Polymer Science and Engineering Department

Executive Summary

- PSE is one of the world's top academic center in the field of polymers, and is typically rated among the top ten U.S. materials departments
- External funding of a PSE faculty member has averaged nearly $800,000 per year, placing PSE in the top echelon of funding among all science/engineering departments in the U.S.
- PSE has retained all its faculty members since 2005 but has not conducted a faculty search since 2007. Two new junior faculty hires are a critical need
- Current campus arrangements for crucial core instrumental facilities, particularly their staffing, are breaking down

Departmental Overview:

The Polymer Science and Engineering Department (PSE) at UMass is one of the world's top academic centers in the field of polymers. Bridging chemistry, physics, engineering, and other disciplines, PSE has adopted much of the character of a materials department in recent years, and indeed, many of its competitors are departments of this focus. PSE enrolls about 120 Ph.D. students from a variety of academic backgrounds. Substantial numbers of undergraduate (25) and graduate students (20) from other UMass departments conduct research in the groups of the 18 PSE faculty members, and the number of post-doctoral research associates in PSE is fairly large (about 25). Research topics are roughly split between polymer chemistry (making new polymers and polymer materials), polymer physics (understanding and measuring the properties of polymers and polymeric materials), and polymer engineering (exploring ways to combine and process polymers so as to improve their properties); the latter is slightly smaller than the first two. The curriculum is designed to provide synergistic foundations in all three sub-disciplines. Important to PSE research are shared research facilities that house expensive, multi-user instruments. PSE technical staff members supervise nine of these facilities operated as cost centers. The overall value of PSE laboratory equipment exceeds $30 million.

Vision for Research and the Faculty/Achieving this Vision:

PSE continually strives for the top position in the academic polymer world. Our research and educational efforts set international standards. While dedicated polymer departments are few in the U.S., they are common in Europe and Asia. In the U.S., the most significant competition is from materials, chemistry, and chemical engineering departments. PSE is typically rated among the top ten U.S. materials departments, a necessary placement for PSE to flourish in teaching and research relative to programs at larger, better known institutions. In intellectual focus, our primary goal is to lead in the fundamental science associated with the chemistry, physics, and materials aspects of polymers. The existing balance between these aspects must be sustained, as the three sub-disciplines feed off each other, and with weakness in one, the other two suffer. At the same time, specific emerging

application areas are seen as attractive complements to this science, for example, nanomanufacturing, drug delivery, sustainable materials, and biomedical devices, each a 'hot' polymer topic for at least another decade. Polymers in biological and medical realms are broader themes that will grow in national importance, and to maintain leadership in the polymer field as a whole, the relevant PSE efforts must grow alongside. Nevertheless, the overall focus must remain on fundamental science as opposed to technology/applications, which aren't sustained absent a strong base in fundamentals. For polymers, the distance between fundamental and applied is anyway small, and all PSE faculty members work both sides.

The chief U.S. competitors for PSE are efforts at UC Santa Barbara, principally in the Materials Department, and at the University of Minnesota, in the Chemical Engineering and Materials Science Department. The new University of Chicago Institute for Molecular Engineering is quickly becoming an equal competitor. In polymer subareas, competition is found at Caltech, Berkeley, Georgia Tech, Univ. of Florida, Univ. of Illinois Champaign-Urbana, and MIT. It is noted that none of these institutions have polymer degree programs and none offers a polymer curriculum to match that of PSE. These institutions are principally competitors in research, and necessarily, in research funding and recruiting top Ph.D. applicants.

Being a central player in the field of polymers, PSE's worldwide impact is large. PSE faculty members have won essentially all major polymer research awards, and the 800+ Ph.D. alumni group is the largest of any U.S. polymer program. PSE authors publish more polymer journal articles and give more polymer talks than authors from any other institution in the world. Over the last decade, the external funding of a PSE faculty member has averaged nearly $800,000 per year, placing PSE in the top echelon of funding among all science/engineering departments in the U.S. PSE must surpass these output statistics over the next decade, as comparable statistics for competitors are catching up rapidly.

