to achieve a satisfactory TOEFL (Test of English as a Foreign Language) score. All students whose first language is not English may be tested upon arrival and may be required to take one or more remedial English courses. All graduate students are expected to have or to develop a proficiency in both written and oral English. Any student, who is found weak in communications, as evidenced by written reports and/or seminar presentations, may be required to take additional English or speech course work.

A student whose bachelor's degree is in any science or engineering field is eligible for admission to the NANO program. However, the following courses are regarded as minimum pre-requisites to this program:

Chemistry: one year, general
Math: one year calculus, ordinary differential equations, matrix algebra
Computer Science: proficiency in a computer programming language
Physics: one year, calculus based

Additional coursework in biology and engineering are recommended for students admitted to the BME program:

Biomedical or Biological Sciences: Anatomy and Physiology, Molecular Biology, Cell Biology and/or Genetics.
Engineering: Statics, Dynamics, Thermodynamics, Solid Mechanics, Fluid Mechanics and Transport Phenomena.

II. GRADUATE STUDENT ADVISOR

The NANO-BME program director serves as a temporary faculty advisor to each new graduate student until such a time as the student selects a permanent advisor (also known as Major Professor) to supervise his/her graduate research. The program director will assist all new graduate students with their course registration and provides each student with information pertinent to the NANO-BME programs.

III. FINANCIAL ASSISTANCE

Financial assistance is available to graduate students through a number of avenues, including graduate fellowships, graduate teaching assistantships (GTA), and graduate research assistantships (GRA). The required applications for all types of financial assistance should be made to the Dean of Graduate Education. Requests may be included in the application package, at the discretion of the applicant.

IV. SELECTION OF RESEARCH TOPIC

Within the first two semesters of graduate studies, all PhD students not supported by a GRA should make appointments with faculty involved in the NANO-BME Ph.D. programs to discuss possible research topics. Each student will be matched with a major professor in accordance with his/her interests. The student must file a Program of Study form with the Office of Graduate Education within the first two semesters of study. An Advisory Committee (also known as the student's thesis/dissertation committee), consisting of the major professor and three to four other faculty, will be formed to guide the student progress. The Advisory Committee is appointed by the Dean of Graduate Education in consultation with the student and the student's major professor. At this time, the major professor becomes the student's advisor on all matters pertaining to guiding the students progress.

V. PROGRAM OF STUDY

Graduate degrees are awarded upon completion of course requirements and demonstration of significant scholarly achievement through independent research. A Ph.D. or MS candidate must demonstrate general competence in the subject matter of his/her chosen field. To this end, the student files and pursues a proposed Program of Study, which includes a list of courses that the student intends to take. This Program of Study must be given preliminary approval before the qualifying exam and final approval before the dissertation defense by the student's advisory committee, NANO-BME Graduate Committee, and the Dean of Graduate Education. The Program of Study must be filed with the NANO-BME Program director during the first year of residence, and again before the qualifying exam. Below are a summary of the required courses for each degree. Example curricula and a schedule of course offerings are found in appendix E.

VI. NANOSCIENCE AND NANOENGINEERING

The core and major emphasis course requirements for the PhD and MS degrees in Nanoscience and Nanoengineering are listed below.

PhD Degree:

COURSE	**CREDITS***
NANO 701 Nano Materials	3
NANO 702 Theory and Applications of Nanoscale Materials	3
NANO 703/703L Instrumentation and Characterization of Nano-Materials	4
NANO 890 Seminar	3
TOTAL NANO Core Credits:	13

Program Major Emphasis: The program major emphasis consists of foundational graduate training at the MS level, and may be fulfilled in part or in full by a previously earned MS degree. Students entering at the BS level are encouraged to select coursework which will provide a framework upon which the PhD can be based. Specific thematic tracks complementary to ongoing research areas in the Nano SE PhD program are outlined below under Major Emphasis-specific requirements (appendix D).

General requirements: Minimally 27 credits, according to program major emphasis. May be fulfilled in part by up to 24 credits applied to an MS degree according to SDSMT graduate school policy.	27-37
Dissertation Research	30-40
TOTAL REQUIRED FOR PhD:	80

Major Emphasis-specific requirements:

In addition to the NANO core curriculum, students may select courses from the thematic tracks identified below, corresponding to active research areas in the Nano SE PhD program. These course sequences are designed to complement and provide context to ongoing research activities. The thematic tracks consist of 27 credits which, when combined with the 13 core course credits, wholly fulfill the coursework requirements for the Nano SE PhD. The research areas matched to each thematic track and their coursework components are synopsized below:

Nanoelectronic and Photonic Materials: Encompasses the synthesis, characterization and theory of nanostructured electronic and photonic materials and devices. Examples are nanostructured solar cells, nanophotonic or plasmonic materials, devices and structures.

