Science of Advanced Materials PhD Program

I. General Description of Proposed Program, Including its Objectives and Activities.

The Ph.D. program in the Science of Advanced Materials (SAM) will address a growing need in Michigan and across the U.S. for workers with training in advanced materials research. The program will build on successful research programs of faculty from several departments in the College of Science and Technology (CST) to provide students with a strong, interdisciplinary foundation in the science of advanced materials, with training in current techniques for the predictive modeling of new materials, their synthesis and their characterization. Students will develop a specialization in one or more areas through advanced coursework and by conducting original research leading to a doctoral dissertation. A vibrant materials research community located in mid-Michigan, featuring major corporate R&D labs at Dow and Dow-Corning, the Michigan Molecular Institute, and high tech start-up companies in the CMU research park, creates a unique niche at CMU for a doctoral program in this area. Students in the program will benefit from scientific interactions with members of this community. Program graduates are expected to find employment in industry, government laboratories or academia. A majority are expected to work in companies developing new materials for commercial and/or technological applications, including transportation, polymer-based materials and alternative energy industries.

The SAM Ph.D. program will be administered by an interdisciplinary council of 4-6 faculty members from various CST departments. A director, chosen from the council, will be responsible for day-to-day operations. Council by-laws have been approved by the prospective program faculty and the CST Dean. While the initial council includes members of both Physics and Chemistry, the council and indeed the program are expected to broaden, including faculty and students from other CST departments with potential for advanced materials research such as Biology, Geology, Mathematics, and Engineering & Technology.

Student learning objectives of the SAM program can be divided into cognitive, behavioral and affective outcomes as follows.

Cognitive outcomes. At the end of the program, our graduates will be able to:

1. Describe the main classes of materials, their typical commercial uses, and their chemical and physical properties
2. Discuss the key structure-property relationships of the main classes of materials
3. Compare and contrast the principal techniques for the structural and chemical characterization of materials
4. Compare and contrast the principal methods used to model the structural and physical properties of materials
5. Compare and contrast the principal methods of materials synthesis
6. Describe the theoretical basis of the main investigative methods used in the graduate's area of expertise and discuss the considerations that determine which methods are best used for a given research problem
7. Apply the principles of organic and inorganic chemical synthesis to materials design problems

Behavioral outcomes. At the end of the program, each graduate will be able to:

1. Critically read the research literature in his or her area of expertise and evaluate the quality of research done by others
2. Identify a research problem in his or her area of expertise
3. Formulate a research plan to solve the problem

4. Use the main methodologies in his or her area of expertise to conduct productive, original research
5. Work effectively in a research team
6. Communicate research results clearly and effectively, using reports, scientific papers, or seminar-type presentations, as appropriate

Affective outcomes. At the end of the program, our graduates should exhibit these professional values:

1. Respect for reason and the scientific method
2. Skepticism in the absence of empirical evidence
3. Integrity in presenting data and research results
4. Respect for the peer review process as specified in the American Chemical Society's Chemist's Code of Conduct and the American Physical Society's Guidelines for Professional Conduct.

II. New Courses to be Incorporated in the Proposed New Program

SAM 620 Chemical Principles in the Science of Materials 3(3-0)
SAM 630 Physical Principles in the Science of Materials 3(3-0)
SAM 690 Special Topics in Science of Advanced Materials 1-9(spec)
SAM 700 Advanced Materials I: Inorganic and Nanomaterials 3(3-0)
SAM 710 Advanced Materials II: Polymers, Composites and Biomaterials 3(3-0)
SAM 720 Materials Characterization and Modeling Lab 3(1-6)
SAM 785 Seminar: Current Topics in the Science of Advanced Materials 1-10(spec)
SAM 796 Directed Research in the Science of Advanced Materials 1-48(spec)
SAM 899 Dissertation 1-12(spec)

III. *Bulletin* Copy

Doctor of Philosophy (Ph.D.) in Science of Advanced Materials

Minimum Totals for Graduation: 90 hours

The science of materials combines elements of chemistry, physics and biology, and requires a solid background in mathematics. The CMU Science of Advanced Materials (SAM) Ph.D. program is designed to create a correspondingly interdisciplinary environment that will train effective researchers without erecting artificial boundaries between disciplines. The formal coursework focuses on the scientific framework for studying materials and is organized around the themes of modeling, characterization, and synthesis. These are the key methodologies employed in materials research and the SAM program emphasizes the synergy among them.

