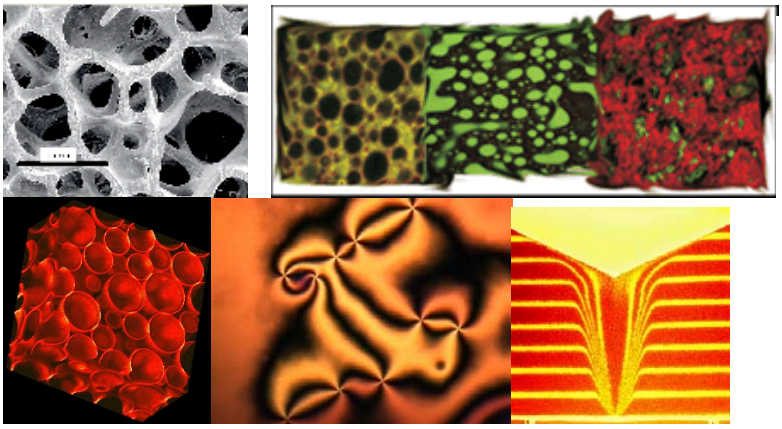
Soft Matter Cluster: Food Science, Physics, and Chemical Engineering

Summary This proposal lays out the rationale to hire in the area of soft materials to establish high-profile research strength in the area of Soft Matter. We propose to hire one faculty member each in the Food Science, Chemical Engineering and Physics departments. These connected hires would enhance the stature of UMass as a major player in this field, open up opportunities for new collective funding, and lay the foundation for future interdepartmental centres or institutes. In the process we will also build bridges between three departments (Chemical Engineering, Food Science, and Physics) with complementary faculty expertise in soft matter science and engineering.

Why soft matter? The phrase *soft matter* refers to a large class of materials of natural, biological and technological significance that include colloids, gels, suspensions, granular media, liquid crystals, polymers, foams and emulsions. What do these seemingly disparate systems have to do with each other? The distinctive properties of all of these systems -- from crème brulée to muscle tissue to sandpiles – arise from two related common features. The first is that they are all inherently multi-scale: there is a crucial level of structural organisation at a stage intermediate between the scale of molecules and the scale of the entire macroscopic system. The second is that they are structurally delicate (hence *soft*), and respond sensitively to changes in external forces and physical-chemical conditions. Soft Materials has spawned its own field of research only in the last couple of decades. The field straddles many disciplines and benefits from diverse technical advances and fundamental scientific insights. Innovations in synthesizing, manipulating and deploying these materials will demand integrating methods from a variety of fields. At the same time, a deeper unified understanding of these diverse systems requires fundamental ideas on ordering, complexity, symmetries and nonequilibrium statistical mechanics. Thus, we believe that the combination of departments we are bringing together in this cluster very naturally exploits the nature of this field whose essence is close interdisciplinary interaction.



Representative systems
Top L to R: Spongy bone tissue; microstructure of multiphase foods
Bottom L to R: Confocal image of emulsion; Topological defects in nematic liquid crystal; Hopper flow of powders

Building on strengths: All three departments involved have a core presence in this area, and the new hires will bring each group closer to the critical mass required to be intellectually influential in the community. The existing infrastructure, opportunities for collaboration, and scientific community are already at sufficient strength to be able to attract top-notch candidates to UMass.

Food Science: Many diseases in developed societies are diet-related. They include obesity, hypertension, heart disease, diabetes and cancer. Consequently there is a pressing need for foods specifically designed to prevent these diseases – notably, foods having reduced fat, calories and/or salt, or high fiber, polyunsaturated fat and selected minerals. These foods however, must also be tasty, convenient, affordable and of high quality overall. At present, making such foods is largely an art and craft rather than science and technology.

The food industry has recognized that the design and control of the properties of structurally complex multi-component foods requires a more fundamental scientific approach, based on physics, rheology, chemistry, physical chemistry, and sensory sciences. Soft Matter Physics provides both a conceptual framework and analytical tools to understand and quantify the properties of food products, extant and planned. It is particularly relevant because foods are by and large soft materials and involve phenomena very similar to those studied in physics proper. Surface interactions in food emulsions, particulates and foams or phase transitions and their relation to texture are two salient examples.