Nano-biotechnology and Nano-imaging: Development of nanotechnologies and methods to influence and or characterize living systems. Examples are live cell, superresolution imaging, electron tomography, cell level and sub-cellular level nano-biotechnologies.

Nano-composites and Applications: Development of multi-component materials with properties exceeding the performance of matrix and nano-phased fillers. Examples are structural, thermal-insulating and optoelectronic organic/inorganic nano-fiber composites.

Nano SE thematic track course sequences:

Approved course numbers and titles (see catalog for full description)		**Nanoelectronic and Photonic Materials**	**Nano-biotechnology and Nano-imaging**	**Nano-composites and Applications**
NANO 704	Crystallography & Struct. Nanomaterials	x	x	x
NANO 709	Scientific Instr. Cont. and Visualization	x	x	x
NANO 714	Fluorescence Spectroscopy	x	x	x
NANO 717	Nanochemistry	x	x	x
NANO 718	Nanomechanics	x	x	x
NANO 705	Nanoelectronics	x		
NANO 706	Nano-biotechnology		x	
NANO 707	Nanocomposites			x
NANO 504	Nanophotonics	x		x
NANO 604	Nanophotonics materials	x		
NANO 708	Nanomaterials for Photovoltaics	x		
NANO 710	Optical Nanoscopy		x	
NANO 712	EM Prop. Of Heterogeneous Materials			x
NANO 713	Nano-biotechnology II		x	
NANO 715	Polymeric Nanomaterials			x
NANO 719	Nanomaterials for Biosensors		x	

Table VI.1: Coursework defining each thematic track and approved thematic electives (indicated by "**x**" under each specific track).

Notes: There are 5 courses common to all thematic tracks, NANO 704, NANO 709, NANO 714, NANO 717, and NANO 718. NANO 705, NANO 706 and NANO 707 are considered flagship courses for their respective specializations. Three additional approved elective courses specific to each thematic track are shown in the table. With approval of the faculty advisor: NANO 504 may be substituted for NANO 714; NANO 715 may be substituted for NANO 717; and NANO 711 may be substituted for NANO 709.

In approving a proposed Program of Study, the Nano SE PhD Program Advisory Committee will take into account acceptable graduate-level courses taken at other institutions or other demonstrations of competence in a particular area. The student should summarize this material as directed in Appendix A, and submit this with the Program of Study.

MS Degree:

The Nano SE PhD program is designed with the precept that the PhD is the terminal degree for completion of the program. However, under circumstances wherein a student has completed the required coursework, and has obtained a minimum of 30 credit hours, a coursework only MS degree can be earned en route to the PhD. The degree requirements are described below in tables VI.1-3 below. The degree is composed of 5 core courses, NANO 504, 701, 702, 703/703L, and 709; and 12 elective credits selected from NANO 604,

704, 705, 715, 717, 719, and 718 or any other graduate-level course approved by the advisor, and 2 credits of NANO788 (MS Project, which can be substituted by NANO 898D).

Table VI.2: Summary of the degree program:

MS Nanoscience and Nanoengineering	Credit Hours	Percent
Required courses, all students	18	60%
Required option or specialization, if any	0	0
Electives (approved 500-700 level courses, including, but not restricted to those listed below)	12	40%
Total Required for the Degree Total	30	

Table VI.3: Required Courses:

Prefix	Number	Course Title	Cr. Hrs.
NANO	504	Nanophotonics	3
NANO	701	Nanomaterials	3
NANO	702	Theory and Application of Nanomaterials	3
NANO	703	Instrument. & Charact. of Nanomaterials	4
NANO	709	Scientific Control and Visualization	3
NANO	788	Nano MS Project	2
		Subtotal	18

Table VI.4: Example MS Elective Courses:

Prefix	Number	Course Title	Cr. Hrs.
NANO	604	Nanophotonic Materials	3
NANO	704	Crystallography and Structure of Nanomaterials	3
NANO	705	Nanoelectronics	3
NANO	715	Polymeric Nanomaterials	3
NANO	717	Nano-chemistry	3
NANO	719	Nanomaterials for Biosensors	3
NANO	718	Nanomechanics	3
		Subtotal	21

VII. BIOMEDICAL ENGINEERING

The core and major emphasis courses requirements for the PhD and MS degrees in Biomedical Engineering are listed below.