The curriculum for the SAM program includes the following components: core courses that establish a solid foundation in the science of materials; advanced courses in a number of specialized areas; seminar courses focusing on the current SAM literature and developing essential skills in scientific communication; and the dissertation.

Students may enter the program with diverse undergraduate backgrounds. To accommodate varied levels of preparation and establish a basis for interdisciplinary training, foundation courses in the chemistry and physics of materials are required. A course in chemical principles (SAM 620) is aimed at students with a strong undergraduate background in physics, but limited training in chemistry; conversely, a course in physical principles (SAM 630) is directed at students with an undergraduate emphasis in chemistry or biochemistry. Students with undergraduate degrees in areas like mathematics, engineering, geology or

biology may opt to take both courses to insure the proper foundation for more advanced study, while students with a strong background in both physics and chemistry may not need either course. An initial interview with the program director or a faculty advisor will determine placement in these courses.

Students in the SAM program may apply for support as teaching or research assistants. Students will normally work as teaching assistants during their first two years and as research assistants during the final three years of the program.

Admission Requirements, Retention and Termination Standards

Students with a bachelor's degree in physics, chemistry, biochemistry, biology, geology, engineering, mathematics or other relevant areas of science will be considered for admission. Applicants must be admitted to the CMU College of Graduate Studies and the SAM program. Transcripts of previous undergraduate and graduate studies, GRE scores, a statement of research interests and letters of recommendation will be used in evaluating candidates for admission.

Applicants already holding an M.S. degree in a materials-related area may also apply for entry into the program. They must submit a GRE subject test in chemistry or physics, in addition to the materials required for all candidates. Relevant graduate coursework taken previously may be counted toward meeting some of the program requirements. A completed M.S. thesis on a materials-related topic will be counted toward the directed research credits required on the SAM Ph.D. Students who have completed the M.S. in physics or chemistry will also be exempted from the qualifying exam.

At the end of the first year all students will complete a qualifying examination covering the material contained in the core courses. Students passing this exam will be granted candidacy status and will continue toward the Ph.D. degree. Those who do not pass will have a second opportunity to take the exam early in the second year. Those who fail a second time will be terminated from the program and encouraged to complete the requirements for an appropriate M.S. degree. These programs generally include some additional courses not required in the SAM program. Most students will be able to complete such courses and the M.S. research thesis requirement in one additional year.

During the second year, Ph.D. students will take a series of cumulative examinations to demonstrate competence in their area of specialization. These exams will be based on coursework, the current scientific literature in the area, and other appropriate material. Students passing these exams will attain dissertator status. Those who fail a portion of the cumulative exams will have a second opportunity to pass that portion. Students who fail a second time will be terminated from the program and encouraged to complete the requirements for an appropriate M.S. degree.

Students normally will be expected to begin directed research work no later than during the first summer of residence. Students will identify a research advisor as early as possible, and form a dissertation committee consisting of at least four members. The committee chair (research director) and two other members will come from the program faculty. One of these will have research expertise outside the student's immediate area of specialization. At least one additional committee member will come from an institution external to CMU, including industrial labs, as appropriate.

During the third year, students will prepare an original research proposal, present it as a seminar to program faculty and students and defend it before the dissertation committee. Students will carry out the bulk of their doctoral research in years 3-5 of the program. The final requirements will be the preparation and oral defense of a scholarly dissertation that presents the results of the student's dissertation research. The oral defense and the dissertation must be approved by the dissertation committee and by the College of Graduate Studies. A student's progress through the program will be monitored by an annual review of his or her overall performance by the program director or dissertation committee.

