Duke University Program in Materials Science and Engineering (revised)

Proposal for a Multidisciplinary Graduate Degree Program between Pratt School of Engineering and Trinity College of Arts & Sciences

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Executive Summary

Materials science and engineering (MSE) research at Duke University comprises internationally recognized efforts in bio-materials, computational materials discovery, electronic and photonic materials, energy materials, metamaterials, and soft materials. A multidisciplinary graduate degree program that takes advantage of these strengths across campus can help improve external recognition of MSE excellence at Duke. The proposed University Program in Materials Science and Engineering seeks to train the next generation of materials scientists and engineers by transcending traditional boundaries set by materials classifications and scientific disciplines.

The program is supported by a materials science and engineering initiative sponsored by the Provost and the Deans of Pratt and Trinity (see MOU in **Appendix E**). For three years, this initiative has engaged a core faculty from Pratt and Trinity with the goal of establishing Duke University as a premier institution for MSE education, research, and innovation. The proposed graduate program is a result of this effort and a core element to elevating MSE visibility at Duke.

This MSE graduate program will attract students that currently do not consider Duke for their graduate education because a degree in MSE is not awarded. Most likely, these students have Bachelor's or Master's degrees from traditional chemical engineering or materials science departments. Recruitment efforts will include outreach to these constituencies, as well as emphasis on groups that are underrepresented in science and engineering.

Thirty course credits are required for students with a Bachelor's degree to receive the M.S. (project option only) or Ph.D. degrees in MSE. The proposed curriculum comprises six core courses, a three-semester seminar course, and three elective courses. The graduate degree requirements are designed to be completed by cohorts of students, and the course offerings are the same for Master's and Ph.D. students, thereby streamlining the task of offering courses by faculty from different departments.

To be successful, the proposed program must accommodate different departmental cultures and financial models within Pratt School of Engineering and Trinity College of Arts & Sciences. Therefore, the program implementation is proposed to develop in two phases. During Phase 1 (Years 1-5), the focus primarily will be on an M.S. degree to establish the program curriculum, community, and culture that will lay the foundation for program expansion in Phase 2 (Years 5+). During Phase 1, a small number of Ph.D. students that have been admitted to home departments within Pratt or Trinity may "opt-in" to the program and earn a Ph.D. degree in MSE. For the purposes of this proposal, only Phase 1 is described in detail.

The proposed program is expected to evolve over time, guided by feedback received through annual assessment of program activities. Extensive conversations have been held with the relevant stakeholders in the development of this graduate program proposal, and the broad support by faculty is demonstrated by the collected letters of support and curricula vitae provided by participating faculty.

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1 Program Rationale

1.1 Motivation for Materials Science and Engineering Education at Duke

Many of the grand challenges that face society today require new and improved materials to help provide solutions, and this need is driving a resurgence in the importance and relevance of education and research in materials science and engineering (MSE). The Executive Office of the President recognized the essential role to be played by MSE in the 21st century with the 2011 announcement of the Materials Genome Initiative for Global Competitiveness by the National Science and Technology Council[1], which stated *"Advanced materials are essential to economic security and human well-being, with applications in … clean energy, national security, and human welfare."* As summarized in a 2008 report of an NSF Workshop - The Future of Materials Science and Materials Engineering Education[2], *"… a majority of the fourteen grand challenges in engineering issued by the National Academy of Engineering—including accessible clean water, economical solar energy, capturing CO2, and restoring and improving the urban infrastructure—require that materials and material systems with properties and performance superior to today's materials be developed. …These challenges imply a continuing need for materials scientists and materials engineers for the foreseeable future."* More recently, an article in The Economist titled "New Materials for Manufacturing", published in December 2015[3], describes "a 'golden age' for materials", and as a result, *"University materials departments are flourishing, spawning a vibrant entrepreneurial culture and producing a spate of innovations… Mastering the greater complexity of materials, as well as their design, engineering, production, supply-chain and life-cycle management, will require new skills and plenty of entrepreneurial talent…".*

Importantly, MSE research at Duke already comprises internationally recognized efforts related to many of these grand challenges, including biomaterials, computational materials discovery, electronic and photonic materials, energy materials, metamaterials, nanomaterials, and soft materials. In addition, many existing MSE research activities at Duke are already multidisciplinary, involving two or more faculty members that span different departments. Missing from the Duke MSE portfolio, however, is a multidisciplinary, coherent, graduate degree program that can help improve external recognition of MSE excellence at Duke by taking advantage of strengths across campus. Thus, the University Program in MSE is proposed as a university-wide graduate program to help harness and focus the MSE intellectual capital that already exists at Duke. Similar to existing University Programs, namely the University Program in Ecology and the University Program in Genetics and Genomics, the proposed program will reside outside of a single department or school. Instead, the program will create a cohesive experience for MSE graduate students by providing a core curriculum that prepares them to conduct research with affiliated faculty across campus, initially from Pratt School of Engineering (Pratt) or Trinity College of Arts & Sciences (Trinity). The University Program in MSE will administer M.S. and Ph.D. graduate programs.

The proposed graduate program will be a central component of a materials science and engineering initiative sponsored by the Provost and the Deans of Pratt and Trinity. A Memorandum of Understanding (see **Appendix E**) documents the university's commitment to development in this area, including funding for initial administrative costs. A core faculty from Pratt (including the departments of Biomedical Engineering, Civil and Environmental Engineering, Electrical and Computer Engineering, and Mechanical Engineering and Materials Science) and Trinity (including the departments of Chemistry, Mathematics, and Physics) has been working for three years to develop a strategy for establishing Duke University as a premier institution for MSE education, research, and innovation. Efforts are currently underway to

[1] https://www.mgi.gov/sites/default/files/documents/materials_genome_initiative-final.pdf
[2] https://www.nsf.gov/mps/dmr/mse_081709.pdf
[3] http://www.economist.com/technology-quarterly/2015-12-05/new-materials-for-manufacturing

include faculty from the Biology department. The proposed graduate program is a direct result of this faculty-led endeavor. As such, the proposed graduate program is fully supported by the faculty submitting the proposal, as well as additional faculty that have submitted biosketches.

The program will offer students a new opportunity to pursue their interests in MSE in a way that promotes contact with affiliated faculty from multiple departments across the campus. Eventually, a research rotation system will provide a formal mechanism for first year Ph.D. students to experience different areas of MSE across campus, as well as different research groups. In addition, the flexibility for Ph.D. students to join a research group in any department, while participating in a core MSE curriculum, will best leverage the strengths available across campus. Students will benefit from exposure to different scientific and engineering perspectives in their core coursework and from the opportunity to join a research group that fits their interests. Through interactions with their peers and with faculty, students will also develop the broad background necessary for addressing materials challenges they are likely to encounter in future research or industrial settings.

The program will also bring benefits for affiliated faculty. First, Pratt, Trinity, and Duke will become more appealing to outstanding graduate students with backgrounds in MSE or chemical engineering, and through their past coursework, these students will bring new skill sets to the research groups that they join. Second, faculty often have projects appropriate for master's students, and their research programs will benefit from successful completion of these projects. Finally, the materials initiative will provide opportunities for faculty hiring and make Duke University more attractive to new faculty working in strategic areas of interest, thereby enhancing the intellectual environment for all faculty affiliated with the initiative.

While a full-scale description of the materials science and engineering initiative is beyond the scope of this proposal, it is important to note that this initiative and the proposed graduate program do not represent an effort to create a new MSE department. Furthermore, should the materials science and engineering initiative sunset, the proposed plan enables a self-sustaining graduate program.

1.2 Phased Approach to Program Implementation

The structure of the master's program is straightforward and can be implemented immediately with the usual two-year startup period required for the first cohort and measured ramp up of class sizes. The Ph.D. program poses additional challenges, as it must be structured to dovetail properly with the different arrangements typically made for Ph.D. students in Pratt and Trinity. The implementation of the program will therefore occur in two phases. Phase 1 will accommodate master's students and a small number of Ph.D. students who are admitted through existing departmental channels and choose to participate in the materials program. In Phase 2, which is anticipated to begin after 5 years of Phase 1, the MSE program will admit its own Ph.D. students, and the research rotations in the first year will be implemented. The present proposal focuses on Phase 1.

The fundamentally different financial models for supporting Ph.D. students within Pratt and Trinity present a unique circumstance compared to existing University Programs at Duke. Pratt Ph.D. students receive 9 months of support in the form of a first-year fellowship (FYF), after which they must join a research group and be supported by an external grant. The practical result is that Pratt students are recruited to join a specific research group upon matriculation. In contrast, Trinity Ph.D. students receive up to two years of support through some combination of FYFs, research assistantships (RAs), and teaching assistantships (TAs). Trinity students typically engage in formal or informal research rotations to find a research group within two years, after which they are supported by external grants. The proposed program must accommodate these different graduate program cultures and financial models.

The most straightforward financial model would be for the program to directly award FYFs to Ph.D. students that are admitted to the program. However, without an external traineeship grant or Provost-level support, this model would divert resources from Pratt and Trinity departments that are allocated by the Graduate School. It is important to note that available traineeships in the MSE field are generally short-term (up to five years) and non-renewable. As such, these resources can be used to seed the Ph.D. program, but they are not available for long-term support (in contrast to NIH traineeships). A possible variation of this central financial model is for the Deans of Pratt and Trinity to allocate FYFs to the program (e.g., five slots each are donated). The program could then directly admit students and award FYFs. From the school/college perspective, if the donated slot is awarded to a student that joins the research group of a faculty member within the school/college, the source of the FYF (University Program or member department) is irrelevant. However, this approach severely limits the ability of an admitted student to select any research group. In addition, regardless of the ability of the program to directly award FYFs, research rotations represent a significant culture change within Pratt. The immediate implementation of a centralized model with rotations, without clearly demonstrating the benefits of the program *in practice*, is not likely to succeed in Pratt. Finally, because the program is not affiliated with a specific department and does not have departmental resources, there is no mechanism to generate funds for backstopping Ph.D. students in these two central financial models.

To address these challenges, the University Program in MSE is proposed to develop in two phases. During Phase 1 (Years 1-5), the program will establish the curriculum, community, and culture that will lay the foundation for eventual program expansion, including the introduction of research rotations. The M.S. program is essential to Phase 1 because Master's students can be admitted to the program directly. As a result, Master's students will be critical to the successful growth and development of the graduate program. In addition, tuition return from the M.S. program will generate financial resources required for the University Program in MSE to become self-sustaining. During Phase 1, Ph.D. students that have been admitted to departments within Pratt or Trinity can choose to complete the University Program in MSE degree requirements in order to earn a Ph.D. in MSE. In this way, the program can help attract Ph.D. students that are interested in the research of a given faculty member in Pratt or Trinity, but would like to participate in a core curriculum and community tailored to MSE. Financially, these Ph.D. students would be supported by the established mechanisms within Pratt or Trinity and subject to any requirements tied to this financial support (such as TA requirements). Specifically, whether a Ph.D. student receives 9-month or 12-month support is not determined by the University Program, but is determined by the existing financial model in the home department. During Phase 1, the University Program in MSE will assume no responsibility for the funding of Ph.D. students.

A schematic diagram of the Phase 1 program is shown in **Figure 1.1**. The green boxes represent matriculating graduate students, the gray boxes represent departmental faculty and faculty committees, the white ovals represent specific degree requirements, and the blue ovals represent additional co-curricular activities. It is important to note that the affiliated faculty are expected to change frequently as M.S. students complete research projects and Ph.D. students are admitted from different departments.

From the perspective of the University Program, this hybrid, "opt-in" approach for Ph.D. students enables rapid establishment of the graduate program and provides opportunities to build broader faculty support and to fine-tune program elements, while eliminating the need to immediately identify new financial resources to support Ph.D. students in MSE. From the home department perspective, the relationship between a departmental faculty advisor and Ph.D. student is unchanged, and Ph.D. students must comply with the existing financial models within the home department (such as 9-month vs. 12-month support). From the student perspective, an additional degree option is available that is administered by the University Program in MSE. As such, Ph.D. students must indicate their interest in

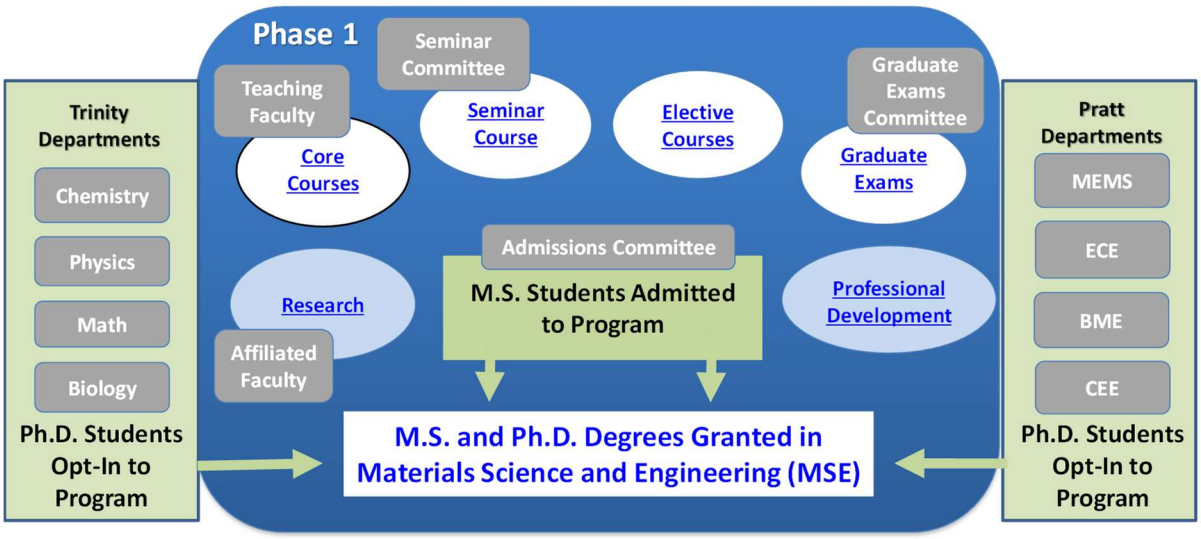


Figure 1.1: Phase 1 University Program in Materials Science and Engineering. M.S. students are admitted directly to the program, while Ph.D. students choose to pursue the Ph.D. in MSE curriculum from their home departments.

obtaining a Ph.D. in MSE before conclusion of the drop-add period during the first semester, and the University Program in MSE must approve students to join the program for the Ph.D. degree. The time restriction for joining the program is critical to ensuring the cohort-based structure of the curriculum. While there is some risk for disparities among Ph.D. students based on their home departments, the UP-MSE curriculum has a strong emphasis on building community that should help mitigate such issues. It is important to note that Phase 1 of the Ph.D. program will not include research rotations because students in Pratt are admitted directly to a specific research group.

In Phase 2 (Years 5+), the program will continue to admit M.S. students directly, while transitioning to an admitting and degree-granting Ph.D. program (i.e., able to independently award FYF slots annually). The main metric that will justify transition to Phase 2 is the successful acquisition of external support for the graduate program, such as an NSF Research Traineeship or an endowment from a donor. Such support will validate the program vision and provide the initial external resources necessary for the program to receive FYFs from the Graduate School without adversely affecting departments in Pratt or Trinity. At the end of a five-year NSF Research Traineeship, for example, the Ph.D. program can continue in the Phase 2 model because FYF slots will be generated by tuition remission from research grants used to support Ph.D. students in the program. During this phase, all Ph.D. students in the program will receive the same FYF support and perform research rotations. These students must join a research group by the end of the first year and be supported by external research grants from their research advisor for 12-month support.

During Phase 2, the program will have autonomy in Ph.D. student recruitment and admissions, as well as flexibility to introduce research rotations. During the research rotations, graduate students will be immersed in a research group on a trial basis while completing a short-term project defined by the affiliated faculty (e.g., literature review, experimental set-up, or simulations). During Phase 2, there also will be increased emphasis on providing options to graduate students interested in a broader range of entities on campus, such as the School of Medicine, Nicholas School of the Environment, Nicholas Institute of Environmental Policy, Sanford School of Public Policy, Kenan Institute of Ethics, and Fuqua School of

Business. For example, the program might detail a program of study for M.D./Ph.D. students in the School of Medicine interested in biomaterials, as well as provide opportunities to introduce these students to potential research advisors across campus. Another example might be to offer a graduate certificate option that would be attractive to students interested in combining environmental science, public policy, ethics, or business with a strong technical focus in MSE. If the metric for a Phase 2 transition is not achieved, but enrollment and student quality remain high, the UP-MSE would continue under the Phase 1 model. For the purposes of this proposal, only Phase 1 is described in detail.

2 Program Description

The Master's and Ph.D. programs proposed here will prepare students for careers in a field where the most important challenges require a synthesis of traditional disciplines and familiarity with classes of materials that have traditionally been studied independently. The goals of the program are to:

a. prepare diverse cohorts of M.S. and Ph.D. students to tackle multidisciplinary MSE challenges in academic, industrial, and national lab settings;
b. prepare a diverse workforce of scientists and engineers at the Master's level with multidisciplinary research experience; and
c. provide equipment training in state-of-the-art, shared research and instrumentation facilities.

In order to address the most important scientific and technological challenges for the next generation, the program must draw from several Duke departments and must be designed to work for students with a variety of educational backgrounds.

The degree requirements are designed to be completed by cohorts of students to emphasize shared experiences that help create a sense of community. **Figure 2.1** shows a schematic overview of the envisioned program structure and curriculum. Thirty course credits are required for students with a Bachelor's degree to receive graduate degrees in MSE (two years for the M.S. or five years for the Ph.D.). For the M.S. degree, only a project option is available. The proposed curriculum requires six core courses (3 credits each) that are designed to cover MSE fundamentals and prepare students to conduct research with affiliated faculty at Duke. These core courses should be taken in the first year. While M.S. students must select six courses from eight options, Ph.D. students may select four to six courses to accommodate specific requirements that may arise from their chosen research groups (i.e., up to 2 of the six core courses may be replaced by courses deemed critical by advisors and students for their research project). In addition to the 18 course credits from the core courses, a three-semester seminar course (3 credits total) and three elective courses (3 credits each) are required, all of which should be completed within the second year for a total of 30 course credits. For M.S. students, a maximum of one elective course may be replaced with an independent study to receive course credit for research. It is important to note that the course offerings are the same for M.S. and Ph.D. students, thereby streamlining the task of offering courses by faculty from different departments. The core courses, seminar course, and elective courses are described in more detail in **Appendix A**. In the case of Ph.D. students matriculating with a Master's degree, course credit requirements are reduced to 21 credits, and the selection of courses must be approved by the DGS. In addition to these required courses, students will have the option to engage in professional development activities offered in partnership with the Pratt Professional Master's Program and the Duke Career Center. The Academic Integrity and Responsible Conduct of Research training required by the Graduate School will be completed in the first semester for M.S. students (4 hours) and within the first three semesters for Ph.D. students (12 hours).

The examinations required for the M.S. and Ph.D. degrees are as follows:

M.S. Project Exam. Completion of a project is a core element of the M.S. degree in MSE. M.S. students will be matched to a project submitted by affiliated faculty within the first year. A project exam is required during the spring semester of the second year in order to complete the M.S. degree. In the project exam,

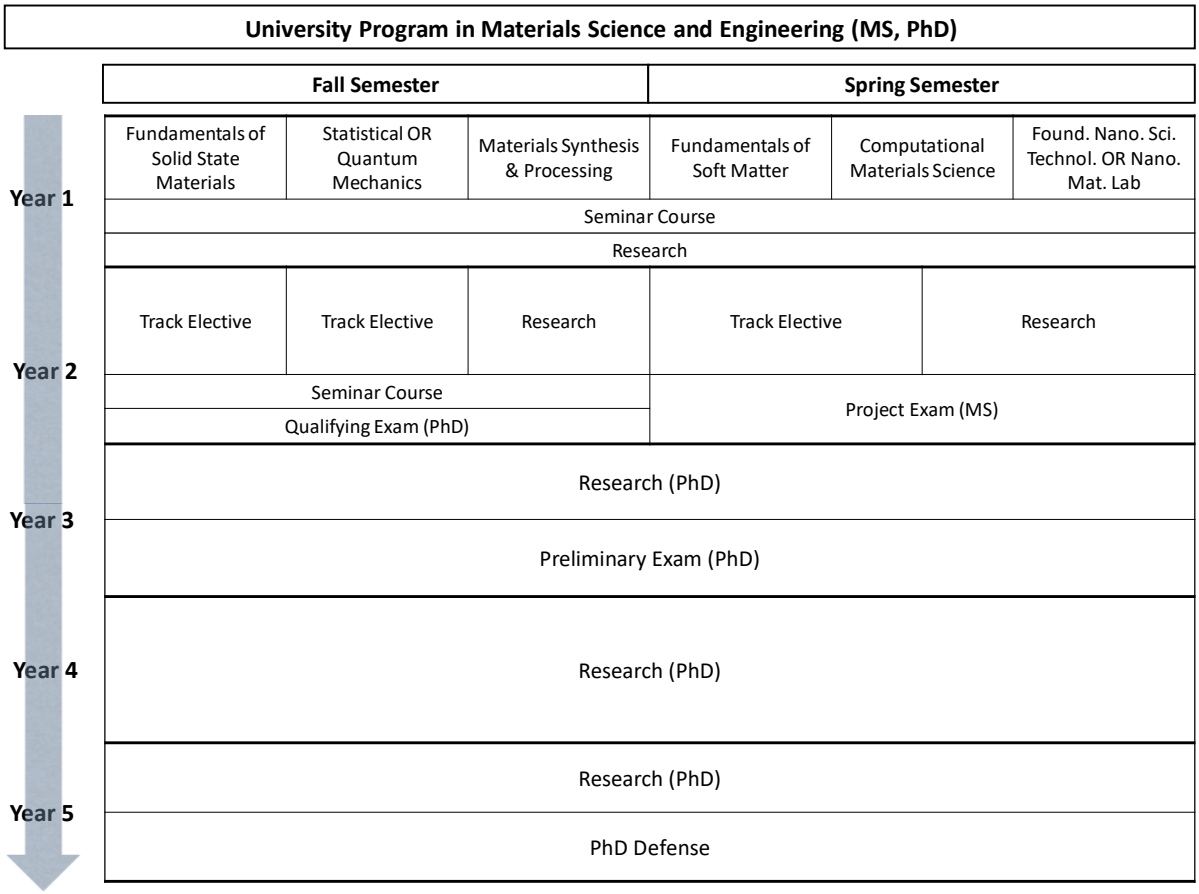


Figure 2.1: University Program in Materials Science and Engineering, M.S. and Ph.D. Curriculum and Program Structure.

a poster presentation is reviewed by the Graduate Exam Committee. A successful project exam will demonstrate strong understanding of the motivation and background of the project, independent effort on some aspect of the project, and outcomes that are consistent with preliminary results/demonstrations for a proposal or sufficient for publication in a manuscript or conference proceeding.

Ph.D. Qualifying Exam. The purpose of the qualifying exam is to monitor the effectiveness of the core curriculum and to help train Ph.D. students in communicating their research. The qualifying exam should be taken during the third semester of study and is administered by the Graduate Exam Committee. The exam score is a composite based on grades earned in the core courses, a poster presentation describing the relevance of a current research project to content learned in the core courses, and a three-page poster abstract. In the case of a failed exam, the Graduate Exam Committee will determine the appropriate action that should be taken by the student (e.g., additional course work, independent study, or continuation of studies in the home department).

Ph.D. Preliminary Exam. The preliminary exam is taken during the spring semester of the third year. The prelim committee should comprise four or five committee members, three of whom are required to be affiliated with the University Program in MSE. The prelim report and presentation will propose a research plan for completion of the PhD.

Ph.D. Defense. Ideally, the PhD defense occurs during the spring semester of the 5th year, with the same rules for committee membership as the preliminary exam.