PhD Degree:

COURSE	CREDITS
BME 601 Biomaterials	3
BME 602 Anatomy and Physiology	3
BME 603 Molecular Biology	3
BME 508 Biomedical Engineering	3
BME 710 Experimental Design and Analysis	3
BME 690/790 Seminar	3
TOTAL BME Core Credits:	18
Elective requirements: Minimally 18 credits, according to program of study. May be fulfilled in part by up to 24 credits applied from an MS degree according to SDSMT graduate school policy. At least 6 credits must be BME courses	18
Dissertation Research	36
TOTAL REQUIRED FOR Biomedical Engineering PhD:	72

MS Degree:

COURSE		CREDITS
BME 601	Biomaterials	3
BME 602	Anatomy and Physiology	3
BME 603	Molecular Biology	3
BME 508	Biomedical Engineering	3

One of the following:		
BME 710	Experimental Design and Analysis	3
MATH 547	Design of Experiments	
CBE 588	Experiment Design: Chem Industry	
BME 690/790	Seminar	2
TOTAL BME Core Credits:		17
BME elective		3
BME 798	Thesis Research	9-10
TOTAL REQUIRED FOR Biomedical Engineering MS:		30

Accelerated Master's Program, BS/MS:

The accelerated master's degree programs will enable a student to complete both a B.S. and M.S. degree in as little as 5 years. Up to 12 credits applied toward the B.S. program may be used to satisfy graduate credit requirements.

Students desiring to participate in an accelerated program are encouraged to apply at the end of their junior year. A minimum undergraduate cumulative GPA of 3.0 is required at the time the student applies to the program.

Course Requirements

Courses must be taken at the 400/500/600 level. Courses taken at the 400 level are subject to the other requirements listed in the catalog. Only courses taken at SD Mines are eligible for dual credit. No transferred courses will be allowed to count toward the accelerated MS degree. An additional 12 semester hours of graduate level credits taken as an undergraduate and not used to fulfill requirements for the undergraduate degree may be used toward a graduate degree (courses must be approved by the student's advisory committee).

The following restrictions apply:

a. The courses must be taken at the 400/500/600 level as an undergraduate. Dual-listed courses taken at the 500-level can be applied to both the B.S. and M.S. degrees. Duallisted courses must be taken at the 500-level.

b. The student must apply to, and be admitted to, the accelerated program prior to taking courses to be credited toward the accelerated program.

c. No courses taken prior to admission to the accelerated program may be counted toward an accelerated graduate degree. No exceptions to this policy will be approved.

d. Courses that are "double counted" must be approved by the program coordinator for inclusion in the program of study prior to registration for the course or the credits will not be applied toward the accelerated graduate degree. No exceptions to this policy will be approved.

e. For accelerated track students only, a 500 level cellular physiology course may be used as an approved substitute for BME 602, a 500 level molecular biology course may be substituted for BME 603, and a 500 level biochemistry, physiology, and anatomy course will substitute for BME 608.

f. Only courses taken at the student's home institution are eligible for dual credit. No transferred courses from other institutions will be allowed to count toward the accelerated master's degree.

g. Students admitted to the accelerated M.S. Program may register for all courses included on his/her program of study and these credit hours may apply to both undergraduate and graduate degree requirements.

VIII. GPA REQUIREMENTS AND COURSE LOAD

A grade of "B" or better in a course will be accepted as evidence of competence in the subject. All candidates for the Ph.D. must obtain an average grade of "B" or better in the overall course of study in accordance with the Graduate School requirements. Grades below "C" cannot be credited toward advance degree requirements. A full load for each semester is considered to be nine semester credit hours

of course work and/or thesis/dissertation. After the dissertation committee has been established, a Ph.D. student must register every semester, in accordance with SDSMT regulations.

Once the student has selected a research topic, he/she will be expected to register for research for a number of credit hours agreed to by his/her research advisor. Students are required to register for two (MS) or three (PhD) 1-credit hour graduate seminars, and are expected to attend regularly and participate.

IX. PhD QUALIFYING EXAMINATIONS

Prior to the end of the fifth semester of study, PhD students will sit for a qualifying examination consisting of two parts:

(i) A written examination based on the core curriculum will be given at the end of the second year of study. This will be a 2 hour written examination, with emphasis equally divided among the required core courses.

(ii) The student will prepare a written research proposal and complete an oral presentation of that proposal in the presence of the Dissertation Committee. The topic is to be prepared by the student with the guidance of his/her research advisor. The topic of the proposal will usually be related to the student's anticipated dissertation research; however, the student's research advisor may require the student to prepare a proposal on an unrelated topic.