Degree Requirements

A. Required Courses I - Science Core (3 hours)
Select one course from the following, after consultation with the program advisor:
SAM 620 Chemical Principles in the Science of Materials 3(3-0)
SAM 630 Physical Principles in the Science of Materials 3(3-0)

B. Required Courses II – Materials Core (9 hours)
SAM 700 Advanced Materials I: Inorganic and Nanomaterials 3(3-0)
SAM 710 Advanced Materials II: Polymers, Composites and Biomaterials 3(3-0)
SAM 720 Materials Characterization and Modeling Lab 3(1-6)

C. Required Courses III – Specialization (12 hours)
The student must enroll in 12 credit hours of graduate courses in one specialized area of materials such as computational materials modeling, polymeric materials, materials characterization, selected in consultation with and approved by the program advisor.

D. Required Courses IV – Current Topics Seminar (6-10 hours)
SAM 785 Seminar: Current Topics in the Science of Advanced Materials 1-10(spec)
The student may enroll multiple times until 6 to 10 credits are earned.

E. Elective Courses (0-12 hours)
The student may enroll in up to 12 credit hours of elective graduate courses selected in consultation with and approved by the program advisor.

F. Research (32-48 hours)
SAM 796 Directed Research in the Science of Advanced Materials 1-48(spec)

G. Dissertation (12 hours)
SAM 899 Dissertation 1-12(spec)

Total: 90 semester hours

IV. Rationale for New Program

A. The Program Supports the Mission and Goals of the Institution

The SAM program will support CMU's central mission to provide the educational foundation for economic growth and social well being in Michigan. The program's commitment to close interaction between students and faculty reflects several of CMU's core values, including student-focused learning, graduate education and the scholarship of discovery and creativity.

Creating the SAM Ph.D. supports CMU's institutional priorities to (1) create an environment that supports teaching and learning as a priority and (3) to enhance the infrastructure for research and creative activities. The SAM program also reflects institutional goals 3 (creating grad programs in niche areas of strength), 7 (use modern technology to promote teaching, learning and research) and 12 (attract external resources). As discussed further below, CMU has the faculty strength and research infrastructure to offer a high quality PhD program with the potential to achieve national prominence.

The SAM Ph.D. program will increase the amount and quality of on-campus research in the sciences. This will have a positive impact on the undergraduate and graduate (M.S.) programs in several CST departments, as it will provide excellent opportunities for student research projects. The SAM program will also contribute to the general intellectual climate of the college and help to promote the culture of scholarship and discovery at CMU.

B. There is a Need (Market and/or Disciplinary) for the Program

The production and sale of synthetic materials are crucial components of the nation's economy. Semiconductors and related electronic materials and plastics and related polymeric materials, for example, represent industries with an economic impact of several hundred billion dollars per year. Recent developments in the physics and chemistry of materials have led to increased atomic-level control over the synthesis and growth of advanced materials designed to meet the specific needs of various technological applications. As a result, advanced materials are being created for applications as diverse as molecular-scale drug delivery and man-made photosynthesis. Michigan is a perennial leader in industrial R&D spending on materials, because of its auto, chemical and pharmaceutical companies. According to the 2007 National Science Foundation (NSF) Science and Engineering State Profiles, Michigan ranked second among all the 50 states in both total industrial R&D spending and per capita R&D spending. An active CMU PhD program in the Science of Advanced Materials will serve these Michigan industries by contributing to both the intellectual capital and the human resources needed to develop profitable advanced materials. Thus, the SAM Ph.D. program can be seen as a clear opportunity for CMU to deliver in its educational mission to the State of Michigan.

Trends in federal research funding reflect the promise and importance of advanced materials. For example, the Division of Materials Research has the largest budget of the six divisions within the Directorate for Mathematical and Physical Sciences (MPS) at the National Science Foundation (NSF), and the requested increase in funding for materials research for FY2008 is larger than that for any other division.

The defense agencies and the Department of Energy are also major supporters of materials research. CMU has been the recipient of major funding from the Army Research Office (ARO), receiving a total of $5.4 million since 2002. This funding supported the creation of a national center of research excellence for dendrimers in Mt. Pleasant. Dendrimers are a type of molecular-scale advanced material. Of the total ARO award, approximately $1.9 million went to directly support CMU faculty research projects and to enhance the research infrastructure at the university. The SAM Ph.D. program will play an important supporting role in the future development of the center by providing graduate student research assistants and the scientific expertise of the faculty.

