EXCELLENCE IN ENERGY SCIENCE RESEARCH: FACULTY HIRING IN PHYSICS AND CHEMISTRY

EXECUTIVE SUMMARY

We propose to hire one physicist and three chemists to bolster the research and teaching profile at UMass Amherst in energy science. The funding outlook for renewable energy research has never been better. This plan serves to add faculty with expertise in solid-state physics, electronic structure, devices and materials synthesis to provide a vital strategic complement to the nationally-recognized excellence of UMass Amherst faculty in soft materials. These hires fill critical gaps in the UMass Amherst portfolio of research expertise that currently hinder our ability to make the largest impacts in energy research. These hires would ensure the expansion of the NSF "Fueling the Future" CCI grant to Phase II status, the continuance of the NSF "Center for Hierarchical Manufacturing" NSEC grant, strengthen the team behind the DOE EFRC grant and create new opportunities from the burgeoning funding base in renewable energy from DOE Basic Energy Sciences, DOE ARPA-E, NSF, DOD and industry. In addition, these hires will guarantee the establishment of undergraduate and graduate education in energy science.

OPPORTUNITY

The present time is the *most* opportune period in history for faculty investments at UMass Amherst in the area of energy research. There is a compelling societal need for fundamental scientific progress that results in game-changing energy technologies. Energy science is by necessity an interdisciplinary research topic. The federal government and industry are pouring funds into basic and applied research in energy conversion, storage and efficiency. Given the vital importance of green energy to a sustainable civilization, it is clear that the research funding opportunities from government and industry will continue on an upward trend for the foreseeable future. Recently, the campus has been successful in winning a significant level of grant funding for energy research and now has the timely opportunity to establish itself as a world leader and increase the base of federal funding. This hiring plan would bolster the recent interdisciplinary initiatives in energy (MassCREST) and nanotech (MassNanoTech) by adding faculty in strategic areas that strengthen the portfolio of expertise in energy science.

HIRING IN SOLID-STATE ENERGY PHYSICS

The Physics Department seeks to hire a world-class physicist doing research in experimental solid-state physics with an emphasis on energy science. Solid-state physics is at the fundamental core of many enabling materials and device technologies in energy technology. Solid-state physics plays a leading role in topics such as energy conversion (solar cells, fuel cells, thermoelectrics), energy storage (batteries, ultracapacitors), energy efficiency (solid-state lighting, electric power management, electrocatalysis), plus a range of nanotechnology applications having impact in energy (electronics, magnetics, photonics). Many potential candidates work on solid-state materials and devices with designed features at the nanoscale, since materials properties can be manipulated and enhanced through nanostructure control. Hiring a physicist would complement the great strength at UMass in chemical synthesis and materials science by adding expertise in materials characterization and device design through experiments that explore and utilize underlying governing properties such as charge transport, interaction of matter with light, quantum energy conversion processes and electromagnetic effects. The Physics Department has a strong condensed matter physics group, especially in the area of soft condensed matter (liquids, polymers, colloids, granular, biological) physics, but has under-representation in solid-state (hard condensed matter) physics. This places the department at a relative disadvantage compared to departments in peer institutions, both with respect to its ability to obtain competitive research grants and its ability to provide world-class graduate education. At the campus level, our energy and nanotech initiatives, although successful, are hampered by under-representation of expertise in solid-state physics in these interdisciplinary research programs. Filling this faculty position would help the campus increase its national research profile and funding portfolio.