A graduate program of the proposed scale will require a Director of Graduate Studies (DGS) and a Director of Graduate Studies Assistant (DGSA). Funds from the materials science and engineering initiative are dedicated to support these positions, initially, until the graduate program becomes self-sustaining. In addition to the DGS and DGSA, faculty participants include teaching faculty for core courses (**Table 2.1**) and three faculty committees (**Table 2.2**): Admissions Committee, Graduate Exams Committee, and Seminar Committee.

Table 2.1: Tentative Teaching Faculty for Core Courses

Faculty	Department	Faculty	Department	Faculty	Department	Faculty	Department
P. Charbonneau	Chemistry	J. Glass	ECE	V. Blum	MEMS	S. Haravifard	Physics
B. Wiley	Chemistry	M. Mikkelsen	ECE/Physics	O. Delaire	MEMS	M. Walters	SMIF
J. Liu	Chemistry	A. Stiff-Roberts	ECE	D. Mitzi	MEMS		
A. Franklin	ECE/Chemistry	J. Lu	Math	S. Zauscher	MEMS		

Table 2.2: Initial UP-MSE Faculty Committees

Admissions Committee		Graduate Exams Committee		Seminar Committee	
Faculty	**Department**	**Faculty**	**Department**	**Faculty**	**Department**
J. Liu	Chemistry	B. Wiley	Chemistry	M. Therien	Chemistry
J. Glass	ECE	A. Stiff-Roberts	ECE	A. Franklin	ECE
D. Mitzi	MEMS	J. Lu	Math	S. Zauscher	MEMS
J. Socolar	Physics	V. Blum	MEMS	S. Haravifard	Physics

Along with the DGS, the Admissions Committee is responsible for selecting M.S. students for admission, as well as matching admitted M.S. students with projects. The Graduate Exams Committee is responsible for conducting the Ph.D. qualifier and M.S. project exams. The Seminar Committee is responsible for identifying speakers for the seminar course. In general, each committee should comprise faculty from the different participating departments and/or research areas across campus. These faculty committee members, along with the teaching faculty and other faculty across campus with self-identified interest in MSE, have the capacity to attract up to 5 Ph.D. students and to support up to 20 M.S. students in research projects. It is important to note that while the affiliated faculty will change over time, the commitment to having representation from the different departments and schools will help maintain the desired character of the graduate program. The faculty participants have submitted brief biosketches, thereby indicating their support of the program (**Appendix B**).

The University Program in MSE will attract students that currently do not consider Duke for their graduate education because a degree in MSE is not awarded. Most likely, these students have Bachelor's or Master's degrees from traditional chemical engineering or materials science departments, and generally, they have interests that diverge from the mechanical properties and applications of materials that are emphasized in the existing Mechanical Engineering and Materials Science (MEMS) degree. Given that traditional chemical engineering and materials science programs will provide fertile recruiting grounds, there is great opportunity to identify new sources of prospective students and to recruit high-quality students from across the country. These students will be attracted to the proposed graduate program due to the world-class MSE research being conducted by Duke faculty across campus and because of the vibrant MSE intellectual community that will be established through the materials science and engineering initiative.

It is important to note that while graduates from chemical engineering and MSE programs constitute the largest and most easily identifiable potential students for the proposed program, the targeted

recruitment of these students in no way limits access to the program by students from other backgrounds. It is envisioned that all the disciplines represented by the affiliated faculty and core research areas will yield prospective students that seek fundamental education in MSE while pursing multidisciplinary research. Furthermore, professionals from companies located in the Research Triangle Park that wish to expand their scientific training could be interested in graduate certificate options combined with other professional degrees, as described for Phase 2.

3 Relationship of New Program with Existing Programs

The top ranked undergraduate chemical engineering programs, per the US News and World Report, are: 1) MIT, 2) U. California-Berkeley, 3) Stanford, 4) U. Texas-Austin, 5) U. Minnesota-Twin Cities, 6) Georgia Tech, 6) U. Wisconsin-Madison, 8) Caltech, 9) Princeton, 10) U. Delaware, 11) U. Michigan-Ann Arbor, and 12) Purdue University-West Lafayette. A survey of departmental research areas from these programs (**Table 3.1**) reveals that structural materials and mechanical properties are rarely emphasized explicitly; yet there is heavy overlap with MSE areas of strength in the proposed graduate curriculum.

It is also important to note that there are several graduate programs offered by university institutes that feature fundamental MSE education paired with multidisciplinary research. **Table 3.2** provides an overview of seven, high-profile MSE institutes. Four of these institutes award graduate degrees outside of a department, and two of those programs provide a research rotation.

In the case of core courses, average enrollments for existing courses are listed in **Table 3.3**. The M.S. students in the proposed graduate program represent an actual increase in total student numbers, while the Ph.D. students represent a re-direction to the core curriculum courses. The capacity of these course enrollments and available classroom sizes are the primary reasons to initially limit the graduate program to a steady-state of 10 incoming M.S. students and 5 incoming Ph.D. students each year during Phase 1.

Six of the eight core courses required for the M.S. and Ph.D. degrees in MSE are already offered on a regular basis, with enrollments that can accommodate up to 20 students per year. The benefit of grouping these courses as a distinct curriculum is that teaching resources can be combined from different departments to increase capacity. Each core course will be cross-listed in the departments of potential teaching faculty so that departmental and UP-MSE teaching obligations are met simultaneously. In this way, redundancy and flexibility can be built into the teaching faculty to account for leaves of absence, as an example. In addition, the responsibility of developing new core courses can be shared among departments. As an example, two new courses are proposed for the University Program in MSE. The first course, Materials Synthesis and Processing, could be taught by Jeff Glass (ECE), David Mitzi (MEMS), or Sara Haravifard (Physics). This course can also meet the teaching requirements for at least one semester in the respective home departments. Thus, the new course does not represent a loss of course content to the departments. The second new course, Fundamentals of Soft Matter, will be taught by Stefan Zauscher (MEMS), and this course will also meet teaching requirements for the home department such that the new course does not represent a loss of content to the department. It is important to note that the ECE 721/MEMS 711 course is already oversubscribed, which is why the proposed graduate program will sponsor an additional section for students in the program. For elective courses, the University Program in MSE serves to identify coherent course sequences in a particular research area; however, given the large number of options available from which three courses must be chosen, there is not the same need to ensure every elective course is always offered. The instructor for the seminar course will be Volker Blum (MEMS), and the DGSA and Seminar Committee will assist with logistics and determining invited speakers, respectively.

Table 3.1: Departmental Research Areas from Top-Ranked Undergraduate Chemical Engineering Programs[4]

Chemical Engineering Programs	Departmental Research Areas	
#1, Massachusetts Institute of Technology	• Biological Engineering • Catalysis & Reaction Engineering • Energy & Environmental Engineering • Materials • Polymers	• Surfaces & Structures • Systems Design & Engineering • Thermodynamics & Molecular Computations • Transport Processes
#2, University of California-Berkeley	• Bioengineering • Catalysis & Reaction Engineering • Electrochemical Engineering • Environmental Engin.	• Microelectron. Processing & MEMS • Polymers & Soft Materials • Theory, Multi-scale Modeling, & Computer Simulation
#3, Stanford University	• Chemistry of Energy • Chemistry of the Environment	• Chemistry of Life
#4, University of Texas-Austin	• Advanced Materials, Polymers & Nanotechnology • Biotechnology • Energy	• Environmental Engineering • Modeling & Simulation • Process Engineering
#5, University of Minnesota-Twin Cities	• Applied & Computational Mathematics • Biological Engineering • Catalysis, Separations & Reaction Engin. • Electrochemical Materials & Devices • Electronic, Magnetic, & Photonic Materials • Electron Microscopy • Energy	• Materials Processing • Materials Theory • Nanomaterials & Nanotechnology • Nanomechanics & Plasticity • Polymer Science & Engineering • Systems Engineering • Transport & Fluid Mechanics
#6, Georgia Institute of Technology	• Biotechnology • Complex Systems	• Energy & Sustainability • Materials & Nanotechnology
#6, University of Wisconsin-Madison	• Applied Mathematics • Bioscience & Engineering • Colloids/Particle Technology • Kinetics & Catalysis • Materials • Nanoscale Science & Engineering	• Polymers & Rheology • Process Systems Engineering • Reactor Modeling & Reaction Engineering • Thermodynamics • Transport Phenomena
#8, California Institute of Technology	• No description of departmental research areas	
#9, Princeton University	• Applied & Computational Mathematics • Bioengineering • Environmental & Energy Science & Technology	• Materials Synthesis, Processing, Structure & Properties • Process Engineering & Science • Thermodynamics & Statistical Mechanics • Transport Phenomena
#10, University of Delaware	• Biomedical • Biomolecular • Bioprocessing • Catalysis/Reactions • Colloids/Interfaces	• Energy/Sustainability • Environment Materials Polymers/Composites • Process Control/Systems Analysis • Thermodynamics Transport/Separations
#11, University of Michigan-Ann Arbor	• Biomolecular Engineering • Catalysis & Reactions • Cellular Engineering • Computing & Simulation • Energy	• Materials • Microfabricated Systems • Nanotechnology • Polymers & Complex Fluids
#12, Purdue University-West Lafayette	• Biochemical & Biomolecular Engineering • Catalysis & Reaction Engineering • Fluid Mechanics & Interfacial Phenomena • Mass Transfer & Separations	• Nanoscale Science & Engineering • Polymers & Materials • Product & Process Systems Engineering • Thermodynamics, Molecular & Nanoscale Modeling

[4] US News and World Report

Table 3.2: Overview of Selected MSE Institutes.

US Materials Institutes	Research Areas		Degree	Notes
Institute of Materials Science and Engineering (IMSE), Washington University in St. Louis	• Plasmonics, Photonics, and Materials for Sensors and Imaging • Computational Materials Science • Energy Harvesting and Storage • Materials for Regenerative Medicine	• Metallic Glasses and Other Complex Structures • Environmental Technologies and Sustainability	M. S. Ph.D.	• Complete two research rotations
Institute for Materials (IFM), Georgia Institute of Technology	• Graphene/New Electronic Materials • Organic Photonics and Electronics	• Mechanical Properties • Other Strengths	None	• Degrees awarded by departments
Materials Science Institute (MSI), University of Oregon	• Chemistry • Physics		M.S. Ph.D.	• Rotation program • Internship
Materials Research Institute (MRI), Pennsylvania State University	• Biomedical Materials & Devices • Electronic Materials & Devices • Materials, Processing, & Characterization	• Nanomaterials, Nanostructures, & Nanofabrication • Polymeric Systems	None	• Intercollege Graduate Degree Program in MSE (M.S. /Ph.D.)
Institute for Materials Research (IMR), The Ohio State University	• Photovoltaics • Magnetoelectronics • Biomaterials and Biosensors	• Computational Materials • Polymers	None	• Degrees awarded by departments
Institute of Materials Science (IMS), University of Connecticut	• Materials Science • Materials Science & Engineering	• Polymer Science	Ph.D.	
Princeton Institute for the Science and Technology of Materials (PRISM), Princeton University	• Quantum Materials and Structures • Large-Area Materials and Devices • Optics and Sensors	• Bio-Nano Interface • Patterning and Self Assembly • Computation Materials Science	None	• Degrees awarded by departments

Table 3.3: Average Enrollments for Core Courses

Core Course	Average Enrollment
CHEM 544: Statistical Mechanics	7
CHEM 548: Fundamentals of Solid State Materials	13
ECE/NANOSCI 511: Foundations of Nanoscale Science & Technology	24 (max capacity 35)
ECE 521: Quantum Mechanics	12
ME 555: Computational Materials Science	12
ECE 721/ME 711: Nanotechnology Mat. Lab/Advanced Mat. Lab	14 (max capacity 14)
NEW: Materials Synthesis and Processing	N/A
NEW: Fundamentals of Soft Matter	N/A

The University Program in MSE will also collaborate with other existing entities on campus. The Master of Engineering (M.Eng.) degree in MSE offered by Pratt is designed to prepare students for technical industry careers by combining required industry prep courses and internship experience with core-discipline course work. Once approved, the University Program in MSE will work to align the proposed curriculum with the needs of M.Eng. students, such as the required internship, and submit a request to the Engineering Faculty Council of the Pratt School of Engineering to allow its administration of the M.Eng. degree in MSE in order to provide coherent, yet distinct, degree options. The proposed graduate program will benefit from the materials fabrication and characterization capabilities available in the Shared Materials Instrumentation Facility (SMIF), access to which will be integrated into the graduate curriculum. Finally, strong relationships with research entities on campus, such as the Fitzpatrick Institute for Photonics (FIP), will help identify research groups for graduate students across campus; while relationships with initiatives, such as the Energy Initiative and the Innovation and Entrepreneurship Initiative, will help expand resources and opportunities available to students.

Despite the exciting promise of the proposed graduate program, it is important to consider potential negative consequences on existing graduate programs and participating faculty. In terms of teaching, an effort has been made to create a core curriculum that primarily uses existing courses already offered on a regular basis by affiliated faculty (but currently distributed in an uncoordinated fashion among departments and schools). With respect to advising responsibilities, there is no impact on undergraduate advising or advising of Ph.D. students; however, for M.S. advising, affiliated faculty will be asked to advise research projects (the number of new projects required each year will grow gradually from five to ten). Finally, it is important to consider how the proposed graduate program will impact the Department of Mechanical Engineering and Materials Science (MEMS), specifically.

While the MEMS department does have “materials science” in its name, MSE research also occurs in the seven other departments shown in **Figure 1.1**. In terms of the Ph.D. program, the MEMS department will participate in the same manner as any other department within Pratt or Trinity, and the impact on departmental Ph.D. programs is negligible during Phase 1. During Phase 2, faculty in Pratt or Trinity will have more choice and can select Ph.D. students from their home departments or from the University Program in MSE. Regarding the M.S. program, if the proposed graduate program were to limit the viability of the MEMS M.S. degree, there could be potential for negative impact on the MEMS department due to financial resources related to the Master’s degree. However, there are a few reasons that the M.S. in MEMS and the M.S. in MSE should co-exist. First, the MEMS department has already demonstrated strength in the Mechanical Engineering track of its M.S. program (which will not be impacted by the proposed M.S. in MSE). Collaboration with the University Program in MSE to provide the Materials Science track is an efficient use of available resources and will provide more flexibility and options for incoming students to select faculty advisors from across the campus. Second, a joint degree in Mechanical Engineering and Materials Science is especially useful for students focused on structural materials, and these students will choose to pursue an M.S. in MEMS. Nonetheless, there is a significant pool of potential MSE graduate students for whom a link to Mechanical Engineering is not desired or beneficial, and these students will choose the M.S. in MSE. Third, the historical strength of mechanical engineering within the MEMS department has resulted in its grouping with other mechanical engineering departments for the purposes of national and international rankings. The University Program in MSE offers Duke the opportunity to be ranked in MSE by encompassing strengths across campus and without establishing a new department. Importantly, the department chair and materials faculty within the MEMS department are strongly supportive of this effort, as indicated in the attached letter of support.

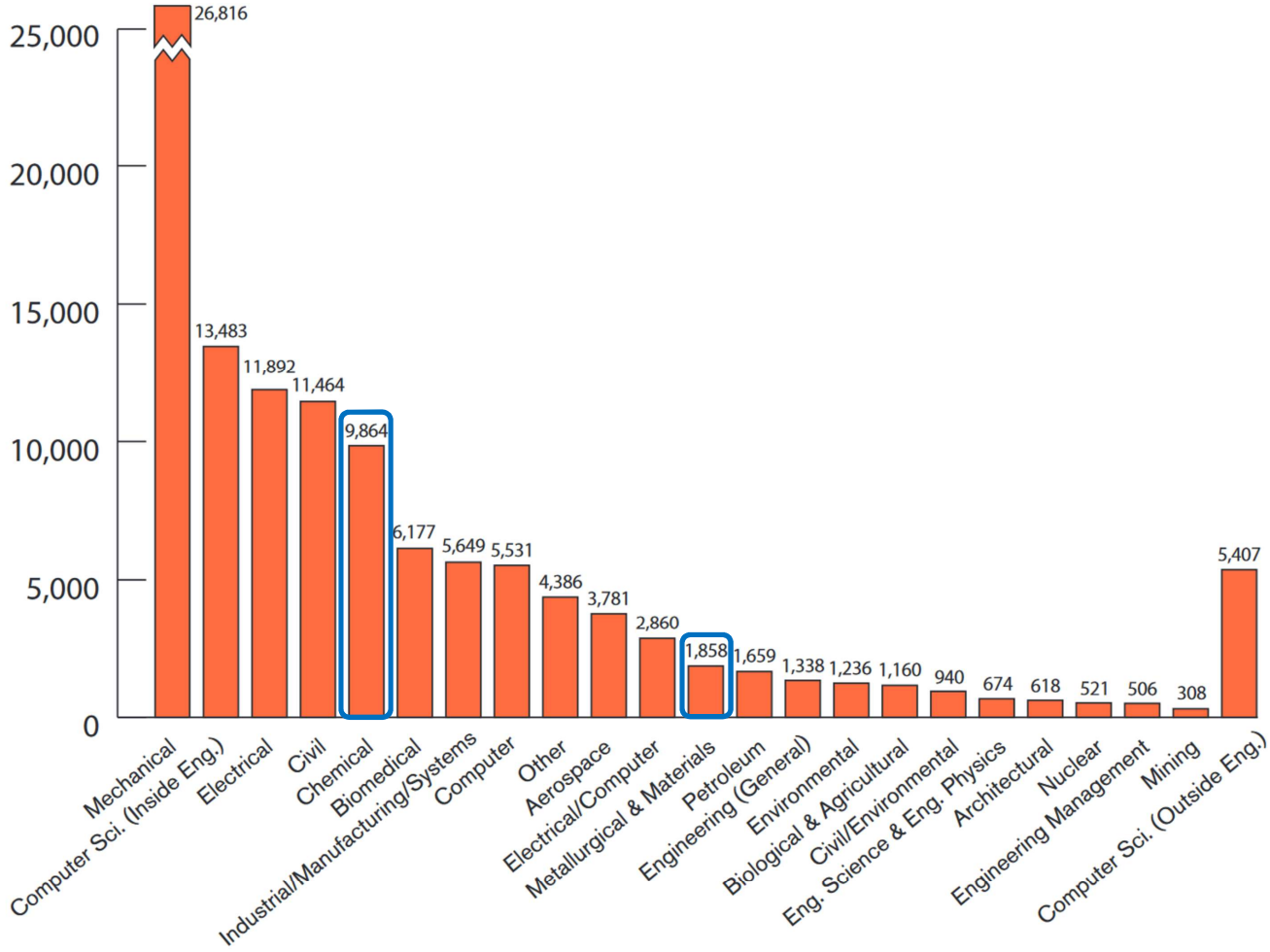
4 Market Research for New Program

Per the report from the American Society for Engineering Education (ASEE), "Engineering by the Numbers (2016),"[5] the pool of potential graduate students in MSE is large. As shown in **Figure 4.1**, Chemical Engineering was the 5th largest discipline in 2015-2016 for awarded Bachelor's degrees (9,864). During the same time, 1,858 Bachelor's degrees were awarded in Metallurgical/Materials Engineering. Thus, for the 2017-2018 academic year, a pool of over 11,000 potential graduate students existed. **Table 4.1** demonstrates that this number of prospective students from Chemical Engineering or Metallurgical/Materials disciplines has grown steadily since 2007. **Figure 4.2** and **Table 4.2** speak to the demand of M.S. degrees in these disciplines. In 2015-2016, 1,788 Master's degrees were awarded in Chemical Engineering, while 1,261 Master's degrees were awarded in Metallurgical/Materials Engineering. As in the case of undergraduate programs, the number of Master's degrees awarded in these disciplines has generally increased since 2007. Considering that during Phase 1, the proposed graduate program seeks to reach a steady state of 10 M.S. and 5 Ph.D. students matriculating each year, there is sufficient demand to meet these enrollment targets.

[5] https://www.asee.org/documents/papers-and-publications/publications/college-profiles/16Profile-Front-Section.pdf

Bachelor's Degrees, 2015–2016

Bachelor's Degrees Awarded by Engineering Discipline: 112,721*



*Total does not include computer science (outside engineering).

Figure 4.1: Bachelor's Degrees Awarded by Discipline (2016-2016), "Engineering by the Numbers," American Society for Engineering Education, 2016.

Table 4.1: Bachelor's Degrees by Discipline (2007-2016), "Engineering by the Numbers," American Society for Engineering Education, 2016.

By the Numbers

ENGINEERING DEGREES, 2007–2016

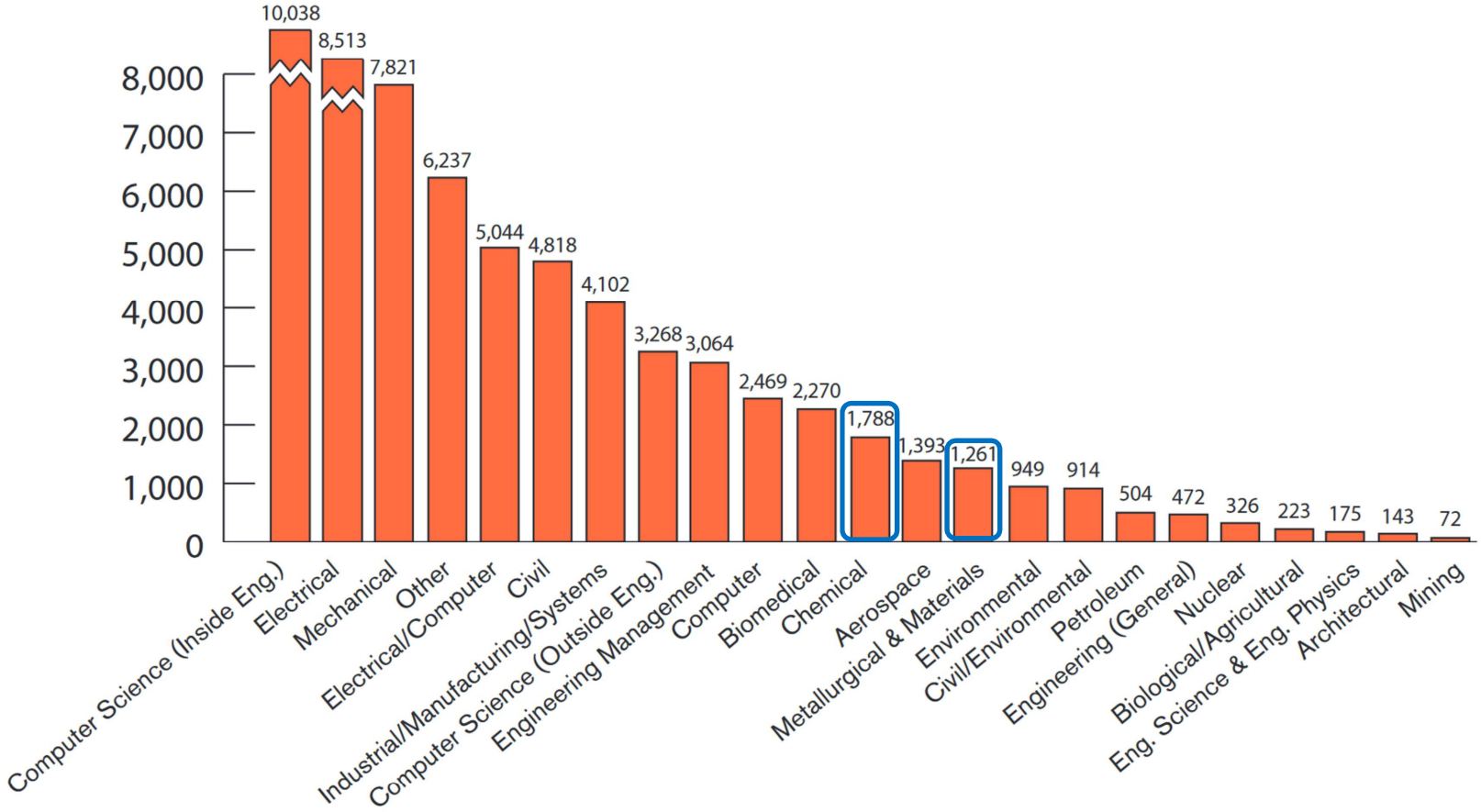
BACHELOR'S DEGREES BY DISCIPLINE 2007–2016

Bachelor's Degrees	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Aerospace Engineering	2,788	2,930	3,057	3,218	3,459	3,668	3,595	3,695	3,803	3,781
Architectural Engineering	625	646	723	753	743	763	660	607	568	618
Biological/Agricultural Eng.	659	623	631	719	796	871	924	1,031	1,100	1,160
Biomedical Engineering	2,969	3,237	3,644	3,670	4,066	4,374	4,709	5,119	5,683	6,177
Chemical Engineering	4,551	4,850	5,185	5,948	6,487	7,245	7,717	8,110	9,090	9,864
Civil Engineering	9,402	10,132	10,508	11,027	12,154	12,309	12,464	12,333	11,900	11,464
Civil/Environmental Eng.[1]	445	464	558	591	709	751	953	881	1,000	940
Computer Engineering	4,046	3,808	3,394	3,340	3,381	3,688	3,906	4,201	4,881	5,531
Computer Science (Inside Eng.)	6,446	5,964	5,652	6,049	6,708	7,371	8,184	9,328	10,970	13,483
Electrical Engineering	11,467	10,790	9,859	9,634	9,942	10,102	10,662	11,261	11,385	11,892
Electrical/Computer Eng.	2,425	2,216	2,194	2,175	2,153	2,426	2,518	2,827	3,429	2,860
Engineering (General)	1,246	1,160	1,246	1,335	1,465	1,192	1,554	1,406	1,394	1,338
Engineering Management	274	331	309	336	315	434	418	436	527	506
Engr. Science and Engr. Physics	460	472	431	526	496	562	524	574	545	674
Environmental Engineering	454	486	503	587	698	905	994	1,012	1,124	1,236
Industr./Manuf./Systems Eng.	3,503	3,367	3,510	3,744	3,727	4,107	4,272	4,877	5,291	5,649
Mechanical Engineering	16,701	17,324	17,375	18,391	19,241	20,369	21,707	23,675	25,436	26,816
Metallurgical/Materials Eng.	963	1,095	1,035	1,152	1,161	1,280	1,415	1,440	1,671	1,858
Mining Engineering	119	153	190	191	213	236	231	324	335	308
Nuclear Engineering	402	415	378	414	469	565	614	584	544	521
Other Engineering Disciplines	2,942	3,211	3,351	3,794	3,730	3,956	4,260	4,202	4,517	4,386
Petroleum Engineering	428	496	654	753	888	1,002	1,079	1,250	1,465	1,659
TOTAL	**73,315**	**74,170**	**74,387**	**78,347**	**83,001**	**88,176**	**93,360**	**99,173**	**106,658**	**112,721**

ENGINEERING MASTER'S DEGREES, 2015–2016

By the Numbers

MASTER'S DEGREES AWARDED BY DISCIPLINE: 62,596*



*Total does not include computer science (outside engineering).