Funding from the federal government for research in advanced materials may be poised for a significant increase in the near future. In *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, the Committee on Prospering in the Global Economy of the 21st Century and the Committee on Science, Engineering and Public Policy of the National Academies of Science recommend more than doubling the federal funding for basic research in fields such as the physical sciences that are related to developing new technologies. Funding should particularly target projects that cut across disciplinary boundaries (p. 137, National Academies Press, 2007). These committees, which include members from industry, academics and public policy organizations, also recommend that the federal government fund 5000 new graduate fellowships for U.S. students each year in areas of national need (p. 168-170). This publication and the studies on which it is based emphasize the need to galvanize the American educational system to better prepare students for a changing employment outlook.

Sources are careful to distinguish between job demand in conventional areas of materials science and demand in advanced materials areas. In a summary presentation of a recent conference on the materials science workforce, sponsored by the National Materials Advisory Board (a unit of the National Academies of Science), Sylvia Johnson of the NASA Ames Research Center, reviewed the findings of

several of the conference speakers. In her presentation, she described a sharp decrease in demand in conventional areas like metallurgy and ceramics, but pointed to areas such as nanomaterials and fuel cell technology as creating a strong demand for Ph.D. level scientists working on advanced materials. The final report from this workshop, *Materials and Society: From Research to Manufacturing – Report of a Workshop*, emphasized "the increasingly interdisciplinary nature of materials science" and the "shortage of talented, well-trained scientists" entering the workforce (p. 3, National Academies Press, 2003). A 2004 article in Science Careers, from the online site for the journal *Science*, reiterated this emphasis on the growing fields in biomaterials and nanotechnology but noted that, because of the inherent interdisciplinary nature of the fields, materials scientists are not tracked specifically, so that specific labor figures are hard to produce (Austin, Jim. "Materials Science: Doing the Numbers", available at http://sciencecareers.sciencemag.org/career_development/previous_issues/articles/3360/materials_science_doing_the_numbers). Yet overall, the workforce demand for Ph.D.-level scientists in the area of advanced materials for the coming decade appears solid.

The proposed SAM Ph.D. is distinct from other materials-related Ph.D. programs in Michigan. The interdisciplinary nature of the program and its focus on fundamental science distinguishes it from other programs in the state and responds to the calls of experts and funding agencies to move away from conventional disciplinary approaches. Traditional programs, like those at the University of Michigan, Michigan State, Wayne State and the Michigan Technological Institute, are all housed in engineering colleges, in Materials Science and Engineering departments, and are organized by material type, with students becoming experts in ceramics, polymers, semiconductors, etc. This type of specialization promotes engineering goals such as formulation and fabrication, and focuses on materials applications and technology. Our vision, by contrast, is to focus on the fundamental science of advanced materials, which we believe is still the seat of greatest activity and promise in the field. The SAM program's organization along methodological lines, into the areas of modeling, synthesis and characterization is unique. These are the key scientific methodologies involved in research on advanced materials, and can be used to address fundamental issues of structure and functionality regardless the material type. We intend for our students to have a solid base in all three areas, while specializing in one.

Structuring the CMU SAM Ph.D. as an interdisciplinary program further sets it apart from other Michigan materials programs. The interdisciplinary format recognizes that understanding materials on a fundamental level requires combining elements of chemistry, physics and biology. It also encourages collaborative research efforts among faculty to develop a richer, more flexible approach to materials problems. We expect this interdisciplinary character to be a major advantage of our program. We also believe that the interdisciplinary CMU SAM Ph.D., with its unique organization along methodological lines, will compete successfully for external program support.

C. Evidence of the Potential for a High-Quality Program

The SAM program will produce highly-trained scientists capable of carrying out quality original research. Admission criteria will be selective, and emphasize not only previous academic success, but also evidence of student creativity and commitment to research. Students must pass two sets of comprehensive exams to complete the program. They will conduct research in their chosen specialty area that will culminate in a doctoral dissertation, defended in a public forum. The dissertation committee will have an interdisciplinary make-up and include at least one member from an institution external to CMU. In most cases students will submit one or more papers describing their research for publication in appropriate scientific journals.