The soft materials approach to food science is currently represented by McClements (food biopolymers, colloids, delivery systems) and Peleg (food rheology, granular materials, modelling of complex food systems). The department has been ranked within the top 7 internationally, and within the top three in the USA in recent surveys (ISI Thomson Scientific). McClements organizes an annual workshop on Food Emulsions at UMass, and organized an international symposium on Delivery of Functionality in Complex Food Systems at UMASS in 2007. The top international groups in this area (Wageningen, Leeds, UC Davis) typically have 3 or 4 scientists working in this area, and so we would like to request an additional hire to further strengthen our group and reach this level.

Physics: Over the last decade we have built up a core presence in the area of soft matter physics. We have three faculty members (Dinsmore, Menon, Candela) who lead experimental efforts in the mechanics and statistical mechanics of colloids, gels, granular materials, and membranes. We have a wide-ranging theory effort (Davidovitch, Machta, Santangelo) in pattern formation, computational complexity, complex fluids, and liquid crystal physics.

We already have a strong national presence and over the last few years, have assumed leadership roles in our research community. Over the last three years our faculty have organised three different workshops at the Aspen Centre for Physics, a Gordon conference, and a soft-matter workshop at the Boulder School. In the Northeast, UMass scientists have been organisers of the annual Granular Materials workshop and the quarterly Complex Fluids workshop. We run an annual summer school for graduate students, which has attracted excellent students from the best institutions and extremely distinguished scientists as lecturers. Nationally, the most highly regarded soft-matter groups in physics departments (Penn, NYU) have about 4 experimentalists in this field and the addition of another faculty member will place UMass physics in this echelon.

Chemical Engineering: Soft matter in nature serves many essential functions, which also are needed in technical applications. New technology can potentially evolve from a

design and use of materials according to nature. Such guidance, for instance, tells us that soft matter in nature is multicomponent and has a variety of cellular structure so that the desired combination of functions gets established. The combination of highly diverse functions (mechanical, optical, biological, diffusive, electrical) requires collaboration of researchers with diverse expertise to be funnelled towards the making of nature-inspired soft materials and their use in devices. Examples are the high-strength nano gels of Haraguchi, in parallel to human knee meniscus and eye cornea, and porous gels as candidates for organ replacement (serving as functional matrix material) and the conducting gels of organic photovoltaic solar collectors.

UMass Engineering has a strong presence in soft matter science and engineering. Areas of expertise are experimental rheology of complex fluids and gels (Bhatia, Rothstein, Winter), computational fluid mechanics (Davis, Pozrikidis) interfacial phenomena (Davis, Pozrikidis, Rothstein), statistical mechanical modeling of colloids (Ford), and synthetic membranes (Ford).

Chemical Engineering has a strong national presence in these areas as documented by high impact numbers of publications, organized workshops, invited lectures, and international awards. We run the annual Amherst Rheology Course which combines experimental aspects of rheology with theoretical modeling and simulation.

Funding base: current and future Our current funding base reflects the diversity of our field, and while able to capitalise on a broad range of national initiatives, the health of our funding is not contingent on continued life of any particular initiative. We have held funding from a broad range of federal agencies, and from a diverse set of industrial sponsors.

Faculty of the Food Science department have an established track record of obtaining funding from the food industry and pharmaceutical industries (medical foods) (*e.g.*, Pepsi, Nestle, Coke, Proctor and Gamble, International Flavors and Fragrances, Wild Flavors, Sensient, Unilever, National Starch), and the USDA, NIH and NSF. Indeed, McClements recently received two grants from the USDA on soft matter physics: formation of nanolaminated coatings to control lipid digestion; creation of filled biopolymer particles to control chemical stability of encapsulated components. . Likewise, soft matter faculty in Physics have in recent years been funded by NSF, NASA and DOE federal grants; we are able to credibly apply to a broad range of NSF directorates (DMR, CBET, CMMI). Physics faculty have also held a variety of industrial funding (Kraft Foods, Xerox, Chevron, Schlumberger) and Engineering faculty are funded by Sabic, ExxonMobil, Daicel, among others. A NSF Cyber-Enabled Discovery & Innovation (CDI) grant was recently awarded to Ford, with a collaborator at Johns Hopkins University, to use the theoretical framework of statistical mechanics to extract information from novel microscopic imaging of the directed assembly of colloidal systems.