Figure 4.2: Master's Degrees Awarded by Discipline (2015-2016), "Engineering by the Numbers," American Society for Engineering Education, 2016.

Table 4.2: Master's Degrees by Discipline (2007-2016), "Engineering by the Numbers," American Society for Engineering Education, 2016.

ENGINEERING DEGREES, 2007–2016

By the Numbers

MASTER'S DEGREES BY DISCIPLINE 2007–2016

MASTERS DEGREES	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Aerospace Engineering	1,056	1,096	1,075	1,166	1,398	1,443	1,308	1,410	1,380	1,393
Architectural Engineering	116	119	121	131	125	150	138	128	128	143
Biological/Agricultural Eng.	149	155	171	197	213	234	244	227	237	223
Biomedical Engineering	1,156	1,221	1,396	1,447	1,558	1,890	1,997	1,918	2,197	2,270
Chemical Engineering	1,036	1,051	1,084	1,162	1,354	1,440	1,456	1,545	1,716	1,788
Civil Engineering	3,368	3,437	3,659	4,088	4,739	5,002	4,778	4,958	4,897	4,818
Civil/Environmental Eng.[1]	178	223	249	282	279	570	754	618	739	914
Computer Engineering	1,479	1,662	1,880	1,712	1,783	1,963	1,883	2,081	2,093	2,469
Computer Science (Inside Eng.)	4,913	4,924	5,373	5,230	5,497	5,756	6,182	6,325	8,359	10,038
Electrical Engineering	5,026	5,735	6,137	6,345	6,666	6,572	6,305	6,536	7,768	8,513
Electrical/Computer Eng.	3,532	3,757	3,682	3,459	3,799	3,824	3,756	4,019	4,840	5,044
Engineering (General)	602	612	729	745	906	666	623	645	557	472
Engineering Management	2,114	2,036	2,240	2,595	2,484	2,665	2,690	2,835	3,020	3,064
Engr. Science/Engr. Physics	205	194	170	248	216	205	209	186	220	175
Environmental Engineering	552	524	552	639	724	788	805	871	898	949
Industr./Manuf./Systems Eng.	2,565	2,669	2,986	2,990	3,359	3,362	3,214	3,514	3,538	4,102
Mechanical Engineering	4,485	4,647	4,757	5,066	5,915	6,237	6,261	6,529	7,169	7,821
Metallurgical/Materials. Eng.	702	715	771	771	852	951	1,049	1,155	1,119	1,261
Mining Engineering	49	54	51	29	47	49	63	49	81	72
Nuclear Engineering	255	268	264	305	324	366	375	316	359	326
Other Engineering Disciplines	3,232	3,655	4,063	4,152	4,320	4,852	5,011	5,407	5,594	6,237
Petroleum Engineering	213	232	222	264	382	387	382	418	524	504
TOTAL	**36,983**	**38,986**	**41,632**	**43,023**	**46,940**	**49,372**	**49,483**	**51,690**	**57,433**	**62,596**

Numerous employment opportunities exist for Ph.D. graduates of the proposed program, especially given the emphasis on multidisciplinary research and education. In addition to academic careers as faculty members in the many related disciplines that have been described, graduates also have career opportunities in industry labs (both established and start-up companies) and government labs. Exposure to a broad range of materials-related skills, concepts and approaches will make M.S. graduates attractive for Materials Engineer positions in industry. The Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook, 2016-17 Edition*[6], states that 25,300 Materials Engineer jobs were available in 2014 and the median pay in 2016 was $93,310 per year. Alternatively, students graduating with M.S. degrees may choose to pursue a Ph.D. in MSE. Finally, the potential for unique exposure and access to social sciences and entrepreneurship at Duke can also lead to careers in policy and business.

5 Financial Projections

A six-year projection of the program expenses and income is shown in **Appendix C**. During the proposed Phase 1 of the graduate program, Ph.D. students are admitted to a home department in Pratt or Trinity, and M.S. students are admitted directly to the University Program in MSE. As such, all financial support for the Ph.D. program, including the support of first-year fellowships, back-stopping of graduate students, and English for International Students (EIS) courses, operate according to existing mechanisms within the home departments. The University Program in MSE is responsible for all costs associated with M.S. students only.

Personnel includes a DGSA and a DGS. The DGSA will be hired at 50% level of effort beginning in FY 17/18. Up to one month of summer salary will be provided as compensation to the DGS. A salary fringe rate of 26.9% is applied, and a 3% COLA increase is assumed each year. Expenses for program operation include website content development and advertising, development of core courses, travel and food for the required seminar course, funds to provide an additional section of the Nanomaterials Characterization Lab (ECE 721/ME 711, which provides training in the Shared Materials Instrumentation Facility), professional development, graduate school allocated costs, support for required EIS courses, graduate student recruitment, graduate scholarships, and miscellaneous expenses. The EIS course expense is an estimate based on two courses being required for half of the matriculating M.S. students each year. The amount for M.S. graduate scholarships is set at 15% of the total M.S. tuition, and will be awarded as 30% or 50% tuition awards based on need and/or merit, and to help promote diversity. It is important to note that the core courses to be offered will be taught by tenure-track faculty and require no additional instructional cost. As stated in the MOU from each department offering a core course, the existing courses can accommodate more students without space limitations on classroom size (with the exception of ECE 721/ME 711).

The UP-MSE has two sources of income. First, in recognition of the essential role the graduate program plays in realizing the vision of the materials science and engineering initiative, seed funding from the initiative will be provided each year through FY 21/22 to support the graduate program. These funds are allocated by the Provost's Office and the Deans of Pratt and Trinity (as described in the MOU in **Appendix E**). Second, the proposed graduate program will generate revenue by tuition return from the M.S. degree program (assuming 35% return for matriculating M.S. students in FY 18/19 (5), FY 19/20 (13), FY 20/21 (18), and FY 21/22 (20)).

This revenue from the M.S. degree program will be used to balance the graduate program budget, and to provide a mechanism to build a reserve fund for program operations and to help enable transition to Phase 2 by providing a backstop for Ph.D. students. Therefore, the entire program balance will be saved to build a general reserve fund ($200K goal). By FY 22/23, given that the graduate program grows as

[6] https://www.bls.gov/ooh/architecture-and-engineering/materials-engineers.htm

projected, the proposed program will be self-sustaining and no longer require contributions from the materials initiative. The M.S. tuition return to Pratt and Trinity will be 65%, shared equally, resulting in a total cumulative return of $2,919,221 by FY 22/23.

By the end of five years, the proposed graduate program will require space for a central office that acts as a hub for program activities. Initial discussions have been held to identify space given the reorganization that will take place upon completion of the new engineering building in 2019. No additional library resources are required because the MSE areas of strength are already present on campus. Central services from the Graduate School and the Career Services Center will be used and related expenses are indicated in the budget in **Appendix C.**

During Phase 1, admissions of M.S. students will be managed by the DGS and Admissions Committee based on academic qualifications, research interests, overall diversity, and faculty project match. Ph.D. students will be admitted according to existing mechanisms within the participating departments of Pratt and Trinity. For both degree programs, the UP-MSE will actively recruit diverse groups of students through the following activities:

Website development. The program website will serve as an important recruiting tool and resource to introduce the program.

Sponsorship of exhibit/career fair booths at professional society meetings. Through professional organizations such as the Materials Research Society (MRS), National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE), the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS), and the Society of Women Engineers (SWE), the program will reach out to potential students in related fields of interest.

Participation in University Materials Council. Through the University Materials Council, the program will establish a presence among the top materials programs in the country and promote the program to the department chairs of strong undergraduate programs.

Recruitment visits to colleges/universities with strong undergraduate MSE programs. The program will facilitate a coordinated effort by affiliated faculty to promote the program during seminar presentations at the top undergraduate chemical engineering and materials engineering programs.

6 Student Community

The community that will be created across campus through the University Program in MSE is an important outcome of this new graduate program. Student diversity will be promoted during recruitment and admissions by taking advantage of existing resources in the Graduate School and by working with the Director for Diversity and Inclusion in Pratt, Dr. Johnna Frierson. For example, participation in the Pratt Graduate School Boot Camp provides an opportunity to introduce the graduate program to members of underrepresented groups.

Professional development will be provided to M.S. and Ph.D. students in partnership with the Duke Career Center and the Pratt Professional Master's Program to complement the academic progress of the graduate students. All students will be encouraged to complete the Skills Workshops for Graduate Students offered by the Duke Career Center, and M.S. students will be invited to attend TechConnect and career fair prep sessions provided by the Professional Master's Program. In addition, more customized series will be offered to Ph.D. students in their 4th year, such as mock interviews, CV preparation, and negotiation. MSE graduate students will also participate in a program-sponsored industry night in order to facilitate networking with national labs and companies. Third-year Ph.D. students will have the option to participate in a year-long journal club designed to provide peer mentoring in writing research manuscripts. This club will also assist in the preparation of the preliminary report for the prelim exam to be taken at the end of the third year. As stated in the budget discussion, it is anticipated that roughly half of the MSE graduate students will be international and require EIS courses.

7 Program Evaluation

The success of the graduate program will be evaluated by tracking the number of applications received, the number of admissions granted, the number of students enrolled, the number of students graduated, student demographics, GPA, and standardized test scores, and job placement within three months of graduation. The collected data will be used to evaluate program quality and outcomes, as well as to collect data for use in evaluation by the Southern Association of Colleges and Schools (SACS). In addition, the program will conduct a review in the third year, as well as an external review every five years, for evaluation by the Graduate School according to established practice. The learning assessment plan is presented in **Appendix D**.

8 Risk Assessment

The risk related to achieving enrollment targets for the graduate program is low due to the conservative estimates for growth of the program. Resources required for marketing and recruitment have been included in the budget. The largest risk related to implementing the curriculum is to coordinate offering the core courses across different departments and schools. However, this risk is mitigated by the fact that most of the core courses are already offered on a regular basis. In addition, the faculty that teach these courses are supportive of this graduate program, as indicated by their submission of a biosketch for the proposal. A high-quality graduate program in MSE will only improve the reputation of Duke University, and this recognition is one of the main goals of the program. As such, all faculty participants are keenly aware of the importance of implementing a strong program. Finally, student enrollment is the largest factor contributing to the financial health of the program. The expensive Master's tuition presents a risk due to affordability, however, the inclusion of scholarship funds and the emphasis on job placement should help mitigate this risk. Importantly, the budget builds a reserve fund that is critical to ensuring the program's success when expanding to include Ph.D. students. Overall, the graduate program will contribute to the financial strength of both Pratt and Trinity.

9 Letters of Support

Letters of support from department chairs of each participating department are included in **Appendix E**. In addition, an MOU describing financial support of the graduate program from the Provost and Deans of Pratt and Trinity is included, as are teaching MOUs describing departmental commitments to offer the core courses required for the proposed program.

Appendix A: Descriptions of Courses and Learning Opportunities

The eight core courses (from which 4 to 6 must be selected) are described below:

1) CHEM 548: Fundamentals of Solid State Materials (1st Year Fall). This course discusses the structure and properties of solid state materials and how these materials are used in diverse applications. The course builds on the students' backgrounds in mathematics, science, and engineering, and provides the foundation needed for more advanced work in materials science. The course focuses on crystal structure, mechanical properties, phase transformations, thermal, electronic, and optical properties of materials. Topics that will be covered include: bonding, crystal structure, defects, diffusion, phases, as well as selected electrical, thermal, optical, magnetic, and chemical properties of metals, ceramics, organic/polymeric/bio materials and nanomaterials.

2) CHEM 544: Statistical Mechanics (1st Year Fall). Fundamentals of quantum and classical statistical mechanics using the ensemble approach. Introduction of modern techniques and applications including the renormalization group treatment of phase transitions and linear response theory of time-dependent statistical mechanics.

3) ECE 521: Quantum Mechanics (1st Year Fall). The goal of this course is to provide a fundamental introduction to the postulates, formalism, and application of quantum mechanics (1D problems, 3D problems, and approximations). Particular attention is paid to the relevance of quantum mechanics to semiconductor materials and devices.

4) NEW: Materials Synthesis and Processing (1st Year Fall). This course will focus on synthesis and processing techniques in the context of the six elective tracks identified for the UP-MSE. The format of the course will comprise 2-3-week sections on each of the track areas with guest lectures and student presentations on each topic. The goal is for students to understand how materials synthesis and processing is linked to resulting material structure, which in turn leads to certain material properties. In addition, students will receive an introduction to the different areas of specialization available at Duke.

5) NEW: Fundamentals of Soft Matter (1st Year Spring). This course in Soft Condensed Matter is designed as a beginning graduate level course for students with a broad range of backgrounds in the sciences and engineering. The main objective of the course is to bring students to a common level of knowledge and competency in Soft Condensed Matter that allows them to pursue more specialized directions in soft matter materials science. The course is based on a popular textbook, and will be augmented with additional readings from the primary literature and with guest lectures by experts on specific topics.

6) ME 555: Computational Materials Science (1st Year Spring). This course examines methods for simulating matter at the molecular and electronic scale. Molecular dynamics, Monte Carlo and electronic structure methods will be covered with emphasis on hands-on experience in writing and/or exercising simulation codes for atomistic and electronic structure simulation.

7) ECE/NANOSCI 511: Foundations of Nanoscale Science and Technology (1st Year Spring). This course is designed to introduce students to the interdisciplinary aspects of nanoscience by integrating important components of the broad research field together. This integrated approach will cross the traditional disciplines of biology, chemistry, electrical & computer engineering, computer science, and physics. Fundamental properties of materials at the nanoscale, synthesis of nanoparticles, characterization tools, and self-assembly are covered.

8) ECE 721/ME 711: Nanotechnology Materials Lab/Advanced Materials Lab (1st Year Spring). This course will give a hands-on introduction to characterization and clean room based processing methods that play an important role in the fabrication and characterization of materials. Clean-room based processing methods to be covered include: basic photolithography, evaporation, electron beam lithography, and wet

and dry etching. Characterization methods to be covered include: atomic force microscopy, scanning electron microscopy, transmission electron microscopy, and X-Ray photoelectron spectroscopy.

The seminar course, which is required for the first three semesters (1 credit hour each), is an integral part of the UP-MSE identity. Seminar speakers will include affiliated faculty, regional faculty, leading national and international MSE researchers, and graduate students (as part of graded requirements or voluntary participation). For the first year, all graduate students must attend the weekly seminars and submit a written summary of the presentations. In the 3rd semester, all graduate students must attend the weekly seminars and make a research presentation. Students will receive constructive feedback on their presentations.

Three electives are needed to complete the course requirements of the M.S. and Ph.D. degrees. The elective courses have been identified from existing courses across Pratt and Trinity, and they have been grouped to reflect research strengths at Duke (**Table A.1**). The three courses can be selected from these groupings in any combination according to research needs or interest. Other courses may be taken as an elective pending approval by the DGS.

Table A.1: UP-MSE Elective Courses

Medical & Biomaterials	Computational Materials Discovery	Electronic & Photonic Materials	Energy Materials	Exploratory Materials (soft-, nano-, meta-)	Sustainable Materials
BME 525*: Biomedical Materials & Artificial Organs	CEE 520*: Finite Element Method	BME 555/CHEM 630: Advances in Photonics	ECE 341L: Solar Cells	BME 529*/ME 512*: Theoretical & Applied Polymer Science	CEE 563/ENVIRON 540: Chemical Fate of Organic Compounds
BME 526: Elasticity	COMPSCI 520: Numerical Analysis	BME 567/CHEM 601: Biosensors	ECE 546: Optoelectronic Devices	BME 522: Intro. Bionanotechnol. Engineer.	CEE 564: Phys.-Chem. Process. in Environment. Engineer.
BME 527: Cell Mechanics & Mechano-Transduct.	ECE 577: Computational Electromagnetics	ECE 526: Devices for Integrated Circuits	ENVIRON 583S: Energy & U.S. National Security	CEE 623: Mechanics of Composite Materials	ENVIRON 638L: Environmental Life Cycle Analysis & Decision
BME 528: Introduction to Biofluid Mechanics	MATH 551: Appl. Partial Diff. Eqns. & Complex Var.	ECE 545: Nanophotonics	ENVIRON 630: Transportation & Energy	CHEM 541: Quantum Chemistry	ENVIRON 811: Sustainable Systems Theory and Drivers
BME 530: Tissue Biomechanics	MATH 561: Numerical Linear Algebra	ECE 572: Electromagnetic Communication Systems	ENVIRON 631: Energy Technology & its Environmental Impact	CS 624/ECE 611: Nanoscale and Molecule Scale Computing	
BME 560: Mol. Basis Membrane Transp. & Biosurf. Engineer.	MATH 563: Applied Computational Analysis	ECE 590: Emerging Nanoelectronic Devices	ENVIRON 711: Energy & Environment	ECE 574: Waves in Matter	
BME 578: Tissue Engineering	MATH 577: Mathematical Modeling	ME 515: Introduction to Electronic Materials	ME 555: Thin Film Photovoltaics	ECE 578: Inverse Problems in Electromagn. & Acous.	
ECE 533: Biochip Engineering	ME 524*: Finite Element Method	ME 555: Optical Properties of Nanomaterials	ME 555: Fundamentals of Electrochemistry	ECE 5XX: Electromagnetic Metamaterials	
ME 519*: Biomedical Materials	ME 639: Comp. Fluid Mechanics & Heat Transfer	ME 759: Electrons & Phonons in Solid State Engineering	MSE 509 (NCSU): Nuclear Materials	PHY 509: Quantum Nanophysics	

Appendix B: Backgrounds and Bios of Key Faculty Participating in the Program

BIOSKETCH

VOLKER BLUM
Associate Professor, Department of Mechanical Engineering and Materials Science
Box 90300, Duke University, Durham, NC 27708
(919) 660 5279
volker.blum@duke.edu

(a) Professional Preparation

University of Erlangen-Nürnberg, Germany	Physics	Diplom, 1996
University of Erlangen-Nürnberg, Germany	Physics	Dr. rer. nat., 2001
NREL, Golden, CO	Computational Materials Science	Postdoc, 2002–2004

(b) Appointments

Associate Professor, MEMS Department, Duke University, Durham, NC	September 2013–
Associate Professor, Chemistry Department (secondary appt), Duke University	April 2015–
Group Leader, Fritz Haber Institute, Berlin, Germany	2009–2013
Scientist, Fritz Haber Institute, Berlin, Germany	2004–2009

(c) Products

Five products most closely related to the proposed project

1. Shin, D., Saparov, B., Zhu, T., Huhn, W., **Blum, V.** & Mitzi, D. B. (2016). BaCu2Sn(S,Se)4 - Earth-Abundant Chalcogenides for Thin-Film Photovoltaics, *Chemistry of Materials*, *28(13)*, 4771–4780.
2. Tu, Q., Lange, B., Parlak, Z., Lopes, J. M. J., **Blum, V.** & Zauscher, S. (2016). Quantitative Subsurface Atomic Structure Fingerprint for 2D Materials and Heterostructures by First-Principles Calibrated Contact-Resonance Atomic Force Microscopy, *ACS Nano*, *10(7)*, 6491–6500.
3. Ren, X., Rinke, P., **Blum, V.**, Wieferink, J., Tkatchenko, A., Sanfilippo, A., Reuter, K., & Scheffler, M. (2012). Resolution-of-identity approach to Hartree–Fock, hybrid density functionals, RPA, MP2 and GW with numeric atom-centered orbital basis functions. *New Journal of Physics*, *14*(5), 053020.
4. **Blum, V.**, Gehrke, R., Hanke, F., Havu, P., Havu, V., Ren, X., Reuter, K., & Scheffler, M. (2009). Ab initio molecular simulations with numeric atom-centered orbitals. *Computer Physics Communications*, *180*(11), 2175-2196.
5. Hart, G. L. W., **Blum, V.**, Walorski, M., & Zunger, A. (2005). Genetic determination of first-principles Hamiltonians. *Nature Materials* 4, 391-394.

Five other significant products

1. Ihrig, A. C., Wieferink, J., Zhang, I. Y., Ropo, M., Ren, X., Rinke, P., Scheffler, M., & **Blum, V.** (2015). Accurate localized resolution of identity approach for linear-scaling hybrid density functionals and for many-body perturbation theory. *New Journal of Physics*, *17*(9), 093020.
2. Marek, A., **Blum, V.**, Johanni, R., Havu, V., Lang, B., Auckenthaler, T., Heinecke, A., Bungartz, H.-J., & Lederer, H. (2014). The ELPA Library - Scalable Parallel Eigenvalue Solutions for Electronic Structure Theory and Computational Science. *The Journal of Physics: Condensed Matter*, 26, 213201.
3. Nemec, L., **Blum, V.**, Rinke, P., & Scheffler, M. (2013). Thermodynamic Equilibrium Conditions of Graphene Films on SiC. *Physical Review Letters*, *111*(6), 065502.