The program curriculum features approximately 30 credit hours of classroom instruction and 60 hours of directed research and dissertation credit. This breakdown reflects the research emphasis of the program and is typical for Ph.D. programs in the physical sciences. The curriculum has been favorably reviewed by several experts from outside CMU, including faculty in established Ph.D. programs, and scientists from government laboratories, research institutions and materials-based industries, including those in mid-Michigan.

Program quality will be assessed primarily through the scholarly productivity of its faculty and students, and by the success of its graduates in the job market (see section E).

D. Evidence of Student Interest and the Potential to Attract Quality Students

CMU has an established track record of attracting quality domestic and international graduate students into the MS programs in PHY and CHM. Since 2000, approximately 50 M.S. degrees have been awarded to students who conducted thesis work in materials-related areas. About half of those students went on to Ph.D. programs at other institutions.

The interdisciplinary structure and the unique organization along methodological lines are competitive advantages of the SAM Ph.D. program that are expected to attract good students to the program. These attributes will appeal especially to students interested in working in industry, where the ability to work in interdisciplinary teams is highly valued.

Another advantage is the presence of a vibrant materials-research community in the Mid-Michigan region. The world's largest materials-based company, Dow Chemical, has major research facilities in Midland, as does Dow Corning, a company focused on silicon-based materials; Helmlock Semiconductors, located just west of Saginaw, is a Dow-Corning subsidiary that develops electronic materials; two high-tech start-ups in CMU's own research park, Dendritic NanoTechnologies (DNT), and Artificial Cell Technologies (ACT), are developing applications for novel nanoscale materials; and the Midland Molecular Institute (MMI), based in Midland, is a private materials research institution that investigates and develops new materials for applications. The proximity of these organizations to CMU brings many opportunities to the program, from interactions with industrial scientists in seminars or local scientific meetings, to working with them on joint research projects, to potential job opportunities for program students after they graduate. CMU faculty have an established track record of collaborating with industrial scientists from the region. These collaborations are expected to expand as the Ph.D. program brings more research manpower to CMU.

These organizations also represent a source of potential students for the program, as they employ a sizable number of B.S. and M.S.-level scientists. In addition to more traditional beginning graduate students, the SAM program will create opportunities for experienced industry employees seeking to further their scientific education by enrolling in a Ph.D. program.

Finally, CMU's modern and well-equipped research facilities and our strong tradition of commitment to teaching and personal mentoring of students are also selling points to prospective students.

E. A Plan for the Ongoing Assessment of Student Learning and the Evaluation of the Need for and Feasibility of the Program

A detailed assessment plan for the SAM Ph.D. program has been developed with the help of CMU's Assessment Coordinator, Denise Webster. The plan includes procedures for assessing both student learning and overall program quality. Briefly, elements to be used to assess student learning include qualifying and cumulative exams, the dissertation proposal, and the final dissertation defense. Program quality will be assessed using measures including: the number and quality of program applicants; student retention and graduation rates; student and faculty research output, including publications and presentations at major scientific meetings; the placement of students in jobs after graduation; and faculty success in securing outside funding. An external review board, including scientists and R&D managers from industry and academics from other institutions, will be created to aid in program assessment.

F. Evidence that the Faculty Can Provide a Quality Doctoral Experience for Students

CMU has the right faculty and research infrastructure to deliver a high-quality Ph.D. in the science of advanced materials. The following faculty members have contributed to the planning for the new program:

CHM:	Tecklenburg, Howell, Fahlman, Chai, Jensen, Mueller
PHY:	Petkov, Fornari, Horoi, Hirschi, Jackson
MTH:	Rakesh

In addition, Juan Peralta and Veronica Barone, new faculty in PHY, and George Kaminski and Dillip Mohanty, faculty in CHM, have research interests that strongly overlap the advanced materials area. While these individuals have not contributed significantly to planning the SAM program, they may participate actively in the future. Their productivity data is **not** included in the paragraphs below.