The written proposal should be no longer than 15 double-spaced, typewritten pages of text, plus nomenclature, references, figures, and appendices. It is recommended that the document be organized in the form shown in Appendix B. This written document must be reviewed by two members of the student's dissertation committee before submission to the full committee. The committee members will point out any problems relating to scope and format. However, final approval of the proposal will only come after the subsequent faculty reading and oral exam.

Copies of the final typed proposal must be submitted to the student's dissertation committee for faculty reading. At this time, a date will be set for the oral presentation by the student of his/her dissertation research proposal. This presentation should closely reflect the contents of the written proposal and should last no longer than 30 minutes, without interruptions. Background information is to be limited to no more than 20% of the document; the majority of the presentation should be a detailed description of the student's proposed research program. The originality and potential significance of the proposed research should be emphasized. Following the oral presentation, the student will be expected to respond to questions from the attending faculty.

The purpose of the examinations is to test the students knowledge in the program subject areas, teach the student how to write technical research proposals, test the student's understanding of the relevant literature, test the student's imagination and judgment in a research environment, and test the student's ability to present work in clear, concise written and oral English. Clear and substantial portions of both the written and oral presentations must demonstrate the student's original ideas. The proposal must be for the most part a product of the student, not that of the advisor or Committee. The outcome of this examination procedure will be a Pass, a Conditional Pass (usually requiring a re-write and/or re-submittal of the proposal), or a Fail. An examination may be repeated only once and only at the discretion of the student's dissertation committee.

Passing the qualifying examination shall be considered equivalent to satisfying both the preliminary and comprehensive examination requirements, as described in the graduate school degree requirements in the SDSMT catalog.

Failing the Qualifying examination: Students who fail the written portion of the exam may retake the exam in the following year, with the permission of the advisor. Students must schedule the oral portion of the qualifying examination by the end of the 5th semester of study (*e.g*. mid-term of the 3rd year).

If a student does not complete and pass both parts of the examination by the end of the 5th semester, an evaluation of the student's progress and eligibility for an assistantship will be initiated during the 6th semester. Contingent on the outcome of this evaluation, a recommendation will be made, with the following outcomes:

a) A specific timeline for completion of these exams, not to exceed one year, will be submitted by the student and/or the faculty advisor, and approved by the NANO-BME Graduate Committee and the NANO-BME Program Director, or

b) The student will be dismissed from the program.

Failure to successfully complete these exams on the second attempt will result in the student being dismissed from the program.

X. ADMISSION TO CANDIDACY

Provided the student has passed both portions of the qualifying examination, the student may apply to his/her major professor for admission to candidacy on an official certification form available from the Office of Graduate Education. At this time, no less than four months before the scheduled dissertation defense, the student will be considered a PhD candidate.

XI. DISSERTATION

Of major importance to the Ph.D. degree are the student's research and the resulting dissertation. The research results are expected to be of publishable quality. The student's research advisor may specifically require publication of one or more peer-reviewed journal articles, equal to or exceeding the NANO-BME PhD publication requirements. The time necessary to complete the Ph.D. requirements depends largely upon how soon a student initiates research and the degree to which he/she devotes effort to its pursuit. Detailed instructions concerning the dissertation and the time schedule that must be followed during the semester of intended completion of the Ph.D. requirements are given in the Graduate Bulletin.

Information on guidelines for writing and formatting a Doctoral Dissertation are available from the Office of Graduate Education. Student should obtain a free copy of "Instruction for the Preparation of Thesis and Dissertation" from the Graduate Office. All students are expected to follow the guidelines found within the manual. The final version of the dissertation must be submitted by the candidate to each member of his/her dissertation committee no later than TWO weeks before the scheduled dissertation defense.

XII. DEFENSE OF DISSERTATION

The student will be required to give an oral presentation (30-45 minutes), open to the public, on the major findings of his/her research. An oral examination will follow the presentation; conducted by the student's major professor with only the student's dissertation committee in attendance. The student's dissertation committee will question the student to test the quality and completeness of the research.

XIII. PUBLICATION REQUIREMENT

Publication in peer-reviewed journals is a pre-requisite to demonstrating achievement at the level of the PhD. It is suggested that each student would be first author on 3 peer reviewed journal articles prior to obtaining the PhD. A minimum of 2 peer-reviewed journal articles are required, with the student being first author on at least 1 published article prior to graduation. Any exception must be approved by the Nano AC.