4. Auckenthaler, T., **Blum, V.**, Bungartz, H. J., Huckle, T., Johanni, R., Krämer, L., Lederer, H. & Willems, P. R. (2011). Parallel solution of partial symmetric eigenvalue problems from electronic structure calculations. *Parallel Computing*, *37*(12), 783-794.
5. Havu, V., **Blum, V.**, Havu, P., & Scheffler, M. (2009). Efficient O (N) integration for all-electron electronic structure calculation using numeric basis functions. *Journal of Computational Physics*, *228*(22), 8367-8379.

(d) Synergistic Activities

- Lead organizer or co-organizer of Hands-On Workshops: "Density Functional Theory and Beyond" for approximately 60-80 students and post-docs. 10 days of morning lectures and afternoon practical sessions on modern electronic structure theory, covering the basics of the field up to advanced topics. Held in Berlin (2009, 2011), Trieste (2013), Los Angeles (2014), Berlin (2015). These summer schools provide a comprehensive introduction and overview of the field of electronic structure theory in computational materials science for students and early-career postdocs, with lectures by some of the leading researchers in the field.
- Lead organizer or co-organizer of conferences, workshops, and invited sessions at society meetings including "Isolated Biomolecules and Biomolecular Interactions 2010, The "Big" Psi-k conference 2010 (in local organization), FHI-aims Developers' and Users' Meetings 2010, 2012, 2014, 2016, invited session at APS March Meeting 2015, focus sessions at APS March Meetings 2016, 2017.
- Service in community organizations and societies: 2013-14 Member (2014: Chair), Nomination Committee, American Physical Society Division of Computational Physics; Member, “N-scaling” committee, psi-k.org (psi-k.org is the leading umbrella organization for electronic structure based computational condensed matter science in Europe and worldwide).
- Community based electronic structure projects: Coordinator and lead developer (since 2014), FHI-aims electronic structure code, cited over 600 times (Google Scholar), over 100 licensing groups. Development in Berlin, Duke, Helsinki, London, Munich, Hefei, and elsewhere. http://aims.fhi-berlin.mpg.de; Consortium member, ELPA massively parallel eigenvalue solver library, http://elpa.rzg.mpg.de; Coordinator, “ELSI” electronic structure infrastructure to solve or circumvent the Kohn-Sham eigenvalue problem, http://elsi-interchange.org (since 2015); Advisory board member, CECAM Electronic Structure Library.
- Reviewer for Journals, Grant Proposals, and Consortia, including *Physical Review Letters, Physical Review B, Journal of the American Chemical Society, Journal of Chemical Physics, Computer Physics Communications*, Alexander von Humboldt Foundation, National Science Foundation (individual and panel), U.S. Department of Energy, Petroleum Research Fund of the American Chemical Society, Austrian Science Fund, PRACE, Materials Chemistry HEC Consortium (MCC), UK (2016), and others.

NSF BIOGRAPHICAL SKETCH

NAME: Charbonneau, Patrick

NSF ID: 000537814

POSITION TITLE & INSTITUTION: Associate Professor of Chemistry and Physics, Duke University

A. PROFESSIONAL PREPARATION

INSTITUTION	LOCATION	MAJOR / AREA OF STUDY	DEGREE (if applicable)	YEAR YYYY
McGill University	Montreal, Quebec	Chemistry	BS	2001
Harvard University	Cambridge, Massachusetts	Chemical Physics	PHD	2006
FOM Amolf	Amsterdam	Computational Physics	Postdoctoral Fellow	2006 - 2008

B. APPOINTMENTS

2015 - Associate Professor of Chemistry and Physics, Duke University, Durham, NC

2009 - Faculty Member of the Program in Computational Biology and Bioinformatics, Duke University, Durham, NC

2008 - 2015 Assistant Professor of Chemistry and Physics, Duke University, Durham, NC

C. PRODUCTS

Products Most Closely Related to the Proposed Project

1. Fusco D, Charbonneau P. Crystallization of asymmetric patchy models for globular proteins in solution. Phys Rev E Stat Nonlin Soft Matter Phys. 2013 Jul;88(1):012721. PubMed PMID: 23944504.
2. Fusco D, Barnum TJ, Bruno AE, Luft JR, Snell EH, Mukherjee S, Charbonneau P. Statistical analysis of crystallization database links protein physico-chemical features with crystallization mechanisms. PLoS One. 2014;9(7):e101123. PubMed PMID: 24988076; PubMed Central PMCID: PMC4079662.
3. Fusco D, Headd JJ, De Simone A, Wang J, Charbonneau P. Characterizing protein crystal contacts and their role in crystallization: rubredoxin as a case study. Soft Matter. 2014 Jan 14;10(2):290-302. PubMed PMID: 24489597; PubMed Central PMCID: PMC3907588.
4. Fusco D, Charbonneau P. Competition between monomeric and dimeric crystals in schematic models for globular proteins. J Phys Chem B. 2014 Jul 17;118(28):8034-41. PubMed PMID: 24684539.
5. Fusco D, Charbonneau P. Soft matter perspective on protein crystal assembly. Colloids and Surfaces B: Biointerfaces. Forthcoming;

Other Significant Products, Whether or Not Related to the Proposed Project

1. Charbonneau B, Charbonneau P, Tarjus G. Geometrical frustration and static correlations in a simple glass former. Phys Rev Lett. 2012 Jan 20;108(3):035701. PubMed PMID: 22400759.
2. Charbonneau P, Corwin EI, Parisi G, Zamponi F. Universal microstructure and mechanical stability of jammed packings. Phys Rev Lett. 2012 Nov 16;109(20):205501. PubMed PMID: 23215504.
3. Charbonneau P, Kurchan J, Parisi G, Urbani P, Zamponi F. Fractal free energy landscapes in structural glasses. Nat Commun. 2014 Apr 24;5:3725. PubMed PMID: 24759041.
4. Charbonneau P, Jin Y, Parisi G, Zamponi F. Hopping and the Stokes-Einstein relation breakdown in simple glass formers. Proc Natl Acad Sci U S A. 2014 Oct 21;111(42):15025-30. PubMed PMID: 25288722; PubMed Central PMCID: PMC4210276.
5. Charbonneau P, Corwin EI, Parisi G, Zamponi F. Jamming criticality revealed by removing localized buckling excitations. Phys Rev Lett. 2015 Mar 27;114(12):125504. PubMed PMID: 25860759.

D. SYNERGYSTIC ACTIVITIES

1. Organization of Chemical Physics Symposia “Physics of glasses and viscous liquids” at the 2013 APS March Meeting, and of the GSNP GSNP Focus Session “Soft Matter Perspective on Protein Assembly” at the 2014 APS March Meeting.

2. Development and teaching of “Chemistry and Physics of Cooking” in collaboration with chef artist-in-residence at Duke, Spring 2013, and Fall 2016 on.

3. Organization of “Unifying Concepts in Glass Physics VI” at the Aspen Center for Physics, February 2015.

4. Organization of CECAM workshop "The Physics of Protein Self-Assembly", in Lausanne, Switzerland, June 2015.

5. Organization with E. Corwin and F. Zamponi of the Boulder School for Condensed Matter and Materials Physics “Frustration and Disorder”, July 2017.

E. COLLABORATORS & OTHER AFFILIATIONS

Collaborators and Co-editors

Ludovic Berthier, Université de Montpellier; Andrew Bruno, SUNY Buffalo; Benoit Charbonneau, University of Waterloo; Eric Corwin, University of Oregon; Alfonso De Simone, Imperial College London; Jeffrey Headd, Johnson & Johnson; Atsushi Ikeda, Kyoto University; Jorge Kurchan, ENS-Paris; Gabriel Lopez, Duke University; Joseph Luft, Hauptman-Woodward Medical Research Institute; Rémy Mosseri, Université Pierre-et-Marie-Curie; Sayan Mukherjee, Duke University; Giorgio Parisi, University Roma La Sapienza; David Richardson, Duke University; Edward Snell, Hauptman-Woodward Medical Research Institute; Joshua Socolar, Duke University; Holger Stark, TU Berlin; Gilles Tarjus, Université Pierre-et-Marie-Curie; Pierfrancesco Urbani, Duke University; Jun Wang, Duke University; Benjamin Wiley, Duke University; Benjamin Yellen, Duke University; Francesco Zamponi, ENS-Paris.

Total Collaborators/Co-Editors: 23

Graduate Advisors and Postdoctoral Sponsors

Daan Frenkel, University of Cambridge; David Reichman, Columbia University.

Total Advisors/Sponsors: 2

Thesis Advisor and Postgraduate-Scholar Sponsor

Irem Altan, Duke University; Lin Fu, Duke University; Diana Fusco, UC Berkeley; Yuliang Jin, ENS-Paris; Pablo Palafox, Deakin University; Sho Yaida, Duke University; Kai Zhang, Columbia University; Yuan Zhuang, Duke University.

Total Advised/Sponsored: 8

Olivier Delaire

a. Professional Preparation

Ecole Centrale Lyon,	Lyon, France	Engineering Physics	Diplôme d'Ingénieur, 1999
Pennsylvania State University,	State College, PA	Nuclear Engineering	MS, 2000
California Institute of Technology,	Pasadena, CA	Materials Science	PhD, 2006
California Institute of Technology,	Pasadena, CA	Materials Science	Postdoc 2006-2007

b. Appointments

Associate Professor, Mechanical Engineering and Materials Science, Duke University, 2016 - present
Staff Scientist, Materials Science and Technology Division, Oak Ridge National Lab., 2012-2015
Shull Fellow, Neutron Sciences Directorate, Oak Ridge National Laboratory, 2008-2011
Research Staff, Engineering and Applied Science, California Institute of Technology, 2007-2008

c. Products

PRODUCTS MOST CLOSELY RELATED
(PI and postdoc/graduate student advisees are underlined)

1. C.W. Li*, J. Hong*, A. May, D. Bansal, J. Ma, T. Hong, S. Chi, G. Ehlers, and O. Delaire#, "Orbitally-driven giant phonon anharmonicity in SnSe", Nature Physics 11, 1063–1069 (2015).

2. Dipanshu Bansal, Chen W. Li, Ayman H. Said, Douglas L. Abernathy, Jiaqiang Yan, and Olivier Delaire#, "Electron-phonon coupling and thermal transport in the thermoelectric compound $Mo_3Sb_{7-x}Te_x$", Phys. Rev. B **92**, 214301 (2015).

3. O. Delaire, I. I. Al-Qasir, A. F. May, C. W. Li, B. C. Sales, J. L. Niedziela, J. Ma, M. Matsuda, D. L. Abernathy, T. Berlijn, "Heavy-impurity resonance, hybridization, and phonon spectral functions in $Fe_{1-x}M_xSi$, M=Ir,Os", Phys. Rev. B 91, 094307 (2015).

4. C.W. Li, O. Hellman, J. Ma, A.F. May, H. Cao, X. Chen, A.D. Christianson, G. Ehlers, D.J. Singh, B.C. Sales, and O. Delaire#, "Phonon self-energy and origin of anomalous neutron scattering spectra in SnTe and PbTe thermoelectrics", Phys. Rev. Letters, 112, 175501 (2014).

5. J. Ma*, O. Delaire*, A. F. May, C. E. Carlton, M. A. McGuire, L. H. VanBebber, D. L. Abernathy, G. Ehlers, Tao Hong, A. Huq, Wei Tian, V. M. Keppens, Y. Shao-Horn, and B. C. Sales, "Glass-like phonon scattering from spontaneous nanostructure in $AgSbTe_2$", Nature Nanotechnology, 8, 445–451 (2013).

OTHER SIGNIFICANT PRODUCTS

1. J. D. Budai*, J. Hong*, M. E. Manley, E. D. Specht, C. W. Li, J. Z. Tischler, D. L. Abernathy, A. H. Said, B. M. Leu, L. A. Boatner, R. J. McQueeney, and O. Delaire#, "Metallization of vanadium dioxide driven by large phonon entropy", Nature, 515, 535–539 **(**2014).

2. Xi Chen, Annie Weathers, Jesús Carrete, Saikat Mukhopadhyay, Olivier Delaire, Derek A. Stewart, Natalio Mingo, Steven N. Girard, Jie Ma, Doug L. Abernathy, Jiaqiang Yan, Raman Sheshka, Daniel P. Sellan, Fei Meng, Song Jin, Jianshi Zhou, Li Shi, "Twisting Phonons in Complex Crystals with Quasi-One-Dimensional Substructures", Nature Communications 6, 6723 (2015).

3. T. Shiga, J. Shiomi, J. Ma, O. Delaire, T. Radzynski, A. Lusakowski, K. Esfarjani, and G. Chen, "Microscopic mechanism of low thermal conductivity in lead telluride", Physical Review B 85, 155203 (2012).

4. O. Delaire, K. Marty , M. B. Stone, P. R. C. Kent, M. S. Lucas, D. L. Abernathy, D. Mandrus, and B. C. Sales, "Phonon softening and metallization of a narrow-gap semiconductor by thermal disorder", Proceedings of the National Academy of Sciences USA, 108, 4725 (2011).

5. O. Delaire, J. Ma, K. Marty, A. F. May, M. A. McGuire, M.-H. Du, D. J. Singh, A. Podlesnyak, G. Ehlers, M. Lumsden, and B. C. Sales, "Giant Anharmonic Phonon Scattering in PbTe", Nature Materials, 10, 614 (2011).

d. Synergistic Activities

1. Mentoring through ORNL HBCU/MEI Faculty Summer Research Program (2013).
2. Lecturing for Oak Ridge Institute for Continued Learning (2013).
3. Member of organizing committee for International Conference on Thermoelectrics 2014, Nashville.
4. Elected member of Los Alamos Neutron Science Center User Group Committee (2010-2011).
5. Presentation to Secretary of Energy Steven Chu: "Advances in Thermoelectric Materials Characterization Using Neutron Reciprocal Space Tomography", ORNL March 2010.

e. Collaborators & Other Affiliations

1. **Collaborators** - total number of collaborators and co-editors (40)

Douglas Abernathy, ORNL; Tom Berlijn, ORNL; Lynn Boatner, ORNL; John Budai, ORNL; Gang Chen, MIT; Andrew Christianson, ORNL; Antonio dos Santos, ORNL; Takeshi Egami, ORNL/UT; Georg Ehlers, ORNL; Keivan Esfarjani, Rutgers; Brent Fultz, Caltech; Olle Hellman, Caltech/Linköping; Veerle Keppens, U. Tennessee; Chen Li, Carnegie; Jiao Lin, ORNL; Lucas Lindsay, ORNL; Mark Lumsden, ORNL; Jeffrey Lynn, NIST; Robert McQueeney, ORNL; David Mandrus, ORNL/UT; Michael Manley, ORNL; Andrew May, ORNL; Michael McGuire, ORNL; Natalio Mingo, CEA-Grenoble; D. Reis, Stanford/SLAC; Zhifeng Ren, U. Houston; Brian Sales, ORNL; Ayman Said, ANL; Athena Sefat, ORNL; Yang Shao-Horn, MIT; Li Shi, UT Austin; Takuma Shiga, U. Tokyo; Junichiro Shiomi, U. Tokyo; David J. Singh, U. Missouri; G. Jeffrey Snyder, Northwestern; Derek Stewart, Western Digital; Matthew Stone, ORNL; Jonathan Tischler, ANL; Mariano Trigo, Stanford/SLAC; Jiaqiang Yan, ORNL

2. **Graduate Advisor(s) -** total number of Graduate Advisors (2)

Brent T. Fultz (Caltech), Arthur T. Motta (PennState)

3. **Postdoctoral Sponsor(s) -** total number of Postdoctoral Sponsors (1)

Brent T. Fultz (Caltech)

4. **Thesis advising and Postgraduate-Scholar Sponsor**

Thesis Advising – Dipanshu Bansal, ORNL; Chengtao Luo, Virginia Tech.
Postgraduate-Scholar Sponsor – Iyad Al-Qasir (2012-2013), assistant Prof. Sharjah University, U.A.E.; Jie Ma (2010 – 2012), assistant Prof. Shanghai Jiao Tong; Chen Li (2012-2015), Carnegie Institution for Science; Jiawang Hong (2013 -), ORNL; Dipanshu Bansal (2015 -), ORNL; Jennifer Niedziela (2015 -), ORNL.

Total number of graduate students advised (2)
Total number of postdoctoral scholars sponsored (6)

Aaron D. Franklin

Professional Preparation:

Arizona State University, Tempe, AZ	Electrical Engineering	B.S.E, 2004
Purdue University, West Lafayette, IN	Electrical Engineering	Ph.D., 2008

Appointments:

Duke University, Durham, NC *07/2014 – present*
Associate Professor, Dept. of Electrical & Computer Engineering and Dept. of Chemistry

Focus of research program is on improving performance and functionality of nanomaterial-enabled electronic devices, including high-performance devices from low-dimensional materials (*e.g.,* 2D films, carbon nanotubes, nanowires) and the low-cost realm of printed electronics. By studying nanomaterial and thin film interfaces, along with the corresponding electron transport phenomena, novel electronic devices and systems are developed in our lab.

IBM T. J. Watson Research Center, Yorktown Heights, NY *01/2009 – 06/2014*
Research Staff Member, Nanomaterial Science & Technology

Revitalized IBM's effort in carbon nanotube transistor research, including record-setting demonstrations of the smallest nanoelectronic transistor (sub-10 nm nanotube FET), first gate-all-around nanotube devices, and a clear path for the purification and placement of nanotubes. Led effort on device-related challenges to a nanotube transistor technology, with team growing from three to eight members in under three years. Also studied devices and interfaces related to other low-dimensional materials, including graphene, boron nitride, and transition metal dichalcogenides. Was recognized by an IBM Outstanding Technical Achievement Award (2014) and IBM Research Outstanding Contributor Award (2013) for revolutionary efforts in nanoelectronics research.

Publications: *Over 40 scientific publications (h-index = 24)*

i. Most relevant:

- A. D. Franklin, "Nanomaterials in Transistors: From High-Performance to Thin-Film Transistors," *Science*, vol. 349, pp. aab2750, (2015); DOI: 10.1126/science.aab2750
- J. C. Claussen, A. D. Franklin, A. Haque, M. Porterfield, T. S. Fisher, "Electrochemical biosensor of nanocube-augmented carbon nanotube networks," *ACS Nano*, vol. 3, 37-44, (2009); DOI: 10.1021/nn800682m (cited 164 times)
- A. D. Franklin, M. Luisier, S. -J. Han, G. Tulevski, C. M. Breslin, L. Gignac, M. S. Lundstrom, W. Haensch, "Sub-10 nm carbon nanotube transistor," *Nano Lett.*, vol. **12**, 758-762, (2012); DOI: 10.1021/nl203701g (cited 218 times)
- H. Park, A. Afzali, S. -J. Han, G. S. Tulevski, A. D. Franklin, J. Tersoff, J. B. Hannon, W. Haensch, "High-density integration of carbon nanotubes via chemical self-assembly," *Nature Nanotechnol.*, vol. 7, 787-791, (2012); DOI: 10.1038/nnano.2012.189 (cited 144 times)
- A. D. Franklin, S. O. Koswatta, D. B. Farmer, J. T. Smith, L. Gignac, C. M. Breslin, S. -J. Han, G. S. Tulevski, H. Miyazoe, W. Haensch, J. Tersoff, "Carbon nanotube

complementary wrap-gate transistors," *Nano Lett.*, vol. 13, 2490-2495, (2013); DOI: 10.1021/nl400544q (cited 44 times)

ii. Also related:

- A. D. Franklin, Z. Chen, "Length scaling of carbon nanotube transistors," *Nature Nanotechnol.*, vol. 5, 858-862, (2010); DOI: 10.1038/nnano.2010.220 (cited 160 times)
- R. Voggu, C. S. Rout, A. D. Franklin, T. S. Fisher, C. N. R. Rao, "Extraordinary sensitivity of the electronic structure and properties of single-walled carbon nanotubes to molecular charge-transfer," *J. Phys. Chem. C*, vol. 112, 13053-13056, (2008); DOI: 10.1021/jp805136e (cited 66 times)
- G. S. Tulevski, A. D. Franklin, A. Afzali-Ardakani, "High purity isolation and quantification of semiconducting carbon nanotubes via column chromatography," *ACS Nano*, vol. 7, 2971-2976, (2013); DOI: 10.1021/nn400053k (cited 49 times)
- A. D. Franklin, S. -J. Han, A. A. Bol, V. Perebeinos, "Double contacts for improved performance of graphene transistors," *IEEE Electron Device Lett.*, vol. 33, 17-19, (2012); DOI: 10.1109/LED.2011.2173154 (cited 44 times)
- S. -J. Han, K. A. Jenkins, A. V. Garcia, A. D. Franklin, A. A. Bol, W. Haensch, "High-frequency graphene voltage amplifier," *Nano Lett.*, vol. 11, 3690-3693, (2011); DOI: 10.1021/nl2016637 (cited 94 times)

Synergistic Activities:

- Development of new courses for Duke and Columbia University graduate curriculums to keep students engaged with latest progress in Emerging Nanoelectronic Devices (2013 – present).
- Panelist for National Science Foundation proposals and fellowships (2013, 2014, 2015).
- Annual contributor to National Engineer's Week outreach efforts at local middle and high schools (2005 – present).
- Book contributor: "Emerging Nanoelectronic Devices," John Wiley & Sons, (2014).
- Organizer or co-organizer at Device Research Conference – DRC (2012 – present), MRS Fall Meetings (2012, 2014), Gordon Research Conference – Nanostructure Fabrication (2014), Applied Physics Society Meeting – APS (2013), IEEE International Conference on Nanotechnology – IEEE Nano (2013).

Jeffrey T. Glass
Duke University
Pratt School of Engineering
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Employment

7/03 – Present	**Professor of Electrical and Computer Engineering** **Hogg Family Director of Engineering Management and Entrepreneurship** Duke University, Pratt School of Engineering
7/08 – 6/11	**Sr. Associate Dean for Education** Duke University, Pratt School of Engineering
1/00 – 6/03	**Joseph F. Toot, Jr. Professor of Engineering & Co-Director of the Institute for the Integration of Management and Engineering** Case Western Reserve University
4/96 – 12/99	**Vice President of Research and Development** Kobe Steel USA Inc.
1/94 – 3/96	**Director of Research and Development** Kobe Steel USA Inc., Electronic Materials Center
8/91 – 12/93	**Kobe Steel, Ltd. Associate Professor** (with tenure) Materials Science and Engineering, North Carolina State University
8/88 – 8/91	**Assistant Professor** Materials Science and Engineering, North Carolina State University
12/85 – 8/88	**Research Scientist**, Kobe Development Corporation on loan as **Visiting Assistant Professor** to North Carolina State University, Department of Materials Science & Engineering

Education

Ph.D.	University of Virginia, May 1986 Department of Materials Science, GPA: 4.0/4.0
M.B.A.	Duke University, December 1999 Fuqua School of Business, Global Executive MBA (GEMBA)
M.S.E.	Johns Hopkins University, May 1983 Department of Materials Science and Engineering, GPA: 4.0/4.0
B.S.E.	Johns Hopkins University, May 1981 Department of Materials Science and Engineering, GPA: 3.69/4.0

Management of Research, Development and Technology-Based Innovation
Massachusetts Institute of Technology, Sloan School Summer Program, June 1997

Executive Development Program
Northwestern University, Kellogg School of Management, July 1992

Adjunct/Consulting Positions (Past and Present)

Expert Witness and Advisory Board Member for Various Companies

Adjunct Professor
School of Engineering, Case Western Reserve University

Adjunct Professor
Kenan Flagler School of Business, UNC-Chapel Hill

Adjunct Professor
Materials Science and Engineering, North Carolina State University

Consultant, Director of Research and Development
Kobe Steel USA Inc., Electronic Materials Center

Honors and Awards

2015 Stansell Family Distinguished Research Award, Pratt School of Engineering, Duke University.

Fellow, The World Innovation Foundation, an independent international research group advising nations and their governments for enhanced sustainability and global economic cooperation, founded by the late Nobel Laureate, Dr. Glenn Seaborg.

2004 Industrial Research Institute, Maurice Holland Award for best paper published in Research Technology Management in 2003

ISI Highly Cited Researcher - the most highly cited individuals within a given research category comprising "less than one-half of one percent of all publishing researchers".