Approximately 85% of PSE alumni are employed in industry, and their job prospects are better than ever despite a recent shift toward smaller employers. They heavily populate the faculties of competitor academic programs, but alumni also work in chemistry, materials, chemical engineering and physics departments at many major U.S. research universities. Industrial employers include Global 500 chemical and materials companies as well as smaller domestic companies and start-up ventures. About 35-40 companies sponsor polymer research projects at UMass through the Center for UMass-Industry Research in Polymers (CUMIRP), the oldest federal government-initiated industry-academic partnership in the U.S. Other tech transfer activities include an increasing number of invention disclosures from PSE faculty members, and start-ups companies sprung from in-house research discoveries. All aspects of industrial collaboration and support must expand to help buffer the increasing fluctuations of federal funding; CUMIRP remains the appropriate portal for these efforts. CUMIRP funding has increased by about 30% in the past two years, and a similar increase is needed (and achievable) over the next two years. To meet this goal, however, the University must streamline barriers in its intellectual property and grant processing policies.

The physical infrastructure for polymer research at UMass is sufficient, and with reasonable accommodation by current programs, two additional faculty members

can be housed in existing PSE space that requires minimal renovation. Part of the accommodation involves a planned shift of significant translational activities to LSL2. No difficult organizational or space-related obstacles should impede PSE from achieving its immediate goal of two successful faculty hires.

The preceding discussion focused on rosier aspects of the efforts needed to reach PSE's vision. Significant obstacles must be overcome to not just maintain, but also to grow, PSE's academic standing in polymers. First and foremost, there must shortly be in-place a plan for faculty rejuvenation, one that is implemented over a short timeframe. PSE has retained all its faculty members since 2005 but has not conducted a faculty search since 2007; in the next few months, the last junior faculty member will be promoted. There is no cadre of emerging junior faculty members to replace those who are beginning to contemplate retirement. As a consequence, the PSE faculty is not becoming more diverse, and the faculty is less able to compete successfully for large federal grants. The performances of PSE faculty hires have always been excellent, with the campus investments in them amply rewarded. For example, every PSE junior hire has won a National Science Foundation CAREER award, and three have won the more distinguished presidential PECASE award. However, to support their efforts, a campus strategic plan for establishing, staffing, and operating major, multi-user facilities important to polymers and other disciplines must be developed. PSE does not have the resources to match the core instrument facilities efforts organized at competitor campuses at the institutional level. At least half of the users of PSE facilities come from other campus units, and PSE's facilities are vital to the research mission of the campus.

To address the faculty hiring issues, PSE proposes immediate efforts to add two new faculty members, one with expertise in the more fundamental aspects of polymer physics and one with expertise in fluid mechanics/engineering. Because of the major gender inequity of the current faculty (17 men, 1 woman), it is anticipated that one, or both, hires will be female. In addition to its impacts on overall climate, this inequity significantly hinders PSE's ability to recruit female graduate students and to obtain federal research funding, since proposal reviewers and program directors often note the inequity. PSE faculty members play major roles in two IALS centers, and PSE anticipates supporting additional IALS faculty hires.

The two hires would be at a junior level. Part of the urgency for such hires traces to federal proposal competitions, which for center grants, consider development of junior faculty members a key component. The next NSF MRSEC competition, for example, is just 18 months away, and re-establishing a MRSEC center is a PSE top priority. As shown over the past 35 years, the presence of a UMass MRSEC does much to enhance the campus' research prestige, and about half of MRSEC research funds flow to campus units other than the home department. Even if a MRSEC were not to be obtained, the positioning of the PSE faculty for the proposal competition will enhance competitiveness for other large federal centers. Such centers are a PSE tradition, and success at center competitions is responsible for much of PSE stature. The portion of funds from federal agencies devoted to center programs will increase over the next decade even as single PI funds diminish, and the multi-

disciplinary, multi-investigator style of center research projects well matches the needs of polymer projects.

Phase-in of new faculty members can be accommodated in existing and allocated space with minimal renovation cost. PSE is able to supply its share of start-up costs, which are modest in light of the existing large base of multi-user equipment.