HIRING IN CHEMICAL ENERGY AREAS

The Chemistry Department is proposing to hire three world-class scientists over the next three years. This aggressive hiring plan is needed for the department, which is on the cusp of becoming one of the country's first-quartile departments. Although the department already boasts great strength in organic/soft materials, key *complementary* strengths are not currently present in the department, inherently putting our campus at a disadvantage relative to peer institutions. The three areas proposed are: electronic structure theory,

device chemistry, and synthetic materials chemistry. The electronic structure theorist will complement our existing theoretical chemistry strengths chiefly represented by dynamacists. The intellectual interplay between the proposed electronic structure theorist and our existing faculty in molecular design and dynamics theory will greatly enhance our abilities to attract center-based activities in UMass in the renewable energy arena. Similarly, while faculty in the department have made great strides in designing new molecules intended for renewable energy devices, a bottleneck in our achievements has been the evaluation of these materials to identify the figures of merit in devices. This has been a significant barrier as we are building our connections with the blooming renewable energy industry. Rapid evaluation of the materials generated at UMass using campus-based specialists will significantly enhance our abilities to build upon this potential. We foresee this will result in IP generation and new external funding focused on the core technologies developed on campus. Finally, the need for a synthetic materials chemist is related to a new scientific grand challenge--"Beat The Leaf"--introduced by the Department of Energy and other funding agencies such as ARPA-E, relating to an expected new competitive research concept. There is no system that is better in harvesting solar energy than that of the leaf, *i.e.* the biochemical process of photosynthesis. In order to develop an artificial system, one needs to understand and envision designing biomimetic systems for energy. Success in this area will vault us ahead of competing institutions in the country. The Chemistry Department proposes that at least one of these three hires be a senior faculty member with significant stature in the field.

TEACHING

Physics

The graduate program in the Physics Department has a compelling need for a new faculty member in the area of solid-state physics from the graduate program teaching perspective. Due to retirements the number of faculty has dropped significantly, making it difficult to offer the full complement of graduate courses in condensed matter physics, placing the quality of the graduate program at risk. Adding a faculty member in solid-state physics would, in particular, allow the Physics Department to re-establish a strong curricular offering in solid-state physics at the graduate and undergraduate level. Faculty in Physics and Chemistry together will develop interdisciplinary courses, as part of the iCons undergraduate program, comprising an energy research theme.

Chemistry

As a consequence of the reduction in size of the Chemistry Department over the last decade (19 of the 33 tenure-track faculty (TTF) members present in 1997 have since retired, leaving only 23 TTF today), we find ourselves under considerable stress simply to teach all of our undergraduate courses. Moreover, our focus on fulfilling these undergraduate teaching obligations has severely affected our graduate curriculum. Here significant gaps in our course offerings threaten to leave our Ph.D. graduates at a competitive disadvantage. Resolution of these difficult issues can only be accomplished by the addition of new faculty. Further compounding our teaching crisis is our own effort to reach competitive critical mass in research. We plan to decrease gradually the number of our lecturers. Furthermore, over the last several years we have enlisted two retired lecturers to teach highly popular one-semester general education chemistry courses. We will no longer do so. Instead, the teaching obligations of these lecturers will be assumed by research-active, tenure-track faculty members. We recognize that this replacement of lecturers by TTF cannot be achieved on a one-for-one basis since TTF cannot be productive in other areas if they carry lecturer-level teaching loads. Nevertheless, the Chemistry Department firmly believes that it is on the right course. Our peer institutions endeavor to carry out teaching and research missions similar to our own, and they operate with significantly more faculty than we do. Without an adequate number of full-time, research-active faculty, we cannot hope to match the breadth of their course offerings to students, and we cannot compete as effectively in the research arena.

SYNERGY AMONG THE HIRES

Renewable energy research is an inherently interdisciplinary area. The condensed matter physicist, synthetic chemist, device scientist, and the electronic structure theorist will each be very complementary to the existing strengths in Chemistry and Physics, as well as with each other. For example, the molecules and materials synthesized by the synthetic chemist could be guided by novel electronic structure theory, and vice versa. The materials created in the lab of the proposed synthetic chemist, not to mention those of our existing synthetic chemists, have to be studied from the perspective of fundamental physical properties

as well as performance in a device. The condensed matter physicist and the device scientist will be able to carry out these studies respectively. We anticipate that most of these new faculty members will have adjunct faculty positions in the other department, because of the close connections between Chemistry and Physics. Several such synergistic possibilities exist, and these are types of synergies that will provide an edge for UMass over our peer institutions in renewable energy research stature.