Invited to National Academy of Engineering, Japan-American Symposium on Frontiers of Engineering (Nov. 2003) and 6th Annual Symposium on Frontiers of Engineering (Oct. 2001)

Outstanding Teacher Award, 1992-93, North Carolina State University

Sigma Xi Research Award for 1991-92, North Carolina State University

1990 Presidential Young Investigator Award, National Science Foundation

Member of Presidential Science Advisor's Committee on the Assessment of Diamond Technology in Japan, 1990.

Kobe Steel, Ltd. Professorship (8/88 - 12/93)

Fellow –The Royal Society for the Encouragement of Arts, Manufactures & Commerce (RSA)

Selected Professional Activities (past and present)

Chair, Industrial Engagement Council – Materials Research Society, 2014 – 2016.
Chair, Technology Inovation Forum and iMatSci – Materials Research Society, Annual Meeting, Fall 2014.
Associate Editor (past) – Journal of Diamond and Related Materials, Elsevier Publishers, London.
Associate Editor (past) – Advances in Materials Science and Engineering, Hindawi Publishing Corp.
Reviewer – Various Faculty Promotions and Engineering Management/Entrepreneurship Programs
International Advisory Board Member – New Diamond and Nano Carbons Conference, Osaka University, Osaka Japan, May 28-31, 2007.
Session Chairperson – Product-Related Technology Session, New Diamond and Nano Carbons, Osaka, Japan, May 31, 2007.
Executive Short Course – Managing Innovation and R&D, Business Institute for Scientists, UNC Kenan Flagler School of Business, May 6 and 7, 2004.
Co-Chair, Committee for Rearch and Technology Commercilization – Duke University, Pratt School of Engineering Board of Visitor.
Co-chair, Local Organizing Committee – ICNDST-ADC Joint International Conference, Resarch Triangle Park, NC, May, 2006.
Ph.D. Thesis examiner – University of Sidney, "Molecular Dynamics Simulation of Amorphous

Silicon Carbon Alloys" by Nicholas Courtenay Cooper, March 31, 2004.
Program Committee – ICNDST-9, Tokyo, Japan, March, 2004
Advisory Board Member – Department of Materials Science and Engineering, North Carolina State University.
Ph.D. Thesis Examiner – University of Sydney, Australia, Ph.D., Alexander Merchant, "An Investigation of Carbon Nitride," Faculty of Science, November, 2001.
International Scientific Steering Committee – 11th European Conference on Diamond, Diamond- like Materials, Carbon Nanotubes, Nitrides and Silicon Carbide, September 2000.
International Committee – Ninth Cimtec - World Ceramics Congress & Forum on New Materials, Florence, Italy, June 1998.
Materials Science and Engineering Department Head Search Committee - North Carolina State University, November 1997.
Advisory Board Member – NC Central University, Physics Department, October 1997.
Program Committee – Diamond Films '97, Edinburgh, Scotland, August 1997.
Program Committee – Micro Mat '97, Berlin, Germany, April 16-18, 1997.
Organizing Committee – Diamond '96, Tours, France, September 1996.
Advisory Board Member – Gorham Conference, Atlanta, GA, March 1996.
Organizing Committee – Diamond Films '95, Barcelona, Spain, September 1995.
Organizing Committee – Diamond Films '94, Il Ciocco, Italy, September 1994.
Organizing Committee – Diamond Films '93, Portugal, September 1993.
Program Committee – Applied Diamond Conference, Tokyo, Japan, August 1993.
Review Panel – Amer. Soc. for Engineering Education, Washington, DC, August 1993.
Session Chairman and International Advisor – Diamond Films '92, Germany, September 1992.
Discussion Leader – Gordon Conference on Diamond Synthesis, Plymouth, NH, June 1992.
Advisory Committee – 7th Trieste Semiconductor Symp., Trieste, Italy, June 1992.
International Steering Committee Member – Diamond Films '91, Nice, France, September, 1991.
Session Organizer and Chairman – Am. Chem. Soc., Symp. on Chem. of Diamond, Aug, 1991.
Program Committee Chairman and Session Chairman – 2nd International Conference on the New Diamond Science and Technology, Washington, DC, September 1990.
Session Chairman – CWRU Workshop on the Sci. and Tech. of Diamond Films, May , 1990.
Advisory Committee Member – National Science Foundation, Materials Research Group in Diamond and Diamond-like Materials, Case Western Reserve University.
Proposal Review – National Sci. Foundation, Army Research Office, NEDO Int. Joint Res. Prog.
Manuscript Review – J. Vac. Sci. Technol., J. Mat. Res., Appl. Phys. Lett., J. Appl. Phys., ICCG-9, ICMC'89, and J. of Crystal Growth.
International Advisor – Diamond Films '90, Montreux, Switzerland, September, 1990.
Program Committee Chairman – Second International Conference on the New Diamond Science and Technology, Washington, DC, September, 1990.
Symposium Co-chairman – Materials Research Society Symposium on Diamond, Boron Nitride, Silicon Carbide and Related Wide Bandgap Semiconductors, Boston, MA, November, 1989.
International Advisor and Session Co-chairman – First International Conference on the New Diamond Science and Technology, Tokyo, Japan, October, 1988.
Technical Program Committee Member and Session Chairman – Fourth Annual SDIO/IST–ONR Diamond Technology Initiative Symposium, July, 1989.
Short Course Instructor – "The Characterization of Diamond Films," Materials Research Society, TMS, Diamond Films '90 (Crans-Montana, Switzerland), Diamond Films '91 (Nice, France); "Growth & Characterization of Diamond Films," Motorola, Inc., Phoenix, AZ, 1992.

Publications, Presentations, and Patents (ISI Highly Cited Researcher, H-Index 46)

>160	Refereed Publications
74	Invited Presentations in 12 countries
15	Patents
7	Books (co-editor)
5	Book Chapters

BIOSKETCH

Sara Haravifard

(a) Professional Preparation

B.Sc. - McMaster University, Canada	Physics	2003
M.Sc. - McMaster University, Canada	Condensed Matter Physics	2005
Ph.D. - McMaster University, Canada	Condensed Matter Physics	2010
Post-Doc - University of Chicago	Condensed Matter Physics	2010 - 2013
Post-Doc - Argonne National Laboratory	Condensed Matter Physics	2010 - 2013

(b) Appointments

William H. Fairbank Assistant Professor 2015 -
Department of Physics, Duke University

Assistant Physicist 2013 - 2015
The James Franck Institute, University of Chicago

Assistant Physicist 2013 - 2015
X-ray Science Division, Argonne National Laboratory

(c) Products

Selected Papers:

- S. Haravifard, D. Graf, A. E. Feiguin, C.D. Batista, J.C. Lang, D.M. Silevitch, G. Srajer, B.D. Gaulin, H.A. Dabkowska, T.F. Rosenbaum (2016) Crystallization of Spin Superlattices with Pressure and Field in the Layered Magnet SrCu2(BO3)2. *Nature Communications* **7**, 11956.

- S. Haravifard, A. Banerjee, J. van Wezel, D.M. Silevitch, A.M. dos Santos, J.C. Lang, E. Kermarrec, G. Srajer, B.D. Gaulin, J.J. Molaison, H.A. Dabkowska, and T.F. Rosenbaum (2015) Interplay of magnetism and structure in the Shastry-Sutherland model. *Proceedings of the National Academy of Sciences USA* **112** (5), E383–E384.

- S. Haravifard, A. Banerjee, J. van Wezel, D.M. Silevitch, A.M. dos Santos, J.C. Lang, E. Kermarrec, G. Srajer, B.D. Gaulin, J.J. Molaison, H.A. Dabkowska, and T.F. Rosenbaum (2014) Emergence of Long-Range Order in Sheets of Magnetic Dimers. *Proceedings of the National Academy of Sciences USA* **111** (40), 14372.

- S. Haravifard, A. Banerjee, J. C. Lang, G. Srajer, D. M. Silevitch, B. D. Gaulin, H. A. Dabkowska, T. F. Rosenbaum (2012) Continuous and discontinuous quantum phase transitions in a model two-dimensional magnet. *Proceedings of the National Academy of Sciences USA* **109** (7), 2286.

- S. Haravifard, B.D. Gaulin, Z. Yamani, S.R. Dunsiger, and H.A. Dabkowska (2012) Neutron Scattering from the Static and Dynamic Lattice of SrCu2(BO3)2 in its Shastry-Sutherland Singlet Ground State. *Physical Review B* **85**, 134104.

- S. Haravifard, K. Fritsch, T. Asano, J. P. Clancy, Z. Yamani, G. Ehlers, T. Nishimura, Y. Inagaki, T. Kawae, I. Swainson, B. D. Gaulin (2011) Co-existing Singlet and Ordered S=1/2 Moments in the Ground State of the Triclinic Quantum Magnet CuMoO4. *Physical Review B* **84**, 094436.

- S. Haravifard, K. C. Rule, H. A. Dabkowska, B. D. Gaulin, Z. Yamani and W.J. L. Buyers. (2007) Neutron and x-ray scattering studies of the lightly doped spin–Peierls system Cu1−xCdxGeO3. *Journal of Physics: Condensed Matter* **19**, 436222.

- S. Haravifard, S. R. Dunsiger, S. El Shawish, B. D. Gaulin, H. A. Dabkowska, M. T. F. Telling, T. G. Perring, and J. Bonca. (2006) In-Gap Spin Excitations and Finite Triplet Lifetimes in the Dilute Singlet Ground State System SrCu2-xMgx(BO3). *Physical Review Letters* **97**, 247206.

Books:

- S. Haravifard, Z. Yamani, B. D. Gaulin. (2015) Quantum Phase Transitions, Invited Chapter in Experimental Methods in Physics: Neutron Scattering – Magnetic and Quantum Phenomena, Edited by D.L. Price and F. Fernandez-Alonso, Academic Press, *Elsevier*.

Press Release:

- *Science Highlight:* Crystallization of spin superlattices using pressure and magnetic field (2016) National High Magnetic Field Laboratory.

- *Faculty Highlight:* New Insights into Quantum Magnets Have Eluded Thorough Understanding for Nearly 30 Years (2014) Department of Physics, Duke University.

- *Science Highlight:* How Magnetic Dimers Interact to Create Long-Range Order (2014) Advanced Photon Source, Argonne National Laboratory.

- *Featured Highlight*: Pressure Tuning of a Quantum Phase Transition in an Exotic Magnetic Material (2013) Neutron Sciences, Oak Ridge National Laboratory.

- *Science Highlight*: Pressure-Tuning the Quantum Phase Transition in a Model 2-D Magnet (2012) Advanced Photon Source, Argonne National Laboratory.

- *Featured Highlight*: Copper-Based Materials Show Strange Spin States (2012) Argonne National Laboratory.

(d) Synergistic Activities

- Invited Member of Oak Ridge National Laboratory Young Investigator External Advisory Committee (Quantum Condensed Matter Directorate)
- Chair of National High Magnetic Field Laboratory User Advisory Committee (DC-field & high B/T facilities)
- Executive Member of Oak Ridge National Laboratory Spallation Neutron Source and High Flux Isotope Reactor User Group Committee
- Member of the organizing committee for the 1st joint Duke-Oak Ridge National Laboratory Workshop on Neutron Sciences
- Member of Duke Physics Fellowship Committee
- Reviewer for National Science Foundation Grant Proposal
- Reviewer for National Institute of Standards and Technology User Proposal

- Reviewer for Oak Ridge National Laboratory User Proposal
- Reviewer for Argonne National Laboratory User Proposal
- Reviewer for Physical Review Letters/ Physical Review B
- Reviewer for Nature/ Scientific Reports
- Reviewer for Material Research Bulletin
- Reviewer for Magnetism and Magnetic Materials Annual Conference Proceeding

(e) Collaborators & Other Affiliations

- Duke University Women in Science, Technology, Engineering and Math
- Argonne National Laboratory Women in Science and Technology
- American Physical Society
- Neutron Scattering Society of America
- The Canadian Association of Physicists
- Canadian Institute for Neutron Scattering
- Materials Research Society

Graduate Advisors and Postdoctoral Sponsors

M.Sc. & Ph.D. Advisor:
Bruce Gaulin, Professor and Brockhouse Chair in the Physics of Materials &
Director of Brockhouse Institute for Materials Research, McMaster University.

Post-Doc Advisor:
Thomas Rosenbaum, President & Sonja and William Davidow Presidential Chair and Professor of Physics, California Institute of Technology.

Post-Doc Advisor:
George Srajer, Deputy Associate Laboratory Director for Photon Sciences & Deputy Director of the Advanced Photon Source, Argonne National Laboratory.

Thesis Advisor and Postgraduate-Scholar Sponsor

Post-Master Scholar: Casey Marjerrison

Ph.D. Student: William Steinhardt

Undergraduate Researchers: Dhruv Luthra, Keegan O'Reilly

Biographical Sketch – Jie Liu

George B. Geller Professor of Chemistry
Department of Chemistry
Duke University
Durham, NC 27708

Tel.: 919-660-1549
j.liu@duke.edu

Professional Preparation

Shandong University	P.R. China	Chemistry	BSc 1987
Shandong University	P.R. China	Chemistry	MSc 1990
Harvard University	Cambridge, MA	Chemistry	PhD 1996

Appointments

2012 - present **George B Geller Professor of Chemistry**, Duke University.
2008 - 2012 **Jerry G. and Patricia Crawford Hubbard Professor of Chemistry,** Duke University
2007 - 2008 **Anne T. and Robert M. Associate Professor of Chemistry,** Duke University, Durham
2005 - 2007 **Associate Professor of Chemistry,** Duke University
1999 - 2005 **Assistant Professor of Chemistry,** Duke University

Honors:

2014 Fellow, the American Physical Society (APS).
2013 Fellow, the American Association for the Advancement of Science (AAAS).
2013 Fellow, the Royal Society of Chemistry (RSC).
2013 Thousand Talent Program, Type B, China.
2007 Endowed chair in Bass Program for Excellence in Undergraduate Education at Duke University.
2002 DuPont Young Professor Award.
2002 Outstanding Oversea Young Investigator Award from NSF-China.
2000 Ralph E. Powe Junior Faculty Enhancement Award from Oak Ridge Associated Universities.
1999 Robert A. Welch Foundation Postdoctoral Fellowship.

Products

Five Products Closely Related to this Proposal:

1) "Gate-Free Electrical Breakdown of Metallic Pathways in Single-Walled Carbon Nanotube Crossbar Networks", Jinghua Li, Aaron D. Franklin, and Jie Liu, **Nano Lett**., 2015, 15 (9), 6058–6065.
2) "Graphoepitaxial effect in the guided growth of SWNT arrays on quartz", Pan Li, Xiao Zhang , Jinghua Li and Jie Liu, **J. Mater. Chem. C**, 2015, 3, 9678-9683.
3) "Importance of diameter control on selective synthesis of semiconducting single-walled carbon nanotubes", Jinghua Li, Chung-Ting Ke, Kaihui Liu, Pan Li, Sihang Liang, Gleb Finkelstein, Feng Wang, Jie Liu, **ACS Nano**, 2014, 8 (8): 8564-8572. DOI: 10.1021/nn503265g.
4) "Understanding the discrepancy between the quality and yield in the synthesis of carbon nanotubes", Xiao Zhang, Pan Li, Hongbo Zhang, Jie Liu, **Nano Research,** 2015, 8(1), 296-302.
5) "Growth of High-Density Aligned and Semiconducting–Enriched Single Walled Carbon Nanotubes: Decoupling the Conflict between Density and Selectivity", Jinghua Li, Weiwei Zhou, Kaihui Liu, Matthieu Pierce, Feng Wang and Jie Liu, **ACS Nano,** 2014, 8 (1), 554–562.

Five Other Significant Products:

1) "Stretchable and High-Performance Supercapacitors with Crumpled Graphene Papers", Jianfeng Zang, Changyong Cao, Yaying Feng, Jie Liu and Xuanhe Zhao, **Scientific Reports**, 2014, 4, Article number: 6492. DOI:10.1038/srep06492.
2) "Highly Efficient Oxygen Reduction Electrocatalysts based on Winged Carbon Nanotubes", Yingwen Cheng, Hongbo Zhang, Chakrapani V. Varanasi and Jie Liu, **Scientific Reports**, 2013, 3, Article number: 3195. DOI:10.1038/srep03195.
3) "Significantly Improved Long-Cycle Stability in High-Rate Li–S Batteries Enabled by Coaxial Graphene Wrapping over Sulfur-Coated Carbon Nanofibers", Songtao Lu, Yingwen Cheng , Xiaohong Wu, and Jie Liu, **Nano Lett.**, 2013, 13 (6), 2485–2489. DOI: 10.1021/nl400543y.

4) "Synergistic Effects from Graphene and Carbon Nanotubes Enable Flexible and Robust Electrodes for High-Performance Supercapacitors", Yingwen Cheng, Songtao Lu, Hongbo Zhang, Chakrapani V. Varanasi, and Jie Liu, **Nano Lett.**, 2012, 12 (8), 4206–4211. DOI: 10.1021/nl301804c.
5) "CMOS-based Carbon Nanotube Pass-Transistor Logic Integrated Circuits", Li Ding, Zhiyong Zhang, Shibo Liang, Tian Pei, Sheng Wang, Yan Li, Weiwei Zhou, Jie Liu and Lian-Mao Peng, **Nature Communications,** 2012, 3, 677.DOI: 10.1038/ncomms1682.

Synergistic Activities

- Symposium Organizer: Foundation of Nanoscience Workshop (Fnano) 2012, 2011, 2010, MRS Spring meeting, Pacifichem 2010, 2015.
- Outreach Activities: Supervisor for undergraduate students from NC SEED program.
- Service: NSF Panel for EPASI Jan 2011, NSF panel for SBIR: 2010, 2011
- Scientific Advisory Board: RFNano Inc., Unidym Inc., Xinnano Inc., Jiefeng Inc.
- Editorial Activities: Editor-in-chief (Nanoscale); Editorial Board member (Journal of Nano Energy and Power Research); Editorial Review Board member (Materials Research Letters)

Biographical Sketch: Jianfeng Lu

Professional Preparation

Peking University	Beijing, China	Mathematics	B.S.; 2005
Princeton University	Princeton, NJ, USA	Applied Mathematics	Ph.D.; 2009

Appointments

- Associate Professor, Department of Mathematics, Duke University, 2016–present
  Secondary Appointment, Departments of Physics and Department of Chemistry
  Affiliated Faculty Member, Fitzpatrick Institute of Photonics,
- Assistant Professor, Department of Mathematics, Duke University, 2012–2016
- Courant Instructor, Courant Institute of Mathematical Sciences,
  New York University, 2009–2012.

Products

Five Most Relevant Products

1. J. Lu and Z. Zhou, *Frozen Gaussian approximation with surface hopping for mixed quantum-classical dynamics: A mathematical justification of fewest switches surface hopping algorithms*, submitted; available at `http://www.arxiv.org/abs/1602.06459`
2. J. Lu and Z. Zhou, *Improved sampling and validation of frozen Gaussian approximation with surface hopping algorithm for nonadiabatic dynamics*, submitted; available at `http://www.arxiv.org/abs/1606.05365`
3. R. Delgadillo, J. Lu and X. Yang, *Gauge-invariant frozen Gaussian approximation method for the Schrodinger equation with periodic potentials*, SIAM J. Sci. Comput., in press; available at `http://www.arxiv.org/abs/1509.05552`
4. J. Lu and X. Yang, *Convergence of frozen Gaussian approximation for high-frequency wave propagation*, Comm. Pure Appl. Math., vol. 65 no. 6 (2012), pp. 759-789.
5. W. E, J. Lu and X. Yang, *Asymptotic analysis of quantum dynamics in crystals: The Bloch-Wigner transform, Bloch dynamics and Berry phase*, Acta Math. Appl. Sin., vol. 29 no. 3 (2013), pp. 465-47

Five Additional Products

1. T.-Q. Yu, J. Lu, C.F. Abrams, E. Vanden-Eijnden, *A multiscale implementation of infinite-swap replica exchange molecular dynamics*, Proc. Natl. Acad. Sci. USA, in press
2. C. Li, J. Lu and W. Yang, *Gentlest ascent dynamics for calculating first excited state and exploring energy landscape of Kohn-Sham density functionals*, J. Chem. Phys. 143, 224110 (2015).
3. J. Lu and F. Otto, *Nonexistence of minimizer for Thomas-Fermi-Dirac-von Weizsäcker model*, Comm. Pure Appl. Math. 67, 1605–1617 (2014).

4. W. E and J. Lu, *The Kohn-Sham equation for deformed crystals*, Mem. Amer. Math. Soc., vol. 221, no. 1040 (2013).
5. J. Lu and X. Yang, Frozen Gaussian approximation for high frequency wave propagation, Commun. Math. Sci., vol. 9 no. 3 (2011), pp. 663-683

Synergistic Activities

- Promoted **communication and collaboration** among researchers in mathematics, chemistry, physics, and materials science. Organized conferences: Collective Dynamics in Biological and Social Systems (Nov 2015), Mathematical and Computational Methods in Quantum Chemistry (May 2016), Algorithms and Applications for Excited State Electronic Structure Theory (Aug 2016), KI-Net Young Researchers Workshop (Nov 2016) and multiple minisymposia.
- Taught **summer schools** for graduate students and junior researchers, including Putting Theory Back in Density Functional Theory at IPAM (Aug 2016), Summer School on Electronic Structure Theory at MSRI/LBNL (Jul 2016), and Topics in Computational Quantum Chemistry at Peking University (Jul 2015).
- Served as a faculty advisor for **high school student research program** at North Carolina School of Science and Mathematics 2015–2016.
- Applied mathematics **course development** on *Introduction to Multiscale Modeling*, *Mathematical Introduction to Quantum Mechanics*, *Applied Computational Analysis*, and *Introduction to Numerical PDEs* for advanced undergraduate and graduate students.
- Served as a **reviewer** for the scientific community. Reviewer for grant proposals and many journals include Appl. Harmon. Comput. Anal.; Arch. Rational Mech. Anal.; Comm. Pure Appl. Math.; J. Amer. Math. Soc.; J. Chem. Phys. J. Chem. Theory Comput.; J. Comput. Phys.; J. Mech. Phys. Solids; Phys. Rev. B; Proc. R. Soc. A; and multiple SIAM journals.

MAIKEN H. MIKKELSEN

PROFESSIONAL PREPARATION

University of Copenhagen, Denmark	Physics	B.S., 2004
University of California, Santa Barbara	Physics	Ph.D., 2009
University of California, Berkeley	Nanophotonics	Postdoc, 2010–2012

APPOINTMENTS

July 2015–present	Nortel Networks Assistant Professor, Duke University
Sept. 2012–present	Assistant Professor, Duke University Electrical & Computer Engineering; Physics (50%–50%)
Apr. 2010–July 2012	Postdoctoral Fellow, University of California, Berkeley Advisor: Prof. Xiang Zhang
Sept. 2004–Dec. 2009	Graduate Student Researcher, University of California, Santa Barbara Advisor: Prof. David Awschalom
Jan. 2004–July 2004	Undergraduate Student Researcher, University of California, Santa Barbara Advisor: Prof. David Awschalom

PRODUCTS – MOST CLOSELY RELATED

†indicates corresponding author, * indicates equal contributors

1. T. B. Hoang*, G. M. Akselrod* & M. H. Mikkelsen†, "*Ultrafast room-temperature single photon emission from quantum dots coupled to plasmonic nanocavities,*" **Nano Letters** 16, 270–275 (2016).
2. G. M. Akselrod, C. Argyropoulos, T. B. Hoang, C. Ciracì, C. Fang, J. Huang, D. R. Smith & M. H. Mikkelsen†, "*Probing the mechanisms of large Purcell enhancement in plasmonic nanoantennas,*" **Nature Photonics** 8, 835 (2014).
3. J. Berezovsky*, M. H. Mikkelsen*, N. G. Stoltz, L. A. Coldren & D. D. Awschalom (2008). "*Picosecond coherent optical manipulation of a single electron spin in a quantum dot*," **Science***,* 320, 349 (2008) cover article.
4. M. H. Mikkelsen, J. Berezovsky, N. G. Stoltz, L. A. Coldren & D. D. Awschalom, "*Optically detected coherent spin dynamics of a single electron in a quantum dot*," **Nature Physics** 3, 770 (2007).
5. J. Berezovsky, M. H. Mikkelsen, O. Gywat, N. G. Stoltz, L. A. Coldren & D. D. Awschalom, "*Nondestructive optical measurements of a single electron spin in a quantum dot*," **Science***,* 314, 1916 (2006).