Turning to core instrumental facilities, the pressing issue is staffing. Several existing facilities, serving more than 50-75 PI groups each year, require constant supervision from technical directors with specialized training. These facilities touch virtually every PSE research project and many others across the campus. A full recovery of facility staffing costs from user fees is unrealistic, as demonstrated conclusively here and elsewhere. Nonetheless, the staffing of facilities does offer the campus a significant return on investment, as many proposed projects, even if requiring limited access, are unfundable if facility access is absent. The current UMass practice of subsidizing core facilities through large, externally funded federal centers is failing as the facilities outlast the funding streams. Without campus action, the campus science and engineering community will see a sharp drop in research funding as technical staff members depart in coming months, making millions of dollars of state-of-the-art equipment go dark. And, of course, recruiting and retention of faculty members will become more difficult, for PSE and more broadly.

A central campus plan for instrument facilities should not be difficult to develop nor costly to implement. PSE suggests the creation of a campus oversight body that coordinates matters such as billing and supervision of business plans. A reasonable cost-sharing system, with staffing costs apportioned among appropriate administrative levels, would suffice. In its vision, PSE imagines the continued operation of all of its existing facilities, and in the longer term, only the occasional need for new, well-vetted facilities. PSE does have a current competitive advantage in its core instrument facilities (the PSE electron microscopy facility, for example, is unmatched in the U.S. polymer community), but the looming staffing issues could change this status almost overnight. Materials-oriented departments are ranked almost as much for their facilities as for their faculty members and students.

Vision for the PSE Doctoral Program/Achieving this Vision

The PSE doctoral program is unique in the nation, if not the world, and peers to the program are hard to identify. In the U.S., major polymer doctoral programs (i.e., stand alone departments with the degree) are rare, and interdisciplinary graduate programs with the degree are maintained at a handful of other universities. None offers as comprehensive a set of polymer courses/experiences as in PSE. In various rankings, particularly the last NRC review, the UMass graduate program was ranked among the top ten of materials programs even as other polymer departments were ranked, in the same category, at 50th or below. These programs rarely 'outcompete' PSE for graduate students. The strongest competition for graduate students comes from the universities mentioned in the previous section

PSE plans to maintain its top polymer ranking while increasing the number and diversity of its graduate students. The PSE Doctoral Program Review projected a 15% increase of doctoral students, commensurate with the burgeoning employment demand and the capacity of UMass polymer facilities, but this increase hasn't begun,

mainly for reasons presented in the last section. The PSE graduate student population is about 55% U.S. and 45% foreign, with the latter percentage slowly increasing. Other graduate polymer programs in the U.S. have higher percentages of foreign students, although their increased percentages may be attributable to their admission of M.S. candidates, a group absent at UMass. PSE plans to keep the U.S. group at 50% or greater. Women comprise about 30-35% of the PSE student group, a number constant for a decade, and underrepresented group members comprise about 10%. Significant activities support the latter group, including several for mentoring, socializing, and professional development. The PSE faculty is highly diverse in underrepresented group members who can serve as effective peer mentors. While higher targets are set for female enrollment, a group that comprises about 40-50% of the field's graduates, our efforts are hindered by a low percentage of women faculty members.

PSE receives about 200-250 doctoral applications each year, accepts 25-30, and typically enrolls 12-18. Recruiting success is thus high, approaching 50% for domestic applications and higher for foreign applications. The number of quality applications is sufficient to achieve the projected increase in student enrollment, with special efforts needed only to recruit more women and underrepresented group members. The standard PSE fellowship, about $25,000 per year, is currently sufficient to attract top-notch U.S. applicants; most U.S. competitors offer slightly larger fellowships, but differences aren't large.

The PSE core curriculum presents sequenced courses in polymer physics, polymer chemistry, and polymer engineering, with unique and highly lauded graduate lab courses incorporated into the first two streams. The curriculum is regularly reviewed and refreshed, and all PSE faculty members rotate teaching through the sequence closest to their own expertise. The curriculum's goal is to train students broadly, so that each student has doctoral level skills across the discipline. This goal means, for example, that chemists learn physics and engineering, while engineers learn chemistry and physics. Breadth is ensured by rigorous qualifying exams that pose a number of questions in each area. The high quality of the PSE core curriculum is widely recognized, and many corporations recruit specifically in PSE because they know they can find individuals with a broader training in polymers than produced elsewhere. Our state-of-the-curriculum is excellent.