PROVEN EXCELLENCE IN ENERGY RESEARCH AT UMASS AMHERST

UMass Centers: The presence at UMass Amherst of four hard-won national research centers--the NSF Center for Chemical Innovation (CCI), *Fueling the Future;* the DOE Energy Frontier Research Center (EFRC), *Polymer-Based Materials for Harvesting Solar Energy;* the NSF Nanoscale Science and Engineering Center (NSEC), *Center for Hierarchical Manufacturing;* and the NSF Materials Research Science and Engineering Center (MRSEC), *MRSEC on Polymers*--provides a foundation of excellence and base of research infrastructure in energy science. The CCI ($1.5M/3yr) and the EFRC ($16M/5yr) have energy science as the major focus and are major new strengths at UMass in energy research. Energy science is a component of both the NSEC ($16M/5yr) and MRSEC ($13.3M/5yr), but these centers, which have a nanotech and polymer materials focus respectively, also provide important research and development infrastructure to the campus' comprehensive energy research effort.

Future Support: The CCI, now in a programmed "starter" phase, is on track to grow significantly to a Phase II CCI center, with a 10-year duration with a $4M annual budget. Our proposal to NSF for this eight-fold increase in funding will be submitted in October 2009. These proposed strategic hires are of great importance to secure this major grant. With a recent surge in interest by the federal government, the level of research support in energy science is at an historic high. DOE, NSF, ARO, ONR, DARPA, NIST, state governments and industrial companies are all now prepared to provide significant funding for energy research both for individual PIs and for major center projects. The DOE alone has recently announced the awarding of $777M over five years for EFRCs, of which the UMass is one. Other agencies have introduced, or have plans to introduce, new funding programs in energy research.

Faculty Leadership and Expertise: The research programs established at UMass Amherst are efforts initiated by faculty who have a long-term vision for energy research on campus. New faculty will find tremendous intellectual synergy and opportunities for collaboration. Although there are many leaders and participants in energy research across several departments at UMass, the following is an accounting of people from Chemistry and Physics only. Thayumanavan (Chemistry) is the director of the CCI and co-director of MassCREST. Auerbach (Chemistry) and Hardy (Chemistry) are Research Team leaders in the CCI. Lahti (chemistry) is co-director of the EFRC. Achermann (Physics), Barnes (Chemistry) and Venkataraman (Chemistry) are Research Team co-leaders in the EFRC. Tuominen (Physics) is co-director of the NSEC and MassNanoTech. Other participating faculty in energy center projects include Dinsmore (Physics), Hardy (Chemistry), Rotello (Chemistry) and Santangelo (Physics). Of course, great strength in energy research leadership exists in other departments as well. To mention a few: Russell (Polymer Science) is director of the EFRC and MRSEC, Watkins (Polymer Science) is director of the NSEC and co-director of MassNanoTech, Coughlin (Polymer Science) is co-director of MassCREST, Lovley (Microbiology) is director of the Geobacter Project, and Leschine (Microbiology) is founder of start-up Qteros (SunEthanol). This collection of faculty has a strong vision for long-term energy research at UMass Amherst.

Facilities: There is well over $10M worth of shared-use facilities available at UMass Amherst for energy research, with more slated for purchase through the CCI, EFRC, NSEC and MRSEC. Many of these facilities have full-time staff to help train students and maintain equipment. These tools and instruments enable the synthesis and fabrication of materials, characterization of structure and morphology, and probes into the chemical, optical, electronic, thermal and magnetic properties of the materials and devices under exploration.

METRICS FOR SUCCESS

One major assessment of success is the expansion of the CCI project to Phase II level. This would represent $40 million in new research funding over 10 years. The new hires are likely to secure individual research grants, which after three years at UMass should be in the range of $200-500K per individual.