PRODUCTS – OTHER SIGNIFICANT

1. J. Huang, T. B. Hoang & M. H. Mikkelsen†, "*Probing the origin of excitonic states in monolayer WSe_2,*" **Scientific Reports** 6, 22414 (2016).
2. T. B. Hoang*, G. M. Akselrod*, C. Argyropoulos, J. Huang, D. R. Smith & M. H. Mikkelsen†, "*Ultrafast spontaneous emission source using plasmonic nanoantennas,*" **Nature Communications** 6, 7788 (2015).
3. G. M. Akselrod, T. Ming, C. Argyropoulos, T. B. Hoang, Y. Lin, X. Ling, D. R. Smith, J. Kong & M. H. Mikkelsen†, "*Leveraging nanocavity harmonics for control of optical processes in 2D semiconductors,*" **Nano Letters** 15, 3578 (2015).
4. G. M. Akselrod, J. Huang, T. B. Hoang, P. T. Bowen, L. Su, D. R. Smith & M. H. Mikkelsen†, "*Large-area metasurface perfect absorbers from visible to near infrared,*" **Advanced Materials** 27, 7897 (2015), cover article.
5. Yang, T. B. Hoang, M. Dridi, C. Deeb, M. H. Mikkelsen, G. C. Schatz & T. W. Odom, "*Real-time Tunable Lasing from Plasmonic Nanocavity Arrays,*" **Nature Communications**, 6, 6939 (2015).

SYNERGISTIC ACTIVITIES

Scientific Advisory Boards & Reviewer Activities

1. Editorial Advisory Board member for the journal *ACS Photonics* (2015 – present).
2. Journal Reviewer for *Nature Photonics, Nature Communications, Advanced Materials, Advanced Optical Materials, Optics Express, Optica, Nano Letters, Scientific Reports, Journal of the American Chemical Society, Small* and others (2012 – present); Proposal Reviewer for *Center for Integrated Nanotechnologies* (CINT) (2013 – present) and for the *Air Force Office of Scientific Research* (2015 – present).

To broaden participation of groups underrepresented in STEM fields

3. *2015 Conference for Undergraduate Women in Physics* (CUWiP), Duke University. Part of local application and planning committee, organized as part of APS (2013 – 2015).
4. Organizer and instructor for *Females Excelling More in Math, Engineering, and Science* (FEMMES). Outreach for 4-6th grade girls in Durham, NC (2014 – present).

Integration and transfer of knowledge

5. Innovations in teaching 3-day workshop, American Association of Physics Teachers (2013).

COLLABORATORS & OTHER AFFILIATIONS

Collaborators and Co-Editors: Christos Argyropoulos (University of Nebraska-Lincoln), Cristian Ciracì (Instituto Italiano di Tecnologia, Italy), Francisco J. Garcia Vidal (Universidad Autónoma de Madrid, Spain), M. Saif Islam (UC Davis), Jing Kong (MIT), Teri Odom (Northwestern University), David R. Smith (Duke), William Tisdale (MIT), Xiaobo Yin (University of Colorado at Boulder), Xiang Zhang (UC Berkeley).

Graduate Advisor: David D. Awschalom, University of Chicago

Postdoctoral Advisor: Xiang Zhang, University of California, Berkeley

Graduate Advisees: (5) Jiani Huang, Jon Stewart, Daniela Cruz, Chao Fang, Qixin Shen

Postdoctoral Advisees: (3) Thang B. Hoang, Gleb M. Akselrod, Andrew Traverso

BIOSKETCH

DAVID B. MITZI **IRG 3, LEAD**

(a) Professional Preparation

Princeton University	Princeton, NJ	Elect. Eng./Eng. Physics	B.S.E. 1985
Stanford University	Stanford, CA	Applied Physics	Ph.D. 1990

(b) Appointments

Duke University, Durham, NC

Professor, Dept. of Mechanical Eng. and Mater. Sci. & Dept. of Chemistry 07/2014 – present

Simon Family Professor of Engineering 07/2016 – present

Focus of new research program is on the development of materials for sustainable energy conversion and storage, most notably in the area of photovoltaics, light-emitting devices and photocatalysis.

IBM T. J. Watson Research Center, Yorktown Heights, NY 06/2009 – 06/2014

Manager, Photovoltaic Science and Technology Department

Initiated and managed a multi-company (TOK, Solar Frontier, IBM) program to develop a low-cost high-throughput approach to deposit thin-film chalcogenide-based absorber layers for high-efficiency solar cells. The program demonstrated solution-deposited CIGS (copper-indium-gallium selenide) solar cells with certified power conversion efficiency of above 15% and $Cu_2ZnSn(S,Se)_4$ kesterite devices with >12% power conversion efficiency, which still represents the world record performance for this earth abundant materials system.

IBM T. J. Watson Research Center, Yorktown Heights, NY 10/1990 – 05/2009

Research Staff Member

Developed a lab and program to study structure-property relationships in organic-inorganic perovskites, as well as other solution-processed high-mobility inorganic semiconductors for thin-film devices (e.g., solar cells, TFTs, LEDs). Studies included examination of solid-state and solution-based synthetic techniques for targeted complex materials, single crystal growth and thin-film deposition processes (vapor phase, melt- and solution-based), crystal structure refinement, measurement of optical, magnetic and electrical properties of bulk and thin-film samples, electronic device fabrication and testing.

(c) Publications: *Over 190 scientific publications (h-index = 70)*

5 Most Relevant Products

- D. B. Mitzi, "Synthesis, Structure and Properties of Organic-Inorganic Perovskites and Related Systems," *Progress in Inorganic Chemistry* (invited chapter) **48**, 1-121 (1999); DOI: 10.1002/9780470166499.ch1 (*cited 611 times*)
- D. B. Mitzi, C. A. Feild, W.T.A. Harrison, A. M. Guloy, "Conducting Tin Halides with a Layered Organic-Based Perovskite Structure," *Nature* **369**, 467-469 (1994); doi:10.1038/369467a0 (*cited 381 times*)
- B. Saparov, D. B. Mitzi, "Organic-Inorganic Perovskites: Structural Versatility for Functional Materials Design," *Chemical Reviews* **116**, issue 7, 4558-4596 (2016); DOI: 10.1021/acs.chemrev.5b00715
- C. R. Kagan, D. B. Mitzi, C. D. Dimitrakopoulos, "Organic-Inorganic Hybrid Materials as Semiconducting Channels in Thin-Film Field-Effect Transistors," *Science* **286**, issue 5441, 945-947 (1999); DOI:10.1126/science.286.5441.945 (*cited 1044 times*)
- D. B. Mitzi, K. Chondroudis, C. R. Kagan, "Organic-Inorganic Electronics," *IBM J. Res. and Dev.* **45**, issue 1, 29-45 (2001); DOI: 10.1147/rd.451.0029 (*cited 394 times*)

5 Additional Products

- D. B. Mitzi, "Thin-Film Deposition of Organic-Inorganic Hybrid Materials," *Chem. Mater.* **13**, issue 10, 3283-3298 (2001); DOI: 10.1021/cm0101677 (*cited 326 times*)

- D. B. Mitzi, "Templating and Structural Engineering in Organic-Inorganic Perovskites," *J. Chem. Soc., Dalton Trans.* 1-12 (2001); DOI: 10.1039/B007070J (*cited 284times*)
- K. Chondroudis, D. B. Mitzi, "Electroluminscence from an Organic-Inorganic Perovskite Incorporating a Quaterthiophene Dye within Lead Halide Perovskite Layers, *Chem. Mater.* **11**, issue 11, 3028-3030 (1999); DOI: 10.1021/cm990561t (*cited 183 times*)
- T. K. Todorov, K. B. Reuter, D. B. Mitzi, "High-Efficiency Solar Cell with Earth Abundant Liquid-Processed Absorber," *Adv. Mater.* Vol. **22**, issue 20, E156-E159 (2010); DOI: 10.1002/adma.200904155 (*cited 914 times*)
- M. Graetzel, R. A. Janssen, D. B. Mitzi, E. H. Sargent, "Materials Interface Engineering for Solution-Processed Photovoltaics," *Nature* **488**, 304-312 (2012); doi:10.1038/nature11476 (*cited 481 times*)

(d) Synergistic Activities

- Member of the Editorial Board for *Advanced Energy Materials* (Wiley) (2011-present)
- Science Advisory Board, Center for Sustainable Materials Chemistry, University of Oregon and Oregon State University (2012 – present).
- Review Committee for the Link Foundation Energy Graduate Fellowships (2014).
- Book editor: "Solution Processing of Inorganic Materials," John Wiley & Sons, 2009 (497 p).
- Organizer or co-organizer of five symposia at MRS Fall / Spring Meetings, including Symposium W "Perovskite-Based and related Novel Material Solar Cells" for Fall 2014.

Joshua E. S. Socolar – Biographical Sketch

- Phone: (919) 660-2557; Fax: (919) 660-2525; E-mail: socolar@phy.duke.edu

Professional Preparation

- B.A., Haverford College, Haverford, PA, High Honors in Physics, 1980.
- Ph.D., University of Pennsylvania, Philadelphia, PA, 1982-1987.
  Thesis in Condensed Matter Theory: "Quasilattices and Quasicrystals."
- Junior Fellow, Harvard Society of Fellows, 1987-1990.
- IBM Visiting Research Scientist, T. J. Watson Research Center, 1990-1992.

Appointments

- Professor of Physics, Duke University, 2011-present.
- Associate Professor of Physics, Duke University, 1999-present.
- Assistant Professor of Physics, Duke University, 1992-1999.
- High School Teacher, The George School, Newtown, Pa. 1981-82.

Selected Relevant Publications

- Y. Yang, L. Fu, C. Marcoux, J. E. S. Socolar, P. Charbonneau, and B. B. Yellen, Phase transformations in binary colloidal monolayers, Soft Matter **11** (2015), pp. 2404-2415. http://dx.doi.org/10.1039/C5SM00009B
- C. T. Hann, J. E. S. Socolar, and P. J. Steinhardt, Local growth of icosahedral quasicrystalline tilings, Phys. Rev. B **94**, 014113 (July 2016). https://doi.org/10.1103/PhysRevB.94.014113
- C. Marcoux, T. W. Byington, Z. Qian, P. Charbonneau, and J. E. S. Socolar, Emergence of limit-periodic order in tiling models, Phys. Rev. E **90** (July, 2014), pp. 012136, http://dx.doi.org/10.1103/PhysRevE.90.012136
- K. S. Khalil, A. Sagastegui, Y. Li, M. A. Tahir, J. E. S. Socolar, B. J. Wiley, B. B. Yellen, Binary colloidal structures assembled through Ising interactions, Nature Comm. **3** (2012), pp. 794. http://dx.doi.org/10.1038/ncomms1798
- T. Byington and J. E. S. Socolar, Hierarchical freezing in a lattice model, Phys. Rev. Lett. **108** (January, 2012), pp. 045701 http://dx.doi.org/10.1103/PhysRevLett.108.045701
- J. E. S. Socolar and J. M. Taylor, An aperiodic hexagonal tile, J. Comb. Theory Ser. A **118** (November, 2011), pp. 2207–2231, http://dx.doi.org/10.1016/j.jcta.2011.05.001
- B. P. Tighe and J. E. S. Socolar, Nonlinear elastic stress response in granular packings, Phys. Rev. E **77** (2008), pp. 031303 http://dx.doi.org/10.1103/PhysRevE.77.031303
- G. Y. Onoda, P. J. Steinhardt, D. P. DiVincenzo, and J. E. S. Socolar, Growing Perfect Quasicrystals, Phys. Rev. Lett. **60** (1988), pp. 2653-56. http://dx.doi.org/10.1103/PhysRevLett.60.2653
- J. E. S. Socolar, T. C. Lubensky, and P. J. Steinhardt, Phonons, phasons, and dislocations in quasicrystals, Phys. Rev. B **34** (1986), 3345 https://doi.org/10.1103/PhysRevB.34.3345
- J. E. S. Socolar and P. J. Steinhardt, Quasicrystals II: Unit Cell Structures, Phys. Rev. B **34** (1986), pp. 617-47. http://dx.doi.org/10.1103/PhysRevB.34.617

Synergistic activities

- Co-PI, Research Triangle MRSEC (2011-present)
- Member, Editorial Board, Physical Review E (2009-2014).
- Member at Large of Executive Committee of the American Physical Society Group on Statistical and Nonlinear Physics (2003-2006).
- Co-organizer of "Dynamics Days: Annual International Conference on Chaos and Nonlinear Dynamics" (January of 2000, 2001, 2004, 2005, 2006, 2008, 2011).
- Developer of new introductory physics curriculum for engineering students, Duke University, 2004-2007.

Collaborators

- Charles Kane (University of Pennsylvania) Tom Lubensky (University of Pennsylvania) Paul Steinhardt (Princeton University) Salvatore Torquato (Princeton University) J. P. Gleeson (University of Limerick), A. Lloyd (NC State University), Peter Mucha (UNC-Chapel Hill), F. Shi (UNC-Chapel Hill), D. Sivakoff (Ohio State University),Travis Byington (Epic Systems, Verona, WI), Hugo Cavalcante (Universidade Federal da Paraíba, Brazil), Daniel Lathrop (University of Maryland), Deirdre C. Lyons (former postdoc, Duke University), Zongjin Qian (graduate student, University of Chicago), Joan Taylor (independent researcher, Burnie, Tasmania), Rui Zhang (Calmar Laser, Sunnyvale, CA), Volkan Sevim (postdoc, UC-San Fransisco), Karim S. Khalil (gaduate student, MIT), Amanda Sagastegui (Exxon Mobil, Baton Rouge, LA), Yu Li (former student at Shanghai Jiao Tong University, current position unknown), Mukarram A. Tahir (graduate student, Duke University), Lin Fu (graduate student, Duke University, NC)
- Professors at Duke University, Durham, NC — Philip Benfey (Biology), Robert Behringer (Physics), Patrick Charbonneau (Chemistry), R. Durrett (Mathematics), Daniel Gauthier (Physics and Biomedical Engineering, now at Ohio State University), Steve Haase (Biology), Alex Hartemink (Computer Science), Edwin Iversen (Statistics), Gabriel Lopez (Biomedical Engineering), Paul Magwene (Biology), David McClay (Biology), David Schaeffer (Mathematics), Benjamin Wiley (Chemistry), Benjamin Yellen (Mechanical Engineering and Materials Science).

Graduate students supervised by Socolar since 2006

Total number (1992-present): 3 postdoctoral advisees; 8 completed PhDs; 1 current graduate student.

- Brian Tighe, PhD (2006). Assistant Professor, Delft University of Technology, Delft, Netherlands.
- Johannes Norrell (2009). Employee of the CIA, Arlington, VA.
- Xinwei Gong (2012). Biological Data Analyst, Theranos, Palo Alto, CA.
- Xianrui Cheng (2012). [Joint supervision with D. McClay, Duke Biology.] Postdoctoral researcher, Stanford University, Palo Alto, CA.
- Mengyang Sun (2013). Internet Data Analyst, Akamai, Boston, MA.
- Chris Varghese (2014). [Joint supervision with R. Durrett, Duke Math.] Postdoctoral researcher, Duke University, Durham, NC.
- Catherine Marcoux (2016). Duke University Physics Department.

Graduate and post-doctoral advisors

- Graduate: Paul Steinhardt, currently at Department of Physics, Princeton Univeristy.
- Post-doctoral: David Nelson, Department of Physics, Harvard University.

ADRIENNE D. STIFF-ROBERTS

PROFESSIONAL PREPARATION

Spelman College	Physics	BS, 1999
Georgia Institute of Technology	Electrical Engineering	BEE, 1999
University of Michigan, Ann Arbor	Electrical Engineering	MSE, 2001
University of Michigan, Ann Arbor	Applied Physics	PhD, 2004

PROFESSIONAL EXPERIENCE

May 2014-present:	Co-founder, NANOrganics, LLC, Durham, NC
Oct 2011-present:	Associate Professor, Department of Electrical and Computer Engineering, Duke University, Durham, NC
Aug 2004-Sep 2011:	Assistant Professor, Department of Electrical and Computer Engineering, Duke University, Durham, NC
Sep 1999-Mar 2004:	Doctoral Student, Applied Physics Program, University of Michigan, Ann Arbor, MI
Jun-Aug 1999:	Summer Research Fellow, AT&T Labs – Research, Red Bank, NJ
Sep 1998-Jun 1999:	Undergraduate Research Assistant, Georgia Institute of Technology, Atlanta, GA
May-Jul 1996:	Summer Intern, NASA Ames Research Center, Mountain View, CA
May-Jul 1995:	Summer Intern, NASA Ames Research Center, Mountain View, CA
Aug 1995-May 1997:	Undergraduate Research Assistant, Spelman College, Atlanta, GA

RELATED PRODUCTS

1. R. Pate and **A. D. Stiff-Roberts**, "The impact of laser-target absorption depth on the surface and internal morphology of matrix-assisted pulsed laser evaporated conjugated polymer thin films," *Chemical Physics Letters*, vol. 477, pp. 406-410, August 2009.
2. R. Pate, K. R. Lantz, and **A. D. Stiff-Roberts**, "Resonant infrared matrix-assisted pulsed laser evaporation of CdSe colloidal quantum dot/poly[2-methoxy-5-(2′-ethylhexyloxy)-1,4-(1-cyano vinylene)phenylene] hybrid nanocomposite thin films," Thin Solid Films, vol. 517, pp. 6798-6802, October 2009.
3. R. Pate, R. McCormick, L. Chen, W. Zhou, and **A. D. Stiff-Roberts**, "RIR-MAPLE Deposition of Conjugated Polymers for Application to Optoelectronic Devices," (INVITED) Applied Physics A: Materials Science and Processing, vol. 105, pp. 555-563, November 2011 (DOI 10.1007/s00339-011-6598-3).
4. W. Y. Ge, A. Atewologun and **A. D. Stiff-Roberts**, "Hybrid nanocomposite thin films deposited by emulsion-based resonant infrared matrix-assisted pulsed laser evaporation for photovoltaic application," Organic Electronics, vol. 22, pp. 98-107, March 2015.
5. Q. Yu, W. Y. Ge, A. Atewologun, G. P. López, and **A. D. Stiff-Roberts**, "RIR-MAPLE Deposition of Multifunctional Films Combining Biocidal and Fouling Release Properties," Journal of Materials Chemistry B, vol. 2, pp. 4371-4378, June 2014 (DOI: 10.1039/c4tb00566j).

OTHER SELECTED PRODUCTS

6. P. Bhattacharya, S. Ghosh, and **A. D. Stiff-Roberts**, "Quantum dot opto-electronic devices," in Annual Review of Materials Research, vol. 34, pp. 1-40, Edited by D. R. Clarke and M. Rühle, Annual Reviews, Palo Alto (2004).
7. **A. D. Stiff**, S. Krishna, P. Bhattacharya, and S. W. Kennerly, "Normal-incidence, high-temperature, mid-infrared, InAs-GaAs vertical quantum-dot infrared photodetector," IEEE Journal of Quantum Electronics, vol.37, pp.1412-1419, Nov. 2001.

8. **A. D. Stiff-Roberts**, X. H. Su, S. Chakrabarti, and P. Bhattacharya, "Contribution of field-assisted tunneling emission to dark current in InAs/GaAs quantum dot infrared photodetectors," IEEE Photonics Technology Letters, vol. 16, pp. 867-869, March 2004.
9. **A. D. Stiff-Roberts**, "Quantum Dot Infrared Photodetectors: A Review," (INVITED) Journal of Nanophotonics, vol. 3, pp. 031607, April 2009.
10. Z. Zhao, C. Yi, K. R. Lantz, and **A. D. Stiff-Roberts**, "Effect of donor-complex-defect-induced dipole field on InAs/GaAs quantum dot infrared photodetector activation energy," Applied Physics Letters, vol. 90, pp. 233511, June 2007.

SELECTED SYNERGISTIC ACTIVITIES

Honors and Awards

- National Academy of Engineering (NAE) EU-US Frontiers of Engineering Symposium Invited Attendee, Finland, 2016
- Presidential Early Career Award for Scientists and Engineers (PECASE), Department of Defense, Office of Naval Research, 2009
- IEEE Early Career Award in Nanotechnology of the Nanotechnology Council for "contributions to the development of nanoscale quantum dots for infrared detection", 2009
- Senior Member, IEEE, 2009
- Office of Naval Research Young Investigator Award, 2007
- National Science Foundation CAREER Award, 2006

Service to Scientific and Engineering Community

- Committee Member, Electronic Materials Conference (EMC), 2016-2019
- Editorial Board Member, Scientific Reports, Nature Publishing Group, Quantum Physics, 2015-2017
- Technical Committee Member, IEEE Electron Devices Society (EDS), Optoelectronic Devices, 2015-2017
- IEEE Teaching Award Committee, 2015-2017
- Program Committee Member, International High Power Laser Ablation (HPLA) and Beamed Energy Propulsion (BEP) Conference, 2014, 2016

Broadening Participation of Underrepresented Groups in STEM

- Education and Outreach Director, NSF Research Triangle Materials Research in Science and Engineering Center (RT-MRSEC), 2015-present.
- Director and Instructor, Student Engineers Network, Strengthening Opportunities in Research (SENSOR) Saturday Academy, 2007 & 2014-Present: The SENSOR Saturday Academy is an outreach program that Stiff-Roberts created as part of the 2006 NSF CAREER Award, and the program has been offered with support by the Burroughs Wellcome Fund. The program serves a single cohort of 24 8th graders from underrepresented minority groups during the entire academic year. Instruction includes the engineering design process, different types of engineering disciplines, and the operation of different sensors for water quality. The Academy also features enrichment opportunities such as lab tours, campus tours, research presentations, and panel discussions.

Innovations in Teaching

- ECE 341L – Solar Cells. Stiff-Roberts created a new course that covers the fundamental materials and device physics related to inorganic and organic solar cells. The course is unique in that it has minimal prerequisites so that it can introduce renewable solar energy to a wide range of students from different disciplines, but interested in energy applications. The course includes an extensive lab component in which students fabricate and characterize organic solar cells to investigate research questions related to the material selection or device fabrication.

Biographical Sketch - Michael J. Therien

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Education and Training

University of California at Los Angeles	Chemistry	B.S. 1982
University of California at San Diego	Chemistry	Ph.D. 1987
California Institute of Technology	NIH Postdoctoral Fellow	1987-1990

Research & Professional Experience:

Duke University	William R. Kenan, Jr. Professor	2009-present
Duke University	Professor of Chemistry	2008
University of Pennsylvania	Alan G. MacDiarmid Professor	2002-2007
University of Pennsylvania	Professor of Chemistry	1997-2002
University of Pennsylvania	Associate Professor	1996-1997
University of Pennsylvania	Assistant Professor	1990-1996

Honors: Fellow, Flemish Academy of Arts and Sciences (2009); International Francqui Chair, Belgium (2008-2009); Fellow, American Association for the Advancement of Science (2005); Visiting Professor Appointments: University of Bordeaux (2010), University of Leuven (2004, 2005, 2008, 2009), Princeton University (2002); W. Heinlen Hall Lectureship, Bowling Green State University (2005); American Chemical Society Philadelphia Section Award (2004); Pederson Lecturer, Central Research and Development Division, E. I. du Pont de Nemours (2003); Journal of Porphyrins and Phthalocyanines Young Investigator Award (2002), Camille Dreyfus Teacher-Scholar (1997-2002), Alfred P. Sloan Foundation Fellow (1995-1997), E. I. duPont de Nemours Young Faculty Award (1995-1997), National Science Foundation Young Investigator (1993-1998), Arnold and Mabel Beckman Foundation Young Investigator (1992-1994), Searle Scholar (1991-1994).