PSE students arrive with diverse academic backgrounds in chemistry, physics, biochemistry, mechanical engineering, chemical engineering, and in some cases, polymers. All take a common core curriculum in the first year before beginning the specialized thesis projects to be pursued across later years. No PSE students are appointed as TAs, although the department pays some students to perform TA duties. The biggest financial challenge for the graduate program is first-year fellowship support, which ideally should not be taken from grants since first-year students are not working on grant-funded projects. Nearly all department RTF return goes to this purpose. As part of PSE's on-going 50th anniversary celebration, a major effort to solicit alumni support for first-year fellowships is underway. A long-term goal of the PSE 50 campaign is to endow fellowships for the entire first-year class, a feat recently accomplished by one of PSE's competitors. In the short-

term, to achieve the larger student group envisaged, significant growth in funding for first-year student support will have to be found elsewhere. A fee-paying master's program is not a viable option. The U.S. market for M.S. polymer graduates is small, the cost of the PSE first-year curriculum is large, and M.S. candidates are, in general, a poor fit to the needs of PSE research projects. Post-docs better service short-term polymer research projects.

Students beyond the first year find homes in various PI research groups, and one PSE distinction is the high fraction of these students, approximately 30%, who are co-advised, under the direction of two or more thesis advisors. Co-advising is consistent with PSE's mission to impart an interdisciplinary polymer education, and in many instances, co-advised students work across polymer chemistry, polymer physics, and polymer engineering in a single project, receiving expert advice at each stage. The average time to Ph.D. degree for PSE is about 4.9 years, longer than ideal but shorter than in most disciplines. This time seems about the same as at competitors. About 85%, of enrolled PSE students complete their Ph.D. programs, far above the norms for polymers or related fields of science/engineering. Access to major facilities, a lack of TA requirements, and a rigorous graduate curriculum explain how PSE so successfully graduates its students. PSE has no plans to change significantly aspects of its graduate program pertaining to more senior doctoral students.

Little, if any, evidence points to a slackening of demand for polymer-trained Ph.Ds., and to the contrary, much evidence points to the opposite. As part of the recent Doctoral Program Review, a survey found well over 95% of the most recent 175 PSE alumni working in polymer-related positions. A further indication of demand for polymer graduates is the initiation of a major polymer effort at PSE's newest competitor, the Univ. of Chicago, led by a PSE alumnus. A bigger uncertainty is whether the field will remain separate or instead merge with "soft matter" materials to create a discipline of broader focus. PSE could readily follow that path should a shift appear profitable. At UMass, PSE dominates materials research but efforts in materials outside of PSE are growing. PSE supports campus initiatives to expand materials and sees itself a critical partner. These initiatives propose to utilize the core instrument facilities already put in place by PSE. This campus expansion reinforces the need to sustain and bolster facility infrastructure.

In recent years about 15% of PSE graduates have taken academic positions at R1 universities, perhaps after post-doctoral experiences at another university or at a national lab. The remaining graduates have found employment in industry. The percentage entering academia has steadily grown, and PSE encourages this trend. Various programs within PSE help to prepare career academics, such as popular courses in research management and scientific teaching (taken by many graduate students from other departments). Few alumni are in positions at teaching-intensive institutions, as few of these institutions offer polymer courses. This year, the American Chemical Society made polymers a mandatory element in accredited undergraduate degree programs, so demand for PSE alumni to serve as faculty members at these institutions can only expand.

Polymer Science and Engineering is a highly interdisciplinary field, and at UMass, connections are routinely made with Chemistry, Physics, Chemical Engineering,

Mechanical and Industrial Engineering, Food Science, and other departments. The major research centers organized by PSE have all had major participation, and even co-leadership, from faculty members outside PSE. As just noted, PSE is interested in fostering the broader materials initiatives on campus, and a PSE faculty member recently started an interdepartmental weekly research seminar carrying the materials theme. In upcoming years, similar connections and activities should be directed at the campus life science endeavors as well as the UMass Medical School in Worcester, where several collaborations are already in place. Collaborative activities are generally organized best from the "bottom-up", but small funding contributions as well as encouragement from the "top-down" can be important. Small and scattered activities among a few PIs nearly always create the 'seeds' from which major, multi-investigator interdisciplinary initiatives emerge.