XIV. GRADUATE COMMITTEE

The graduate committee will be formed according to the rules laid out by the Graduate office. One member of the committee must fulfill the requirements of the graduate office to act as the graduate representative, and therefore must not be a NANO-BME program faculty advisor. A list of NANO-BME program faculty will be provided to the graduate office annually by the NANO-BME Graduate Committee or on request.

Appendix A

GRADUATE ADVISORY COMMITTEE SIGNATURE PAGE

The original program of study is due to the Office of Graduate Education no later than midterm of the second semester of registration as an advanced degree-seeking candidate.

If the program of study is being revised, a new form must be submitted, complete with all approval signatures.

_____ Original _____ Revision

Student Name and ID #: _____ Today's Date: _____
(Print)

Current Ph.D. Department/Program: _____

Specialization/emphasis (if applicable): _____

Undergraduate degree received: _____

State your dissertation research area, as close to the anticipated topic as possible:

_____

_____

Graduate Advisory Committee:

By signing below I agree that the courses listed represent a specific program leading toward graduation.

Major Professor (Print Name & Dept)	**Signature**	**Date**
Graduate Division Representative (Print Name & Dept)	**Signature**	**Date**
Committee Member (Print Name & Dept)	**Signature**	**Date**
Committee Member (Print Name & Dept)	**Signature**	**Date**
Committee Member (Print Name & Dept)	**Signature**	**Date**
Committee Member (Print Name & Dept)	**Signature**	**Date**
Committee Member (Print Name & Dept)	**Signature**	**Date**
Program Coordinator (Print Name & Dept)	**Signature**	**Date**

I certify that the courses listed represent a specific program leading toward graduation. I understand that the course list can be changed at a later date with the approval of my Graduate Advisory Committee.

Submitted for approval by: _____ _____
Signature of Student **Date**

Dean of Graduate Education: _____ _____
Signature of Dean **Date**

Coursework Schedule

(Note: See graduate education website for most recent approved forms: http://www.sdsmt.edu/Academics/Graduate-Education/Grad-Ed-Forms/.)

Appendix A

International students <u>not exempted</u> from the Graduate English Proficiency Program <u>must include</u> English 390 in the coursework schedule.

Courses transferring from another program at SDSMT or from another institution must be identified as such with an asterik (*) in front of the course name. Courses transferring from another institution require attachment of transcript copy evidence. Courses transferring from an institution outside the United States must also include a course <u>description</u> from the transferring university.

<u>Required courses</u> include only those course credits which apply toward degree requirement, including 300-400 level courses approved by petition or on waiver by the Graduate Education and Research Committee. Courses not required and not previously approved on waiver should be listed as <u>Others</u>.

All courses should be listed by semester date, in the order of planned completion. (Sem/Yr example Fall 2020, Spring 2021, etc.) (Under Course Name spell out course title completely.)

		Number of Credit Hours		
Sem/Yr	**Course name and number**	**Required Courses**	**Research**	**Others**

(Note: See graduate education website for most recent approved forms: http://www.sdsmt.edu/Academics/Graduate-Education/Grad-Ed-Forms/.)

Appendix B

RECOMMENDED OUTLINE FOR THE WRITTEN PORTION OF THE RESEARCH PROPOSAL

1. Cover page
2. Summary (one page) including:
   - research objectives
   - significance of the proposed research
   - student's original contributions
3. Literature survey (maximum 3 pages), including:
   - the general literature in the field
   - specific literature on the proposed topic
4. Proposed research program (~8 pages, not including figures), including:
   - research objectives
   - expected significance
   - broad design of experiments and/or modeling to be undertaken
   - description of proposed experimental and/or numerical methods
   - relation of the proposed program to the goals of the research cited in the literature survey
5. Extension of the research to future work
6. A clear and concise statement of the student's original contributions
   – schedule for completion of research
7. Nomenclature
8. References
9. Appendices
   A. Copy of the reference most pertinent to the proposed research program
   B. Other relevant materials.

Appendix C

FACULTY AND RESEARCH INTERESTS

Dr. Robert B. Anderson, Associate Professor of Nanoscience and Biomedical Engineering, PhD South Dakota School of Mines and Technology; Photonics, optics, super-resolution imaging, computational methods.

Dr. Johnica Morrow, NANO-BME Program Coordinator, Nanoscience and Biomedical Engineering, PhD University of Nebraska, Program administration, instruction and parasitology.

Dr. Tugba Ozdemir, Assistant Professor of Nanoscience and Biomedical Engineering; PhD Pennsylvania State University, Biomaterials and Tissue Engineering.