These cross-departmental connections will allow us to create new and unusual packages of expertise in relation to funding agencies. For example we will be able to put in applications for NSF's NIRT and GOALI programs. It will also position us to apply for larger group grants such as a Soft Matter IGERT, and Soft Matter REU programs. We are also formulating a strategy to apply for an NSF Physics Frontier Center (typically 10-13

M$ over 5 years) in the next round of competition in 2011. There is also a high probability that cooperative research in this area will create generate new intellectual property and be the seed for new startup companies, which will help in the economic development of the area.

Importantly, while there will be immediate returns on investments made in these hires, the funding profile is so broad, that these returns do not hinge on some specific funding trend; thus the return on investment will continue to be stable.

Direction of hire The areas of hire will not be extremely narrowly focused, but will seek to fill lacunae in areas where we are not currently represented. In addition to excellent accomplishment and promise in their own discipline, an important qualification for a successful candidate in this cluster-hiring scheme will be the ability to make cross-campus connections. To better ensure this and to convey to candidates the seriousness of intent to foster interdisciplinary connections, each department will seat one member from each of the other two departments on their faculty search committee. We discuss more specific departmental considerations below.

Food Science department would like to hire a new faculty member in the area of soft matter physics and foods. This person would be expected to develop a nationally and internationally recognized program in food soft materials. The aim of the research would be to develop quantitative structure-function relationships between the macroscopic properties of food materials(rheology, appearance, stability, flavour) and the microscopic and mesoscopic properties of their structural components (particle properties, size, morphology, interactions). This work would involve applying the basic principles and methods of soft matter physics to solve important societal problems: the creation of high quality food products designed to address critical health needs, such as obesity, diabetes, heart disease, and cancer.

Physics seeks to add an experimentalist with technical skills complementary to our existing faculty, such as a specialist on structure who works with modern synchrotron facilities, or someone in the area of modern fluctuation rheology such as two-point microrheologies. Such a colleague would immediately bring new strengths to the department and draw collaborations from colleagues across campus.

Chemical Engineering needs to add an engineering faculty member in the area of soft, multi-component, cellular materials. The new faculty shall bring manufacturing expertise in tissue engineering, foams, soft sensors, soft photovoltaics, soft membranes. The properties of these materials are dictated by their architectural complexity at the nanoscale and microscale, and great technological advances will arise from a detailed control of this complexity (topology).

Benefits of hire Strategically coordinated hires in this area will forge new linkages between two departments that are newly-partnered in CNS, and connect with the College of Engineering. This multifaceted cooperation would create a unique multidisciplinary team that would establish UMASS and the campus as a nationally and internationally recognized center of excellence in this important new area.

There are examples nationally of very successful connections between Physics and Engineering (UC Santa Barbara, Harvard) which we do not currently have at UMass. We

do not know of any university in which there are strong connections between Physics and Food Science: this will be unique to UMass. Examples of connections between Engineering and Food Science do exist (Texas A&M) and we could clearly benefit internally by developing such connections

The construction of a broader network across campus will also aid greatly our efforts at educating graduate students and upper-level undergraduates who work in our research groups. The addition of new faculty in these areas will make it possible to offer upper-level courses in these subjects. Soft matter courses in any of our departments will be more broadly advertised amongst other groups and be tailored to campus strengths.

Management of cluster The individuals hired will be members of their own department first and then partners in the broader umbrella of the soft-matter community. However, we will try as best as possible to put in place a structure that ensures that the cluster stays connected. We will plan two annual soft-matter meetings internal to UMass, with the dual purpose of presenting brief research reports open to all faculty and students, and then a second session for setting of strategies to pursue large-scale grants.

We will also create a website that highlights our soft-matter activitieswhich in particular will link to and from all relevant departmental and PI webpages. This will be a useful clearing house for information, as well as an excellent recruiting tool to demonstrate to potential graduate students, postdocs and faculty the sweep of activities across campus in this area.

We will also attempt to maintain connections between faculty at various levels by having a faculty mentor for new faculty from a partner department (in addition to any departmental mentoring scheme that is currently in place). The external member of the faculty search committee would be an obvious choice for a person to serve in such a role.

Other campus resources Fundamental as well as technical developments in soft matter can play a valuable role in understanding biophysical activity and processes. All the relevant departments are investing in biophysics research. A healthy soft-matter community on campus will strengthen the inter-departmental biophysics effort. Likewise, there have been close connections between some of our departments and the Polymer Science department, and faculty listed in this proposal have benefited from and contributed to activities of the MRSEC. A further strengthening of the Soft Matter effort on campus would strengthen these existing ties.