Five Products Closely Related to this Proposal:

1) Helical Wrapping of Single-Walled Carbon Nanotubes by Water Soluble Poly(*p*-phenyleneethynylene), Y. K. Kang, O.-S. Lee, P. Deria, S. H. Kim, T.-H. Park, D. A. Bonnell, J. G. Saven, and M. J. Therien, *Nano Lett.* **2009**, *9*, 1414-1418.
2) Phase Transfer Catalysts Drive Diverse Organic Solvent Solubility of Single-Walled Carbon Nanotubes Helically Wrapped by Ionic, Semi-Conducting Polymers, P. Deria, L. E. Sinks, T.-H. Park, D. M. Tomezsko, M. J. Brukman, D. A. Bonnell, and M. J. Therien, *Nano Lett.* **2010**, *10*, 4192–4199.
3) Dynamics and Transient Absorption Spectral Signatures of the Single-Wall Carbon Nanotube Electronically Excited Triplet State, J. Park, P. Deria, and M. J. Therien, *J. Am. Chem. Soc.* **2011**, *133*, 17156–17159.
4) Ionic Self-Assembly Provides Dense Arrays of Individualized, Aligned Single Walled Carbon Nanotubes, J.-H. Olivier, P. Deria, J. Park, A. Kumbhar, M. Andrian-Albescu, and M. J. Therien, *Angew. Chemie.* **2013**, *52*, 13080-13085.
5) Single-Handed Helical Wrapping of Single-Walled Carbon Nanotubes by Chiral, Ionic, Semiconducting Polymers, P. Deria, C. D. Von Bargen, J.-H. Olivier, A. S. Kumbhar, J. G. Saven, and M. J. Therien, *J. Am. Chem. Soc.* **2013**, *135*, 16220−16234.

Five Other Significant Products:

6) Effect of Solvent Polarity and Electrophilicity on Quantum Yields and Solvatochromic Shifts of Single-Walled Carbon Nanotube Photoluminescence, B. A. Larsen, P. Deria, J. M. Holt, I. N. Stanton, M. J. Heben, M. J. Therien, and J. L. Blackburn, *J. Am. Chem. Soc.* **2012**, *134*, 12485−12491.
7) Exploiting Plasmon Induced Hot Electrons in Molecular Electronic Devices, D. Conklin, S. Nanayakkara, T.-H. Park, M. F. Lagadec, J. T. Stetcher, X. Chen, M. J. Therien, and D. A. Bonnell, *ACS Nano*, **2013**, *7*, 4479–4486.
8) Fluence-Dependent Singlet Exciton Dynamics in Length-Sorted Chirality-Enriched Single-Wall Carbon Nanotubes, J. Park, P. Deria, J.-H. Olivier, and M. J. Therien, *Nano Lett.* **2014**, *14*, 504−511.
9) Potentiometric, Electronic, and Transient Absorptive Spectroscopic Properties of Oxidized Single-Walled Carbon Nanotubes Helically Wrapped by Ionic, Semiconducting Polymers in Aqueous and Organic Media, P. Deria, J.-H. Olivier, J. Park, and M. J. Therien, *J. Am. Chem. Soc.* **2014**, *136*, 14193−14199.
10) Unambiguous Diagnosis of Photoinduced Charged Carrier Signatures in a Stoichiometrically Controlled Semiconducting Polymer-Wrapped Carbon Nanotube Assembly, J.-H. Olivier, J. Park, P. Deria, J. Rawson, Y. Bai, A. Kumbhar, and M. J. Therien, *Angew. Chem., Int. Ed. Engl.* **2015**, *54*, 8133–8138.

Synergistic Activities

External Reviewer, United States Department of Energy, Nanotechnology Centers (2003 – 2010); Selection Committee, Beckman Young Investigator Program (2003 – present); Scientific Advisory Board, Center for Nanoscale Materials, Argonne National Laboratory (2005 - 2014); Interfacial Synthesis Team Leader, DOE Energy Frontier Research Center at UNC-Chapel Hill (2012-2014); Editorial Advisory Board, ACS Central Science (2015 – present).

Collaborators

Extramural Collaborators: Paul J. Angiolillo (Physics, St. Joseph's University); J. Kent Blasie and Jeffery G. Saven (Chemistry, University of Pennsylvania); Dawn Bonnell (Materials Science and Engineering, University of Pennsylvania); Dan Hammer (Bioengineering, University of Pennsylvania); Jorge Santiago-Avilés (Electrical Engineering, University of Pennsylvania); Sébastien Bonhommeau and Vincent Rodriguez (Chemistry, University of Bordeaux, France); Eric Borguet (Chemistry, Temple University); Felix N. Castellano (Chemistry, North Carolina State University); Koen Clays and Thierry Verbiest (Chemistry, Katholieke Universiteit of Leuven, Belgium); William F. DeGrado (Pharmaceutical Chemistry, UCSF); Andrew J. Ferguson and Jeffrey L. Blackburn (Chemical and Materials Science Center, NREL); Steven R. Flom (Optical Sciences, U.S. Naval Research Laboratory); Malcolm D. E. Forbes (Chemistry, Bowling Green State University), Thomas J. Meyer, Wei You (Chemistry, University of North Carolina at Chapel Hill); Steve Doorn (Center for Integrated Nanotechnologies, Los Alamos National Laboratory).

Graduate Advisor: Prof. W. C. Trogler, Department of Chemistry, University of California at San Diego.
Postdoctoral Sponsor: Prof. H. B. Gray, Department of Chemistry, California Institute of Technology.

Ph.D. Thesis Advisor (last 5 yrs; total): Pravas Deria (Southern Illinois University), Animesh Nayak (U.N.C. Chapel Hill), Jaehong Park (National Renewable Energy Laboratory), Ian N. Stanton (Edinburgh Instruments), Mary G. Glesner (Invista), Joshua Stecher (University of Wyoming): **Total: 43**
Postgraduate Scholar Sponsor (last 5 yrs; total): Mariem Canales (General Electric), Wei Qi (Wondfo Biotech), Mark Zhang (Ivoclar Vivadent), Jennifer Ayres (Aerotek). **Total: 30**

Mark D. Walters
Director, Shared Materials Instrumentation Facility
Duke University
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Durham, NC 27708
(919) 660-5486
mark.walters@duke.edu

A. PROFESSIONAL PREPARATION

College/University	Major	Degree &Year
University of North Carolina	Physics	BA, 1981
University of Virginia	Engineering Physics	MS, 1986
North Carolina State University	Materials Science Eng	PhD, 1989

B. ACADEMIC/PROFESSIONAL APPOINTMENTS

2002-present	Director, Shared Materials Instrumentation Facility, Duke University
2001-2002	New Product Introduction Manager, JDS Uniphase, Research Triangle Park, NC
2000-2001	Product Development Manager, JDS Uniphase, Research Triangle Park, NC
1999-2000	Product Development Manager, Cronos Integrated Microsystems, Research Triangle Park, NC
1994-1999	Program Manager, Microelectronics Center of North Carolina (MCNC), Research Triangle Park, NC
1989-1994	Member Technical Staff, Microelectronics Center of North Carolina (MCNC), Research Triangle Park, NC
1986-1989	Associate Member Technical Staff, Microelectronics Center of North Carolina (MCNC), Research Triangle Park, NC
1984-1986	Graduate Research Assistant, University of Virginia, Charlottesville, VA

C. PUBLICATIONS

Publications Most Closely Related to Proposal

1. V.R. Dhuler, M.D. Walters, R. Mahadevan, A.B. Cowen, and K.W. Markus 1997. “A Novel Two Axis Actuator for High Speed Large Angular Rotation,” Proc. of Ninth International Conference on Solid-State Sensors and Actuators (Transducers 97), Chicago, June16-19.
2. C.A. Ball, M.D. Walters, and R.L. Wood 1996. “Contamination Issues for MEMS Fabrication,” Cleanrooms, **10**, p.26.
3. D.A. Koester, K.W. Markus, and M.D. Walters 1996. “MEMS: Small Machines for the Microelectronics Age,” Computer, **29**, p.93.
4. D. Temple, A. Reisman, G.G. Fountain, M. Walters, and S.V. Hattangady 1993. "Mechanical Stress in SiO_2 Films Obtained by Remote Plasma-Enhanced Chemical Vapor Deposition," J. Electrochem. Soc., **140**, p.571.
5. G. Jones, S. Jones, B. Dudley, and M. Walters 1989. “Microstructure for Control of Multiple Electron or Ion Beams,” IEEE Trans. Electron. Devices, **36**, p.2686.

Other Significant Publications

(Patents)

1. Zhu; Terry D.; Walters; Mark, October 21, 2003, “MEMS optical switches having obliquely angled inputs and outputs relative to a face thereof and moveable reflectors with parallel positions therein and methods of forming same,” Patent #6,636,655.
2. Dhuler; Vijayakumar R.; Koester; David A.; Walters; Mark D.; Markus; Karen W., April 29, 2003, “Method for fabricating a microelectromechanical bearing,” Patent #6,555,201.

3. Dhuler; Vijayakumar R., Walters; Mark David; Hill; Edward A.; Cowen; Allen Bruce, August 6, 2002, "Moveable microelectromechanical mirror structures and associated methods," Patent #6,428,173.
4. Dhuler; Vijayakumar R. and Walters; Mark David, May 14, 2002, "Microelectromechanical valves including single crystalline material components," Patent #6,386,507.
5. Dhuler; Vijayakumar R.; Hill; Edward A.; Mahadevan; Ramaswamy; Walters; Mark David; Wood; Robert L., August 14, 2001, "MEMS variable optical attenuator," Patent #6,275,320.

D. SYNERGISTIC ACTIVITIES

- Director of the Shared Materials Instrumentation Facility (SMIF) which operates as an interdisciplinary shared use facility of Duke University, and is available to Duke University researchers and educators from the various schools and departments as well as to external users from other Universities, government laboratories or industry. SMIF is a member of the Research Triangle Nanotechnology Network (RTNN), which is part of the NSF sponsored National Nanotechnology Coordinated Infrastructure (NNCI) program.
- Executive Committee member of the Research Triangle Nanotechnology Network (RTNN).
- Instructor for an interdisciplinary advanced materials laboratory course that is a requirement for both the biologically inspired materials and materials systems graduate certificate program and the nanoscience graduate certificate program
- Coordinator for the SMIF Undergraduate User Program (SUUP) which provides a hands-on undergraduate research experience in the Pratt School of Engineering that enables undergraduate students access to the SMIF cleanroom and characterization capabilities.
- Coordinator for the Duke University "Class Based Exploration" program, which encourages faculty members to use SMIF capabilities as part of the undergraduate or graduate classroom learning experience

COLLABORATORS AND OTHER AFFILIATIONS

Collaborators Over The Last 48 Months:

Not applicable

Graduate and Postdoctoral Advisors

Not applicable

Thesis Advisor and Postgraduate Scholar Sponsors over the Last Five Years:

Not applicable

BENJAMIN J. WILEY

Assistant Professor
Department of Chemistry
Duke University

EDUCATION

B.S.	Chemical Engineering, University of Minnesota, Minneapolis, MN (2003)
Ph.D.	Chemical Engineering, University of Washington, Seattle, WA (2007)

EXPERIENCE

2009-present	Assistant Professor, Department of Chemistry, Duke University, Durham, NC
2007-2009	Postdoctoral Research Fellow, Department of Chemistry and Chemical Biology, Harvard University, Boston, MA
2003-2007	Graduate Research Fellow, Department of Chemistry, University of Washington, Seattle, WA

AWARDS

Beilby Medal	2015
Thomson Reuters Highly Cited Researcher	2014
NSF CAREER award	2012
Ralph E. Powe Junior Faculty Enhancement Award	2011
Ruth L. Kirschstein National Research Service Award for Individual Postdoctoral Fellows, *NIH*	2008-2009
Colloid and Surface Science Division Poster Award, *ACS*	2006
Graduate Student Gold Award, *MRS*	2005
NSF-IGERT Graduate Fellowship, *University of Washington*	2004-2006
Runstad Fellowship, *University of Washington*	2003-2004
NSF-IGERT Early Bird Award in Nanotechnology, *University of Washington*	2003
Roon Award, *Federation of Societies for Coatings Technology*	2003

PRODUCTS (from ~72 publications)

(i) Products Most Closely Related to the Proposed Project

(1) Ye, S.; Rathmell, A.R.; Chen, Z.; Stewart, I.E.; Wiley, B.J. Metal Nanowire Networks: The Next Generation of Transparent Conductors. *Adv. Mater.*, 2014, 26, 6670-6687.

(2) Chen, Z.; Ye, S.; Stewart, I.E.; Wiley, B.J. Copper Nanowire Networks with Transparent Oxide Shells That Prevent Oxidation without Reducing Transmittance. *ACS Nano*, 2014, 8, 9673-9679.

(3) Chen, Z.; Ye, S.; Wil-son, A.R.; Ha, Y.-C.; Wiley, B.J. Optically Transparent Hydrogen Evolution Catalysts made from Networks of Copper-Platinum Core-Shell Nanowires. *Energy Environ. Sci.,* 2014, 7, 1461-1467.

(4) Chen, Z.; Rathmell, A. R.; Ye, S.; Wilson, A. R.; Wiley, B. J. Optically Transparent Water Oxidation Catalysts Based on Copper Nanowires. *Angew. Chem. Int. Ed.* 2013, 52, 13708-13711. *Highlighted in C&EN.*

(5) Rathmell, A.R.; Nguyen, M.; Chi, M.; Wiley. B.J. Synthesis of Oxidation-Resistant Cupronickel Nanowires for Transparent Conducting Nanowire Networks. *Nano Lett.* 2012, 12, 3913.

(ii) Other Significant Products

(1) Ye, S.; Chen, Z.; Ha, Y.-C.; Wiley, B.J. Real-Time Visualization of Diffusion-Controlled Nanowire Growth in Solution. *Nano Lett*, 2014, 14, 4671–4676.

(2) Stewart, I.E.; Rathmell, A.R.; Yan, L.; Ye, S.; Flowers, P.F.; You, W. Wiley, B.J. Solution-Processed Copper-Nickel Nanowire Anodes for Organic Solar Cells. *Nanoscale*, 2014, 6, 5980-5988.

(3) Ye, S.; Rathmell, A.R.; Ha, Y-C.; Wilson, A.R.; Wiley, B.J. The Role of Cuprous Oxide Seeds in the One-Pot and Seeded Synthesis of Copper Nanowires. *Small*, 2014, 10, 1771-1778.

(4) Mutiso, R. M.; Sherrott, M.C.; Rathmell, A.R.; Wiley, B. J.; Winey K. I. Integrating Simulations and Experiments to Predict Sheet Resistance and Optical Transmittance in Nanowire Films for Transparent Conductors. *ACS Nano* 2013, 7, 7654-7663.
(5) Wu, J.; Zang, J.; Rath-mell, A.R.; Zhao, X.; Wiley, B.J. Re-versible Sliding in Networks of Nanowires. Nano Lett. 2013, 13, 2381.

SYNERGISTIC ACTIVITIES

(i) Education

(a) High School Education: Supervisor for underrepresented 4 students from the NC Project Seed Program, and 2 students from the North Carolina School for Science and Math

(b) Undergraduate Education: Currently mentoring 5 (of 22 total) undergraduate research assistants. Developed new course to teach sophomore chemistry in the context of nanotechnology and materials science (Chem 210).

(c) Graduate Education: Developed new course on materials chemistry in the context of nanoscience.

(ii) Professional Service

(a) Reviewer for Journals: Science, Nat. Nano., Angew. Chem., Nano Lett., JACS, Chem. Rev., Adv. Mater, J. Phys. Chem, ACS Nano, ACS Appl. Mater. Interfaces, ACS Catalysis, Langmuir, Small, Nanoscale, Chem. Comm. Chem. Mater., Mater Chem., Eur J. Inorg. Chem., Nanoscale, Cryst. Growth Des., Int. J.Hyperthermia, Chem. Phys. Lett., Rapid Res. Lett., J. Exp. Nanosci.

(b) Reviewer for Funding Agencies: NSF, NIH, DOE, NRAS

Collaborators:

Duke University: Patrick Charbonneau, Ashutosh Chilkoti, Jeff Glass, Gabriel Lopez, David Smith, Joshua Socolar, Benjamin Yellen
MIT: Xuanhe Zhao
North Carolina State University: Yong Zhu, Henry Lamb, James Lebeau
University of North Carolina: Wei You, T. J. Meyer
University of Pennsylvania: Karen Winey
Chinese Academy of Sciences: Zhi-Yuan Li
Oak Ridge National Lab: Miaofang Chi

Graduate and Postdoctoral Advisors:

Ph.D.	Xia Y., University of Washington, Seattle, WA
Post-Doctoral	Whitesides, G.M., Harvard University, Boston, MA

Graduate Advisees: Aaron Rathmell (2009-2013), Adria Wilson (2009-2014), Samuel Alvarez (2012-present), Patrick Flowers (2012-present), Ian Stanton (2012-present), Matthew Catenacci (2013-present), Christopher Reyes (2014-present)

Postdoctoral Fellows: Shengrong Ye (2012-present), Yoon-Cheol Ha (2012-2013), Zuofeng Chen (2012-2014)

Undergraduate research participants:

Past: Derek Chenet, Prithviraj Singha Roy, Evan Seidel, Stephen Bergin, Minh Nguyen, Kathleen Lan, Daniel Agocs, Tim Zhang, Tori Reynolds, Tera Kashgarian, Roger Chavez, Abbas Shikari, Aman Kansal, Katherine Shirrell, Ben Lee, Christopher Reyes, Lucy Downy
Current: Kaitlin Hubbar, Vaibhav Tadepalli, Rita Somogyi, Dorothy Jones, Samuel Brougher

High School research participants:

Past: Selina Boyd, Justin Yu, Kevin Valakuzhy, Joshua Howell, Donathan Bryant, Ben Samson

BIOSKETCH

STEFAN ZAUSCHER
Sternberg Family Professor of Mechanical Engineering and Materials Science
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(a) Professional Preparation

University of Hamburg, Hamburg, Germany		Vordiplom Holzwirtschaft, 1987
Oregon State University, Corvallis, OR	Materials Science	M.S., 1992
University of Wisconsin-Madison, Madison, WI	Materials Science	Ph.D., 2000

(b) Appointments

At Duke University, Durham, NC:

Sternberg Family Professor of Mechanical Engineering and Materials Science	7/2012–present
Professor, Dept. of Mechanical Engineering and Materials Science	7/2012–present
Professor, Dept. of Biomedical Engineering (Secondary Appt.)	7/2012–present
Professor, Dept. of Chemistry (Secondary Appt.)	7/2012–present
Assoc. Professor, Dept. of Mechanical Engineering and Materials Science	7/2007–06/2012
Assoc. Professor, Dept. of Biomedical Engineering (Secondary Appt.)	2/2009–06/2012
Asst. Professor, Dept. of Mechanical Engineering and Materials Science	9/2000–06/2007

At State University of New York, Syracuse

Asst. Professor, Faculty of Paper Science and Engineering	1/2000–08/2000

(c) Products (selected from more than 100 peer reviewed publications)

Five products most closely related to the proposed project

1. Tu, Q., Lange, B., Parlak, Z., Lopes, J.M., Blum, V., **Zauscher, S.** (2016). "Quantitative Subsurface Atomic Structure Fingerprint for 2D Materials and Heterostructures by First-Principles Calibrated Contact-Resonance Atomic Force Microscopy," *ACS Nano*, 233511, 1-3. DOI: 10.1021/acsnano.6b02402
2. Li, N.K., Fuss, W. H., Tang, L., Gu, R., Chilkoti, A., **Zauscher, S.**, Yingling, Y. (2015). "Prediction of solvent-induced morphological changes of polyelectrolyte diblock copolymer micelles," *Soft Matter*, 42, 8236-8245. DOI: 10.1039/C5SM01742D
3. Gu, R., Lamas, J., Rastogi, S. K., Li, X., Brittain, W., **Zauscher, S.** (2015). "Photocontrolled micellar aggregation of amphiphilic DNA-azobenzene conjugates," *Colloids and Surfaces B: Biointerfaces*, 135, 126-132. DOI:10.1016/j.colsurfb.2015.07.010
4. Tang, L., Tjong, V., Li, N., Yingling, Y. G., Chilkoti, A., **Zauscher, S.** (2014). "Enzymatic Polymerization of High Molecular Weight DNA Amphiphiles that Self-Assemble into Star-like Micelles," *Advanced Materials*, 26(19), 3050-3054. DOI: 10.1002/adma.201306049
5. Coles, J.M., Chang, D.P., **Zauscher, S.** (2010). "Molecular mechanisms of aqueous boundary lubrication by mucinous glycoproteins," *Current Opinion in Colloid and Interface Science*, 15(6), 406-416. DOI 10.1016/j.cocis.2010.07.002

Five other significant products

1. Parlak, Z., Tu, Q., **Zauscher, S.** (2014). "Liquid contact resonance AFM: analytical models, experiments, and limitations," *Nanotechnology* 25(44), 445703. DOI:10.1088/0957-4484/25/44/44703
2. Zhang, J., Parlak, Z., Bowers, C.M., Oas, T., **Zauscher, S.** (2012). "Mapping mechanical properties of organic thin films by force-modulation microscopy in aqueous media," *Beilstein Journal of Nanotechnology*, 3(1), 464-474. DOI:10.3762/bjnano.3.53

3. Ferris, R.J., Lin, S., Therezien, M., Yellen, B., **Zauscher, S.** (2013). (Invited) "Electric Double Layer Formed by Polarized Ferroelectric Thin Films," *ACS Applied Materials & Interfaces*, 7, 2610–2617. DOI:10.1021/am3031954
4. Tjong, V., Tang, L., **Zauscher, S.**, Chilkoti, A. (2014). "'Smart' DNA Interfaces," *Chemical Society Reviews*, 43, 1612-1626. DOI:10.1039/C3CS60331H
5. Cohen Stuart, M. A., Huck, W. T. S., Genzer, J., Müller, M., Ober, C., Stamm, M., Sukhorukov, G. B., Szleifer, I., Tsukruk, V. V., Urban, M., Winnik, F., **Zauscher, S.**, Luzinov, I., Minko, S. (2010.) "Emerging applications of stimuli-responsive polymer materials," *Nature Materials*, 9, 101–113. DOI:10.1038/nmat2614

(d) Synergistic Activities

- **Education:** Dr. Zauscher is the PI of the Research Triangle MRSEC (RT-MRSEC), and was the Education Director for the Center from its inception in 2011 until 2015. In these roles he has been strongly committed to broaden the participation of URG in STEM. For example, in partnership with Texas State University (PREM), he created a highly diverse, selective and successful REU program. By strategically recruiting and selecting outstanding undergraduate students and supporting their research careers and professional development, RT-MRSEC strives to provide a diverse pipeline to graduate school and potential future involvement in graduate level MRSEC research. Furthermore, Dr. Zauscher and RT-MRSEC received the 2016 Duke Graduate School Dean's Award for Inclusive Excellence in Graduate Education for its consistent and intentional creation of an environment that demonstrates dedication to exemplary inclusiveness and diversity in graduate education. For excellence in research and undergraduate education, Dr. Zauscher was inducted in 2012 into the Bass Society of Fellows.
- **Professional Service:** Dr. Zauscher is an international leader in the emerging field of biointerface science. From 2009-2010 he served as the elected Chair of the Biomaterials Interfaces Division of the American Vacuum Society (AVS). In 2014, he organized and chaired the Gordon Research Conference (GRC) in Biointerface Science.
- **Research:** In his own research and as PI of RT-MRSEC, Dr. Zauscher is strongly committed to foster collaboration and cross-disciplinarity. In 2013, he led a successful NSF-MRI proposal to bring Small Angle X-Ray Scattering (SAXS) instrumentation to the Triangle Region of NC. The state-of-the-art SAXS instruments are housed in Duke's Shared Materials Instrumentation Facility (SMIF), and serve the greater Research Triangle community for research and education.
- **Scientific Outreach:** In 2010, 2013, and 2016, he has been a co-organizer of the Triangle Soft Matter workshop. The goal of this workshop, held every year at one of the Triangle Universities, is to spark interactions and collaborations between soft-matter research groups in the Triangle area. The workshop format is very informal, and an emphasis is placed on spurring conversations between researchers in all areas of soft matter research.