The SAM faculty group maintains strong research programs in the areas of materials modeling, synthesis and characterization. In the five year period from 2001-2006, this group published nearly 130 research papers in peer-reviewed journals and made more than 100 presentations at national or international scientific conferences. The papers were published in some of the best international journals in the field, including the Journal of the American Chemical Society, Chemistry of Materials, Journal of Chemical Physics, Physical Review Letters, Physical Review, Tetrahedron Letters, and Journal of Nanotechnology and Nanoscience.

This group also includes campus leaders in providing both undergraduate and M.S. students with quality research experiences. In the 2001-06 period mentioned above, this group supervised students in 33 M.S. thesis projects and 35 undergraduate research projects. Most of these students participated in local forums to present their research (SRCEE and regional conferences in Michigan) but, in addition, graduate students gave 33 presentations and undergraduate students 24 presentations at national or international conferences. And much of this work was published in peer-reviewed journals. Graduate students were co-authors of 35 peer-reviewed publications and undergraduate students were co-authors of 24 publications.

As a group, the prospective SAM faculty has an established funding track record. Recent external grants have come from NSF, DOE, NIH, the Army Research Office, the Petroleum Research Fund, Research Corporation, and industry sources. In the 2005-06 and 2006-07 academic years, this group accounted for $297,000 and $574,000 in external grants, respectively. These grants returned a total of $201,000 to CMU in indirect costs over the two years. This record of success is particularly significant given the strong competition for these research dollars. At NSF, for example, only one proposal in every three submitted to the Division of Materials Research is funded. In addition to external grants, this group was awarded $104,896 in PRIF grants and $58,545 in REF grants over this same time period.

Additional new faculty hiring will strengthen the program in several ways. Hiring new faculty with active research programs will impact the level of grant funding awarded, build scientific infrastructure on campus, fund graduate research assistantships and post-doctoral positions and return a significant amount of indirect costs to the university. In programmatic terms, new faculty will strengthen or complement existing teaching and research, and especially target areas that bridge existing research strengths or add expertise in key areas of advanced materials such as biomaterials. This will promote collaborative research efforts and enhance the interdisciplinary character of the program. The dual strategy of focused hiring and promoting faculty teamwork will lead to a nationally recognized area of research strength in SAM that will attract students and industrial partners to CMU.

V. Resource Implications

A. Financial resources required to support the program

The most critical need of the program is for graduate assistantships for the Ph.D. students. Essentially all Ph.D. students in the physical sciences in U.S. graduate programs are supported by GA's. The SAM Ph.D. program therefore cannot expect to attract students without

offering GA support. The long-term plan for the SAM program calls for students to be supported on teaching assistantships during their first two years in the program and on grant-funded research assistantships during the remaining three years. A need for 12 billeted TA positions is anticipated once the program is fully operational, corresponding to a total of approximately 30 students in the program. In the short term, 12 CMU-funded GA positions phased in over two years are needed to start the program. Typical GA stipends at competing programs are approximately $21,000 for the calendar year.

A second need is for a program manager. The program is expected to grow over time to include a total of approximately 30 Ph.D. students and to actively involve about 15 faculty members. The program manager will coordinate recruitment activities, handle budgeting and accounting duties, and supervise clerical tasks for the program.

The program can be started with existing faculty. The additional teaching load represented by SAM program coursework will be small, since much of the curriculum is made up either of directed research or courses already offered in the PHY and CHM M.S. programs. In the short term, the additional load can be met by hiring temporary faculty on an ad hoc basis to teach courses in Physics and Chemistry to release SAM faculty for program coursework. Within the first five years, however, additional faculty lines will be needed to secure the long term sustainability of this program. First, to mount a successful program, base teaching loads for program faculty must be reduced to levels comparable to those in departments with competing programs. This is approximately 3 courses per academic year, or half the typical load for a faculty member at CMU. Second, there is a programmatic need for new faculty lines in growth areas such as biomaterials, and in areas such as polymer physics, where a strategic hire would knit together existing CMU research groups and bring added synergy to the program. One new line, that of a biomaterials faculty, has been approved by the Provost for Fall 2008. Adding four additional new faculty lines in a phased way over the first five years will insure needed course reductions for program faculty and will add significant research strength to the program. These new lines will be requested on an on-going basis through normal channels.