Dr. David Salem, Professor of Chemical and Biological Engineering / Materials and Metallurgical Engineering / Nanoscience and Biomedical Engineering, Director Composites and Polymer Engineering Laboratory; PhD University of Manchester; Polymer Nano-composties and Polymer Physics.

Dr. Brandon Scott, Assistant Professor of Nanoscience and Biomedical Engineering; Biochemistry, Live Cell Fluorescence imaging, cellular biology, membrane biophysics.

Dr. Steve Smith, Professor Nanoscience and Biomedical Engineering; PhD University of Michigan, Ann Arbor; Energy and time-resolved nanoscale optical spectroscopy, superresolution bio-imaging, nanophotonics, electronic and photonic properties of nano- and energy-materials.

Dr. Travis Walker, Associate Professor of Chemical and Biological Engineering, PhD Stanford University, Biomaterials, Microfluidics and Rheology.

Dr. Congzhou Wang, Assistant Professor Nanoscience and Biomedical Engineering; PhD Virginia Commonwealth University; Nano-biotechnology, nano-biomechanics, nanosensors, metal-organic framework (MOF) chemistry and applications.

Dr. Scott Wood, Assistant Professor Nanoscience and Biomedical Engineering; PhD Clemson University; Bio-Engineering, Nano-Bio-Mechanics of chondrocytes, Mechano-biology.

Dr. Shan Zhou, Assistant Professor Nanoscience and Biomedical Engineering, PhD Georgia Tech; Self-assembly and ligand chemistry, high speed atomic force microscopy.

Dr. Zhengtao Zhu, Associate Professor of Chemistry, PhD SUNY Binghamton, Organic-inorganic nano-composites, Nano imprinting and lithography.

Appendix D

Elective courses:

NANO 401 Introduction to Nanoscience	3
NANO 475/575 Advanced Processing/Nanoengineering of Polymeric Materials	2
NANO 404/504 Nanophotonics	3
NANO 604 Nanophotonic Materials	3
NANO 704 Crystallography and Structure of Nanomaterials	3
NANO 705 Nanoelectronics	3
NANO 706 Nano-Biotechnology	3
NANO 707 Nanocomposites	3
NANO 708 Nanomaterials for Photovoltaics	3
NANO 709 Scientific Instrumentation, control and Visualization	3
NANO 710 Optical Nanoscopy	3
NANO 711 Scientific Instrumentation, control and Visualization II	3
NANO 712 Electromagnetic Properties of Heterogeneous Materials	3
NANO 713 Nano-Biotechnology II	3
NANO 714 Fluorescence Spectroscopy	3
NANO 715 Polymeric Nanomaterials	3
NANO 717 Nanochemistry	3
NANO 718 Nanomechanics	3
NANO 719 Nanomaterials for Biosensors	3
NANO 720 Contemporary Condensed Matter Physics	3
NANO 722 Nano-biomaterials	3
NANO 791 Independent study	1 to 3
NANO 792 Topics	1 to 3
NANO 721 Adv. Electricity and Magnetism	3
NANO 743 Statistical Mechanics	3
NANO 777 Quantum Mechanics I	3
NANO 779 Quantum Mechanics II	3

Appendix D

Nano curriculum thematic tracks

Nano-electronic and photonic materials:			
504	nanophotonics	15 credits	Common
714	fluorescence spectroscopy		
709	computer and visualization		
717	nano-chemistry		
718	nano-Mechanics		
705	nanoelectronics	3 credits	Keystone
704	crystallography	9 credits	Electives
708	photovoltaics		
604	nanophotonic materials		
Nano-biotechnology and nano-imaging:			
504	nanophotonics	15 credits	Common
714	fluorescence spectroscopy		
709	computer and visualization		
717	nano-chemistry		
718	nano-mechanics		
706	nano-bio technology	3 credits	Keystone
710	optical nanoscopy	9 credits	Electives
713	nano-bio technology II		
719	Nanomaterials for Biosensors		
Nano-composites and applications:			
504	nanophotonics	15 credits	Common
714	fluorescence spectroscopy		
709	computer and visualization		
717	nano-chemistry		
718	nano-mechanics		
575	polymer composites	3 credits	Keystone
704	nanocrystallography	9 credits	Electives
712	electromagnetic composites		
715	nano-polymers		
Nano core courses:			
701	nano-materials	13 credits	Core
702	theory and application of nanomaterials		
703	characterization of nanomaterials		
890	nano seminar		
898	nano research	40 credits	

Table I: Nano Curriculum showing three thematic tracks, common and core courses and research credits.