Appendix C: Financial Projections (Six-year Projection of Program Expenses, Income, and Return)

University Program in Materials Science and Engineering	FY 17/18	FY 18/19	FY 19/20	FY 20/21	FY 21/22	FY 22/23
Expenses:						
Personnel						
Director of Graduate Studies Assistant (50% of base salary)	24,479	25,213	25,970	26,749	27,551	28,378
Director of Graduate Studies (0.5-1.0 mo. summer salary)	8,014	16,509	17,004	17,514	18,039	18,581
Fringe (26.9%)	8,741	11,223	11,560	11,907	12,264	12,632
Total personnel:	**41,233**	**52,945**	**54,534**	**56,170**	**57,855**	**59,590**
Operations						
Website and Advertising	10,000	0	0	0	0	0
Course Development	10,000	5,000	5,000	5,000	5,000	5,000
Seminar Course (Travel and Food, two semesters)	0	16,000	16,000	16,000	16,000	16,000
SMIF Course (Spring semester)	0	16,000	16,000	16,000	16,000	16,000
M.S. Project Funds	0	12,500	32,500	45,000	50,000	50,000
Professional Development (industry night/4th year PhD)	0	5,000	5,000	5,000	8,000	8,000
Graduate School Allocated Costs ($600 per student)	0	3,000	7,800	10,800	12,000	12,000
EIS Courses for M.S. students ($1110 per student)	0	5,550	14,430	19,980	22,200	22,200
Graduate Student Recruitment Travel	15,000	8,000	8,000	8,000	8,000	8,000
Graduate Student Scholarships (15% of total tuition)	0	40,155	108,579	156,354	180,676	187,903
Supplies and Miscellaneous	5,000	5,000	5,000	5,000	5,000	5,000
Total Operations:	**40,000**	**116,205**	**218,309**	**287,134**	**322,876**	**330,103**
Total Expenses:	**81,233**	**169,150**	**272,843**	**343,303**	**380,730**	**389,693**
Income:						
Support from Materials Initiative (MI)	81,233	75,455	50,000	50,000	50,000	0
Total # M.S. Students	0	5	13	18	20	20
M.S. Tuition (Fall and Spring)	0	53,540	55,682	57,909	60,225	62,634
Total M.S. Tuition Paid	0	267,700	723,861	1,042,360	1,204,504	1,252,685
Tuition Return for M.S. Program (35%)	0	93,695	253,351	364,826	421,577	438,440
Total Income:	**81,233**	**169,150**	**303,351**	**414,826**	**471,577**	**438,440**
Program Return:						
UP-MSE Balance (100% goes toward reserve)	0	0	30,509	71,522	90,846	48,747
Cumulative UP-MSE Reserve	N/A	N/A	30,509	102,031	192,877	241,624
Total Return to Pratt & Trinity (32.5% each)	N/A	174,005	470,510	677,534	782,928	814,245
Total Cumulative Return to Pratt & Trinity:	**N/A**	**174,005**	**644,515**	**1,322,048**	**2,104,976**	**2,919,221**

Appendix D: Learning Assessment Plan

The proposed graduate program is expected to evolve over time, guided by feedback received through annual assessment of program activities. The assessment tools to be used include:

i) student and faculty online surveys to evaluate attitudes and to track population demographics;
ii) graduate student individual development plans (IDPs) for review by the DGS;
iii) learning outcomes evaluation forms to be completed by the committees administering the M.S. project exam and the Ph.D. exams;
iv) exit surveys to determine overall student opinion of the program and to track career placement; and
v) on-site evaluation forms for all workshops provided for the UP-MSE.

The collected data will be used to evaluate program quality and outcomes, as well as to collect data for use in evaluation by the Southern Association of Colleges and Schools (SACS). In addition, the MSE graduate program will conduct a program review in the third year, as well as an external review every five years, for evaluation by the Graduate School according to established practice.

Appendix E: Letters of Support

Duke UNIVERSITY | PRATT SCHOOL of ENGINEERING

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Memorandum of Understanding
Between the Office of the Provost, the Pratt School of Engineering and the Trinity College of Arts & Sciences
Regarding the Support for the Joint Materials Science Entity

January 25, 2017

Because it is in the best interests of the university and its faculty and students to collaborate broadly across the institution and because our academic activities can only be enriched by interdisciplinary partnerships, the Office of the Provost, the Pratt School of Engineering and the Trinity College of Arts & Sciences have agreed to jointly create and support an interdisciplinary partnership designed to foster this collaboration specifically in the area of materials science. In order to continue this collaboration and to support the strategic plan, the three units have agreed to extend and enhance the previously agreed to arrangement.

Time Frame – The initial agreement (MOU dated October 14, 2015) guaranteed funding for this effort through September 30, 2018. Because all parties agree to change the time frame of support to align with Duke's fiscal year, the extended period of support for this initiative will be from July 1, 2018 – June 30, 2022. This agreement may be renewed by mutual agreement of the participating parties.

Leadership – A Director for this entity will be chosen from among the faculty of the relevant departments. The director will have overall responsibility for this initiative, working with the faculty steering committee to identify research opportunities and develop the graduate program. The director will appoint an associate director, collaborate with the Deans of both schools to identify potential joint faculty hiring opportunities, and develop an inclusive organizational structure. In collaboration with the Graduate School, the director will also participate in the selection of a Director of Graduate Studies (DGS) for the program. The DGS will have oversight of the graduate program including the financial resources dedicated to it and will receive appropriate compensation for that work as is customary in the school in which their appointment resides. It is our intention that Adrienne Stiff-Roberts serve an initial term as the DGS for the program given her significant involvement in the creation of the graduate program.

Financial Commitment – Based on current projections, it is estimated that approximately $400,000 of the initial total commitment (MOU dated October 14, 2015) will remain at the end of the initial period of agreement (September, 30, 2018). Given this large carry over balance, it is the expectation that the joint materials entity use these carry over funds before seeking new funds from the partners. Again, based on current projections, these funds are expected to last at least through June 30, 2019. Therefore, each supporting unit shall provide $70,000 per year for the time period of July 1, 2019 – June 30, 2022 in support of this effort for a total annual commitment of $210,000. These funds will be under the direction of the named Director of this entity with expenditures made according to the relevant financial policies of Duke University. Of this commitment, at least $50,000 per year will be under the direction of the DGS and dedicated to support of the graduate program. In July of each year, all three entities will transfer their committed portion to this fund. The purpose of the funds is to develop a strategic plan for the joint Materials Science initiative that includes (but is not limited to) potential faculty recruitment and development of a graduate student program.

Once a Director of this entity is named, the Pratt School of Engineering and the leadership of the Triangle MRSEC will work with the new Director to discuss what, if any, of the current Triangle MRSEC activities will be absorbed into the materials entity. Based on these decisions, a proportional amount of the annual Pratt commitment to the Triangle MRSEC may be provided to fund these activities.

Masters Revenue Return – It is the intention of the Schools participating in this program to share the net masters student tuition revenue as follows: 35% to the materials entity, 32.5% to Pratt and 32.5% to A&S. We recognize that, as is the usual practice in Pratt, should students participate in the Graduate School led English for International Students or a similar program, the fee for that service will be paid by the materials entity from their share of the revenue return. Specific details pertaining to the accounting process required to ensure this sharing arrangement is clear and efficient will be determined once a firm program launch date is established.

Financial Self-Sustainability – It is the intention of all parties that the overall program become financially self-sustaining, and it shall be the responsibility of the director to ensure this is the case. Current financial projections (attached to this MOU for reference) indicate that the proposed masters program will generate sufficient revenue to support program operations likely in 2023; however, other sources of revenue should be sought. Once the overall program has reached the point of becoming financially self-sustaining, the funds committed in this agreement will serve only as a backstop and will be provided only if they are needed to maintain basic operations over and above the funding made possible from the masters revenue return or other sources of revenue identified by the director.

This agreement is renewable upon mutual consent of the appropriate representatives from the supporting units.

The undersigned agree to the terms outlined in this document.

Sally Kornbluth
Provost

01.30.2017
Date

Valerie Ashby
Dean, Trinity College of Arts & Sciences

01.27.2017
Date

Ravi Bellamkonda
Vinik Dean, School of Engineering

01.26.2017
Date

cc: Sandy Connolly
Susan Bonifield
Amy Oates

Duke UNIVERSITY | PRATT SCHOOL of ENGINEERING

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January 25, 2017

Adrienne Stiff-Roberts
iMSEI Education Director
Associate Professor
Department of Electrical and Computer Engineering
Duke University
Durham, NC 27708

Dear Adrienne:

We write in strong support of the proposed University Program in Materials Science and Engineering, which will offer M.S. and Ph.D. degrees. We view this graduate program as an important element of a broader, campus-wide effort to elevate recognition of the materials excellence that already exists at Duke. Materials Science and Engineering is a highly interdisciplinary topic and therefore perfectly fits within the context of a cross-school program.

In acknowledgement of the challenges associated with launching a new graduate degree program that spans Pratt and Trinity, we support the phased implementation of the program. We agree that the approach described as Phase 1 in the proposal poses minimal negative impact on existing programs and structures, and provides the best alternative for fostering a successful program launch.

In support of this effort, we have extended an MOU providing funds for the materials science and engineering initiative through June 30, 2022 at a total annual commitment of $210,000 (split equally among the Provost, Trinity and Pratt). A portion of these funds will help support the proposed graduate program until it becomes self-sustaining.

Being that the proposed program represents a new graduate structure on campus and that no financial model exists, we have carefully reviewed the proposed budget and agree to split the M.S. revenue, with 35% going to the University Program in Materials Science and Engineering, 32.5% to Pratt, and 32.5% to Trinity. It is important to note that a portion of the revenue received by the graduate program will be returned to the campus-wide materials science and engineering initiative in support of its efforts to create an environment in which the program can thrive. If the program grows as expected, we support the need to identify space on campus for a central office to house the graduate program.

We expect that the University Program in Materials Science and Engineering will help strengthen educational collaboration and coordination between Pratt and Trinity. Furthermore, this is an area that has profound importance for addressing Grand Challenges within the areas of health, energy, and sustainability. We therefore believe that the materials community that will be fostered on campus as a result of this program will contribute to the goals of the new University strategic plan.

Sincerely,

Ravi Bellamkonda, Ph.D.
Vinik Dean, School of Engineering

Valerie Ashby, Ph.D.
Dean, Trinity College of Arts & Sciences

cc: Susan Bonifield
Sandy Connolly
Dan Kiehart
Brad Fox

Duke | DEPARTMENT OF Mechanical Engineering and Materials Science

Ken Gall
Chair of the Department of Mechanical Engineering and Materials Science
Duke University
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August 31, 2016

Adrienne Stiff-Roberts
iMSEI Education Director
Associate Professor
Department of Electrical and Computer Engineering
Duke University
Durham, NC 27708

Dear Adrienne:

On behalf of the Department of Mechanical Engineering and Materials Science, I am writing to provide my strong support of your proposal for a new graduate program in Materials Science and Engineering. I have carefully considered the impact of this MSE graduate program on the M.S. and Ph.D. degrees offered by my department. I find that the MSE Ph.D. program has been constructed to have minimal negative impact on the existing doctoral program. To the contrary, this new degree option should expand the recruitment pool of Ph.D. students available to my faculty, and help elevate visibility of the materials science component of the MEMS department.

Regarding the M.S. degree, the MEMS department is growing our Master's program. In fact, the number of accepted M.S. students in MEMS is 31 for the current academic year; yet 24 of these students have confirmed selection of the Mechanical Engineering track. Indeed, for the past three academic years, the total number of matriculating M.S. students in the MEMS department is 13, most of whom have followed the Mechanical Engineering curriculum track. Thus, current demand for the M.S. in MEMS is strongest for the mechanical engineering side of the department, and we can continue to build upon this strength. Considering that the current Materials Science track for the M.S. degree in MEMS comprises several courses from other departments, this MSE graduate program will help increase capacity to teach these courses on a regular basis. This stabilized curriculum will also help grow a distinct material science track related to structural materials within MEMS. We think students interested in such structural materials will select the MEMS graduate program, which complements the MSE degrees that focus more on functional materials.

MEMS faculty that are likely to attract MSE graduate students include Volker Blum, Chuan-Hua Chen, Hadley Cocks, Stefano Curtarolo, Piotr Marszalek, David Mitzi, Teh Yu Tan, Jennifer West, Ben Yellen, Stefan Zauscher, and myself. As you know, many of these materials science faculty have been involved in the development of this graduate program since the beginning, and I have been participating in the materials science and engineering initiative since my arrival on campus.

The MEMS department is pleased to offer four core courses and 9 courses from which MSE students can select electives. Two of the core courses that will be offered are new and will be offered originally by the MEMS department: Fundamentals of Soft Matter, and Materials Synthesis and Processing. These courses fit within the framework of course requirements for MEMS degrees, and therefore, do not represent losses to existing required courses. The existing core and elective courses are offered on a regular basis and can accommodate up to 20 additional students from the MSE program.

I am excited about the potential of this new graduate program, especially for my department, as we help lead the way to materials excellence on campus.

Best Regards,

Ken Gall
Professor in the Department of Mechanical Engineering and Materials Science
Chair of Department of Mechanical Engineering and Materials Science
Associate Director in the Pratt School of Engineering, MEDx Initiative

Duke UNIVERSITY | PRATT SCHOOL of ENGINEERING

Department of Electrical & Computer Engineering

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August 31, 2016

Adrienne Stiff-Roberts
iMSEI Education Director
Associate Professor
Department of Electrical and Computer Engineering
Duke University
Durham, NC 27708

Dear Adrienne:

I was very interested to learn more about the materials science and engineering initiative designed to establish a new graduate program and to promote MSE research across Pratt and Trinity. ECE has already established strong ties with Trinity through faculty joint appointments in Chemistry, Math, Physics, and Computer Science, and as a department, we value the benefits that result from strong partnerships with Trinity. I support your proposal for a new graduate program in Materials Science and Engineering, and I am very supportive of your service as the Director of Graduate Studies for this program.

ECE Faculty that are likely to attract MSE graduate students, in addition to our groups, include April Brown, Steve Cummer, Aaron Franklin, Jeff Glass, Maiken Mikkelsen, and Willie Padilla. In addition to strengthening materials related research on campus, this graduate program will provide a new mechanism to expand course offerings in areas of interest to multiple departments, such as a renewed course in Solid State Physics.

ECE is pleased to offer three core courses and 11 courses from which MSE students can select electives. Most of these courses are currently offered on a regular basis and can accommodate up to 20 additional students from the MSE program. One notable exception is ECE 721 - Nanotechnology Materials Lab, which is offered by SMIF, and regularly has a waitlist of students that cannot be accommodated in the course. The planned support of an additional course section sponsored by the MSE graduate program should help alleviate this problem.

Thank you for your leadership in bringing this graduate program to fruition, and I look forward to working with you.

Best Regards,

David Smith
James B. Duke Professor of Electrical and Computer Engineering
Chair of Department of Electrical and Computer Engineering

Duke
UNIVERSITY

Stephen L. Craig
William T. Miller Professor and Chair
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August 3, 2016

Adrienne Stiff-Roberts
iMSEI Education Director
Department of Electrical and Computer Engineering
Duke University
Durham, NC 27708

Dear Adrienne:

On behalf of the Department of Chemistry, I am writing in support of your proposal for a new graduate program in Materials Science. The advantages to Chemistry include:

1. A mechanism to broaden our student recruitment base. Several of our faculty (Beratan, Charbonneau, Craig, Liu, Therien, Wiley, Yang) have research programs that would benefit from materials science Ph.D. students who might not apply to a Chemistry Ph.D. program.

2. Expanding and formalizing course offerings in materials.

3. Strengthening co-curricular ties with Pratt in an area where we have many collaborations but little educational coordination. For example, we are not large enough to independently staff a master's program, but will be able to participate in the M.S. associated with Materials Science graduate program.

We are especially pleased to partner on the offering of a statistical mechanics course that will serve students across campus who have material related interests.

The level of collaboration and communication across schools during the development of this proposal has been inspiring, and I am excited to see the program get started. Best of luck with your proposal; I look forward to working with you as the program launches!

Warmest regards,

Stephen L. Craig

Duke | DEPARTMENT OF Physics

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October 6, 2016

Adrienne Stiff-Roberts
iMSEI Education Director
Associate Professor
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Duke University
Durham, NC 27708

Dear Adrienne:

I enjoyed meeting with you, David Mitzi, and Josh Socolar to discuss the proposed graduate program in materials science and engineering. I think this effort presents an opportunity to better engage both Trinity and Pratt to coordinate course offerings of interest to multiple departments, such as Statistical Mechanics and Quantum Mechanics. In addition, several Physics faculty members are likely to attract graduate students with interest in materials science and engineering, including Harold Baranger, Bob Behringer, Albert Chang, Gleb Finkelstein, Sara Haravifard, Stephen Teitsworth, and myself. Therefore, I am writing in support of your proposal for a new graduate program in Materials Science and Engineering.

We are pleased to contribute to the development and instruction of one of the core courses, Materials Synthesis and Processing, which constitutes a new offering. We also look forward to having graduate students in this program select PHY 509 – Quantum Nanophysics as a possible elective course. This course is offered on a regular basis and can accommodate up to 20 additional students from the proposed program.

I also considered the proposed phased implementation of the Ph.D. program, and I think that the option for limited numbers of Ph.D. students to select the materials science and engineering curriculum will have no negative impact on our department, given that students continue to meet teaching assistant requirements.

I look forward to working with you to ensure that this program is a success.

Best Regards,

Warren S. Warren
Professor and Chair, Department of Physics

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August 31, 2016

Adrienne Stiff-Roberts
iMSEI Education Director
Associate Professor
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Durham, NC 27708

Dear Adrienne:

As a participant in the materials science and engineering initiative for the past two years, I am very supportive of the efforts to establish a new graduate program in this area. I also support the phased implementation of the Ph.D. program, and I think that the Phase 1 model can be very successful. Increasing the prominence of Duke in materials by offering M.S. and Ph.D. degrees in materials science and engineering will benefit both Pratt and Trinity, and I am pleased that the Department of Biomedical Engineering can contribute to this endeavor.

Several BME Faculty will help attract new MSE graduate students to Duke, including Ravi Bellamkonda, Nenad Bursac, Joel Collier, Brenton Hoffman, Jennifer West, and myself. In addition, the 11 elective courses offered by BME will help highlight biomaterials as an important area of research and education on campus. These elective courses are generally offered on a regular basis and can accommodate up to 20 additional students from the MSE program.

I am confident that BME will also benefit from a larger footprint in the materials space, and I look forward to working with you on this graduate program.

Best Regards,

A. Chilkoti

Ashutosh Chilkoti, PhD
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February 3, 2017

Adrienne Stiff-Roberts
iMSEI Education Director
Associate Professor
Department of Electrical and Computer Engineering
Duke University
Durham, NC 27708

Dear Adrienne:

I am writing in support of a new graduate program in Materials Science and Engineering. In the big picture view, this program will provide a mechanism to broaden sustainable materials research across campus. By introducing more graduate students, and their faculty advisors, to the sustainability aspects of prospective new materials, the Department of Civil and Environmental Engineering can help Duke better take advantage of emerging funding opportunities in this space. It

CEE Faculty that are likely to attract MSE graduate students include Wilkins Aquino, Fred Boadu, John Dolbow, Tomasz Hueckel, Helen Hsu-Kim, Lee Ferguson, Mark Borsuk, and myself. Through the NSF-sponsored CEINT, CEE already has established ties with Chemistry, Biology, and the Nicholas School of the Environment. This graduate program will help increase emphasis on sustainable materials by recruitment of new graduate students and a coordinated effort to expand course offerings in partnership with participating departments. It is our hope that faculty in our department will participate in a program where students are attracted to the study of Materials Science and are admitted directly to that program. However, this program will also likely be an asset to students that we admit and advise for doctoral work in CEE.

We are pleased to offer four courses from which MSE students can select electives: CEE 520 – Finite Element Method, CEE 623 – Mechanics of Composite Materials, CEE 563/ENVIRON 540 – Chemical Fate of Organic Compounds, and CEE 564 – Physical and Chemical Processes in Environmental Engineering. These courses are currently offered on a regular basis and can accommodate up to 20 additional students from the MSE program.

I have participated on the committee initiating this materials science and engineering effort for the past year, and I am very pleased that our work has reached this important milestone. Good luck.

Best Regards,

MR Wiesner

Mark Wiesner
James B. Duke Professor of Civil and Environmental Engineering
W. H. Gardner, Jr. Department Chair of Civil and Environmental Engineering

Duke UNIVERSITY | DEPARTMENT OF MATHEMATICS
TRINITY COLLEGE *of* ARTS & SCIENCES

October 2016

Adrienne Stiff-Roberts
iMSEI Education Director
Associate Professor
Department of Electrical and Computer Engineering
Duke University
Durham, NC 27708

Dear Adrienne:

Thank you for presenting the plans for a new graduate program in materials science and engineering that spans Trinity and Pratt. I think that this graduate program will help grow research ties between Math and departments within Pratt as well as strengthen materials research at Duke which is of interest to the applied mathematics group in math. Furthermore, the proposed graduate program also will enable coordination in expanding mathematical science course offerings which include math content. Initial faculty that are likely to attract MSE graduate students includes Jianfeng Lu and possible Tom Witelski. The emphasis on materials science aligns with existing plans within the Department of Mathematics to hire in the area of computational materials science. Therefore, I am writing in support of your proposal for a new graduate program in Materials Science and Engineering.

We are pleased to offer four courses from which MSE students can select electives: MATH 551 - Applied Partial Differential Equation & Complex Variables, MATH 561 - Numerical Linear Algebra, MATH 563 - Applied Computational Analysis, MATH 661 and 663 - Numerical PDEs, and MATH 577 - Mathematical Modeling. In addition, we will cross-list the core course, ME 555 - Computational Materials Science, in order to teach this course occasionally, when needed. The elective courses are offered on a regular basis and can accommodate additional students from the MSE program. I have also considered your phased implementation of the Ph.D. program. I think that the Phase 1 model has no real impact on our department, as long as students still meet their teaching assistant obligations, and the gradual approach of the proposal will allow for required tweaks while heading toward the Phase 2 plan. I am happy to work with you to ensure that this program is a success. I am confident that we will be able to find a model which is finically sustainable. Programs such as this are important to Dukes future. We need to find a way to ensure there are no impediments to such cross department and cross school programs. They are particularly

important to the mathematical sciences.

Sincerely,

Jonathan C. Mattingly
Professor of Mathematics and Statistical Science
Chair of Mathematics Department
Duke University

Duke University
Department of Biology

Box 90338
Durham, NC 27708
USA

6 October 2016

Adrienne Stiff-Roberts
iMSEI Education Director
Associate Professor
Department of Electrical and Computer Engineering
Duke University
Durham, NC 27708

Dear Adrienne:

Thank you for meeting with me and with the Biology Department faculty to discuss the proposed graduate program in materials science and engineering. We are supportive of this effort to create an interdisciplinary graduate program that can help strengthen research and education in biomaterials across campus. Biology faculty that I imagine could potentially participate in the program by attracting graduate students include Sonke Johnsen, Dan Kiehart, Sheila Patek, and Dave Sherwood. We look forward to working with you to build more connections between this program and Biology. Best of luck on your proposal!

Sincerely,

Mohamed Noor
Professor and Department Chair