Starting the program will require no new resources beyond current budgets, but it would require converting budgets for existing provisional programs into base budgets. A 2010 project, the Advanced Materials Research (AMR) Initiative, currently provides support for seven GA lines for materials research, a half-time program manager position, and sufficient teaching support to cover the additional load of the SAM coursework. (Note that the AMR proposal was written by and involves the same core group of faculty members responsible for the SAM program request.) The 2010 funding continues through January of 2010. In addition, the PHY and CHM departments currently have a total of six GA lines that are supported by the Provost's GA Enhancement Funds. This program is nominally set to expire in Fall 2008. Continuing the 2010 and GA Enhancement projects into the future as base budgeted items (at somewhat increased stipend levels) will provide the needed support to start the SAM Ph.D. program.

The SAM Ph.D. program is expected to generate considerable grant funding. As mentioned above, the long-term plan is for external grants to provide the resources for GA positions for students beyond their second year in the program. In addition, funds for research equipment, research related travel, and additional research personnel (i.e. post-docs) will also be sought through external grants. These external grants will return significant amounts of indirect funds to CMU. As noted in section IV.F above, SAM faculty members have been very successful in attracting external research support. In the past two years their grants have returned over $200,000 in indirects to the university. Such indirect returns will serve to offset the net cost of the program to the university.

When considering the cost-effectiveness of creating a program in advanced materials at CMU, a key point to note is the fact that the research infrastructure is already in place to mount a successful program. SAM faculty members have successfully attracted external grant funds to purchase research equipment and instrumentation to support their work. Recent additions include

a Beowulf-style computing cluster in PHY, valued at approximately $250,000, and a 500 MHz NMR device for analyzing the structure of polymeric materials, valued at approximately $750,000. No additional funds for research equipment are needed to start the program.

A detailed discussion of budget issues related to the SAM Ph.D. is given in the proposal approved earlier (Feb. 2006) by the Academic Planning Council.

B. Additional Resources to Adequately Support the Doctoral Program

The SAM Ph.D. program will make full use of existing research and teaching facilities at CMU. The Dow Science building (opened in 1992) is equipped with modern classroom, office, and lab space to support the program. Computer labs to support student computing needs are available in both the physics and chemistry departments, and several high capacity computers are available for research. As mentioned above, the scientific instrumentation needed to start the program is already in place and being used by program faculty. Funds to purchase additional equipment will be sought through external grants as needed.

The CHM and PHY departments employ a number of staff members who provide support for faculty research. In CHM, three full-time stockroom supervisors manage the inventory of chemicals and supplies for teaching and research labs; a full-time electronics technician (shared with PHY) maintains equipment and instrumentation used for teaching and research; this individual also designs and builds equipment for specialized applications as needed; a part time glass blower creates and repairs scientific glassware; and a full-time instrumentation analyst oversees the operation of the NMR lab and the mass spectrometers. In PHY, a full-time machinist runs a fully equipped machine shop, building and maintaining laboratory equipment as needed.

Current Park Library holdings and subscriptions in the materials area are sufficient to get the program started. The library recently added the Sci-Finder and Inspec research databases that support materials research. Additional library resources will be needed in the longer term, for example, to add to our collections in growth areas such as biomaterials. These resources will be requested on an on-going basis through normal channels.

Sufficient classroom, office and lab space is available to start the program. Finding space for additional graduate students will present some challenges, but by sharing offices and utilizing desk space in research labs for advanced students, it is expected that the Physics and Chemistry departments can accommodate the new students to be enrolled the program. As discussed above, the phased creation of up to five new faculty lines will be needed by the program in the future. It is anticipated that existing office and lab space in the Dow Science Building can accommodate these new lines.

Finally, the program is likely to require modest increases in the Supplies and Equipment budgets of the PHY and CHM departments to support program-related activities. These increases will be requested through normal channels as needed.