Appendix E
SAMPLE CURRICULUM AND PROJECTED COURSE OFFERINGS

Course Offerings Schedule:

FA 21	SP 22	FA 22	SP 23	FA 23	SP 24	FA 24	SP 25	FA 25
Nano 702	Nano 504	Nano 703	Nano 604	Nano 702	Nano 504	Nano 703	Nano 604	Nano 702
Nano 703	Nano 701	Nano 705	Nano 701	Nano 703	Nano 701	Nano 705	Nano 701	Nano 703
elective	Nano 708	Nano 706	Nano 704	Nano 712	Nano 708	Nano 706	Nano 704	Nano 712
Nano 717	Nano 709	Nano 707	Nano 710	Nano 713	Nano 709	Nano 707	Nano 710	Nano 713
elective	Nano 719	Nano 711	Nano 718	Nano 717	Nano 719	Nano 711	Nano 718	Nano 717
	elective	Nano 714	elective	elective	elective	Nano 714	elective	elective
	Nano 890	Nano 715	Nano 890		Nano 890	Nano 715	Nano 890	

Example Curricula:

PhD student entering program with MS (research intensive):

									Credits:
	Nano 702 (3)	Nano 701 (3)	elective (3)						
	Nano 703 (4)	elective (3)							16
seminar		Nano 890 (1)		Nano 890 (1)		Nano 890 (1)			3
research	Nano 898 (2)	Nano 898 (5)	Nano 898 (9)	Nano 898 (8)	Nano 898 (9)	Nano 898 (8)			40
transfer									21
	9	9	9	9	9	9			80

PhD student entering program with MS (coursework intensive):

									Credits:
	Nano 702 (3)	Nano 701 (3)	elective (3)	elective (3)	elective (3)	elective (2)			
	Nano 703 (4)	elective (3)							24
seminar		Nano 890 (1)		Nano 890 (1)		Nano 890 (1)			3
research	Nano 898 (2)	Nano 898 (2)	Nano 898 (6)	Nano 898 (5)	Nano 898 (6)	Nano 898 (6)	Nano 898 (3)		30
transfer									23
	9	9	9	9	9	9	3		80

PhD student entering program at the BS level (research intensive):

										Credits:
	Nano 702 (3)	Nano 701 (3)	elective (3)	elective (3)	elective (3)	elective (3)				
	Nano 703 (4)	elective (3)	elective (3)	elective (3)	elective (3)	elective (3)				37
seminar		Nano 890 (1)		Nano 890 (1)		Nano 890 (1)				3
research	Nano 898 (2)	Nano 898 (2)	Nano 898 (2)	Nano 898 (1)	Nano 898 (3)	Nano 898 (5)	Nano 898 (9)	Nano 898 (9)	Nano 898 (7)	40
transfer										0
	9	9	9	9	9	9	9	9	7	80

MS student:

						Credits:
	Nano 702 (3)	Nano 701 (3)	Nano 714 (3)	Nano 718 (3)	elective (3)	28
	Nano 703 (4)	Nano 709 (3)	elective (3)	elective (3)		
seminar		Nano 890 (1)		Nano 890 (1)		2
research	Nano 898 (2)	Nano 898 (2)	Nano 898 (3)	Nano 898 (2)		2
	9	9	9	9	4	32

Student Assessment:

Assessment of student progress is a continual process throughout the graduate program, the foremost responsibility rests with the faculty advisor, graduate committee and *the students themselves*. By working together, the student, advisor and committee can inform research decisions, build and confirm relevant skills and competencies in the student, and ensure meaningful contributions to the students' area of specialization. Students learn to frame, plan, execute and analyze nanoscience, nanoengineering and biomedical engineering research by regular consultation, primarily with their advisor, and secondarily with other committee members or outside experts as determined by ongoing evaluation of research. Short-term and long-term goals are framed, and continually assessed and adjusted as a research program evolves.

A program of study is designed to complement the student's proposed research area, in consultation with the faculty advisor, preferably in the first semester. Adjustments are made as needed within the first two to three years of the program. A written exam covering key concepts covered in the core curriculum is administered no later than the end of the students second year, to assess the demonstration of advanced knowledge covered in the core curriculum. On or before spring semester of the third year, PhD students prepare a written research proposal and defend this to their PhD committee. At that time, the committee will assess the students' knowledge of the relevant literature, as demonstrated in the research proposal and during the proposal defense. The committee will assess the level of specialized knowledge based on the contents of the proposal, which should include preliminary work and likely publication(s) documenting this, or minimally concrete evidence that such publications are forthcoming. Any deviation from these schedules must be approved by the NANO-BME Graduate Committee (NANO-BME GC), as outlined in the Nanoscience and Biomedical Engineering Graduate Program Handbook.

Student participation in professional meetings and campus research symposia will provide an assessment as to the level and quality of the students' research and are encouraged. Participation in the NANO-BME Expo is required by all students in the NANO-BME programs. This allows the students to develop oral and written communication skills and is assessed by groups of at least two Faculty and one student judge. The PhD dissertation and defense will assess the PhD students' original contribution, as measured by products including the dissertation and mandatory peer-reviewed publications, per the program publication requirement. Publications, required oral presentations and research proposal will also document the students' abilities and accomplishments in utilizing contemporary tools, methods and theory to evaluate the results of their research.

The Ph.D. proposal and proposal defense, and later the PhD dissertation and defense, are evaluated to ensure they address contemporary challenges in nanoscience and nanoengineering or a closely aligned field, and that the student demonstrates cognizance and understanding of the relevant scientific and technical literature. Further, these document that the student has demonstrated significant accomplishments in the relevant methods, tools, and theory pertaining to their chosen research topic, and have attained the appropriate level in written and oral communication to clearly convey their findings. The PhD advisor and committee are charged with assessing the impact of the student's work on the field, and ensuring the student exhibits high professional ethics.

External peer review of student research, based on conference participation (preferably peer-reviewed) and peer-reviewed journal publications are quantifiable metrics which assess student progress during the course of the PhD program, and can be tied to program outcomes. Table one shows the measures by which progress on the program outcomes can be assessed, and their corresponding metrics for success. In addition to the student and advisor paying careful attention to the steady progress towards meeting these metrics, the NANO-BME program administration also tracks these metrics. The NANO-BME GC, which meets monthly, will assess each student's progress on a semester basis in order to ensure timely completion of the degree.

Appendix F

OUTCOMES	MEASURES	METRICS
(1) Students demonstrate advanced knowledge of the physics, chemistry and engineering at the nano-scale	Qualifying Exam.	70% overall minimum.
	Cumulative GPA.	Equal or exceed 3.0.
	Publications.	2 Peer-reviewed articles.
(2) Students demonstrate specific knowledge as pertaining to their area of specialization.	Dissertation.	Successfully defended.
	Presentations.	3 seminars minimum.
	Publications.	2 Peer-reviewed articles.
(3) Students will utilize contemporary methods, tools, and theory to perform research in their area of specialization.	Research credits.	Pass/Fail.
	Dissertation.	Successfully defended.
	Publications.	2 Peer-reviewed articles.
(4) Students are cognizant of the scientific literature in their area of specialization, and understand contemporary issues and frontiers.	Presentations.	3 seminars minimum.
	Research proposal.	Successfully defended.
	Dissertation.	Successfully defended.
	Publications.	2 Peer-reviewed articles.
(5) Students will develop a technically sound research plan to address a research problem.	Research proposal.	Successfully defended.
	Dissertation.	Successfully defended.
	Experimental plans.	Approved by advisor.
(6) Students will communicate effectively in written and oral presentations.	Presentations.	3 seminars minimum.
	Research proposal.	Successfully defended.
	Dissertation.	Successfully defended.
(7) Students demonstrate intellectual honesty when working with data and ideas.	Research proposal.	Successfully defended.
	Publications.	2 Peer-reviewed articles.
	Dissertation.	Successfully defended.
(8) Students have made an original contribution to nanoscience or nanoengineering.	Presentations.	3 seminars minimum.
	Publications.	2 Peer-reviewed articles.
	Dissertation.	Successfully defended.

Table 1: NANO-BME Program Outcomes, measures and metrics for assessment of student achievement.

Program and Curriculum Assessment:

The NANO-BME GC will also review curriculum annually, in light of contemporary developments in the fields of nanoscience, nanoengineering and biomedical engineering and ensure curriculum is updated accordingly. The following elements for continuous improvement are implemented:

i. Each course syllabi, agenda, and lecture materials will be examined and discussed in committee.

ii. Grade distributions and student surveys will be evaluated to identify any areas which may need improvement.

iii. A self-assessment will be maintained by the NANO-BME GC, in preparation for external reviews, to be completed on a time schedule set by University and SDBOR policy (currently seven years).

iv. A three-year self-study will be completed by the NANO-BME GC, in preparation for the external review on the seventh year.

The above elements, including both internal and external reviews, are a mechanism for continuous improvement, ensuring relevant curriculum and optimal training of Nanoscience and Nanoengineering and Biomedical Engineering Graduate students.