Center for Templated Synthesis and Assembly at the Nanoscale

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The University of Wisconsin at Madison (UW), one of the largest public research universities of the nation, has built much of its reputation and success on a strong tradition of collaboration between the science and engineering disciplines. The UW Nanoscale Science and Engineering Center (NSEC) assembles a diverse group comprising established, world-renowned senior faculty and promising junior faculty from over ten departments. The tightly interwoven multidisciplinary program addresses the self-assembly of complex materials and building blocks at the nanoscale with an exquisite level of detail, including the development of a unique program to explore their societal implications. The UW possesses the infrastructure and breadth of expertise required for a successful and vibrant NSEC. The research mission of the NSEC is organized into four interdisciplinary research thrusts that explore the concept of self-assembly at the nanoscale from different angles:

Thrust 1: *Directed Self-Assembly and Registration of Nanoscale Chemical Architectures* addresses the question of assembling nano-structured objects into functional nanoscale systems. It explores the self-assembly of block copolymers on nanopatterned substrates, the convergent assembly of pre-fabricated nanoscale elements on nanoscale patterns, and the biologically-directed assembly of nanowires and nanorods for development of innovative biosensors. The group relies on superb nano-patterning facilities and considerable expertise in the synthesis, manipulation and characterization of nanoscale building blocks, ranging from flexible copolymers to rigid nanowires. Recently we have integrated self-assembling block copolymer into the lithographic process so as to enable extension of current manufacturing practices to dimensions of 10 nm and less. The domains of block copolymer films could be directed to assemble into defect-free periodic and non-regular device oriented structures over arbitrarily large areas and in registry with lithographically defined periodic chemical surface patterns. The use of block copolymers in this context addresses pressing issues of sub 1 nm control over feature dimensions, reduced line edge roughness, and scalability. Recent work has also been aimed at the functionalization of spherical and cylindrical nanoparticles, and the subsequent intercalation into lamellar and cylindrical block copolymer morphologies. Particular attention is being paid to asymmetric nanoparticles that may possess unique directional character by virtue of the intrinsic composition of the material or through the selective modification with molecules bearing functional groups that impart specific physical or chemical properties. We have successfully formed highly complex polymeric structures by using block copolymers to extend surface patterns into 3-dimensional structures and are currently focusing primarily on understanding how the chemical groups exposed on the nanoparticles control their subsequent intercalation into the block copolymer structures.

Thrust 2: *Templated Chemical Synthesis of Sequence Specific Heteropolymeric Nanostructures* explores guided processes of chemical synthesis and assembly on the nanoscale. The group seeks to establish novel thermodynamically-controlled, template-directed synthetic strategies that bring an unprecedented level of control to the synthesis of amide heteropolymers with discrete sequences, shapes and assembly propensity. The group also explores the self-assembly of synthetic, highly stable but unnatural β-peptide sequences into unique nanostructures which are carefully characterized and examined in the context of several applications, including their use for antimicrobial materials and liquid-crystal based biosensors. Of particular note, the thrust has recently performed exploratory studies of the self-assembly of a series of unnatural β-peptide sequences in solution. These studies reveal a rich phase behavior with a remarkable dependence of microstructure on the three-dimensional nanoscopic architecture of the β-peptides. The latter can be manipulated in a general and facile manner via control of the sequence of the β-peptides. The thrust has also recently discovered liquid crystalline phases arising in systems comprised of non-amphiphilic β-peptide sequences. This result suggests approaches to the nano-scale design of materials suitable for biological sensing. In addition to studies in bulk solution, the thrust has initiated an effort aimed at studying the self-assembly of β-peptides at surfaces: these studies have revealed that β-peptides do form organized monolayers at interfaces. This result opens up the possibility of fundamental studies of single-molecule mechanical and electrical properties of individual β-peptides. Other areas of activity in the thrust include investigations of antimicrobial activityies of β-peptide-based nanostructures, and the development of synthetic strategies leading to amide heteropolymers.

Thrust 3: *Driven Nano-Fluidic Self Assembly of Colloids and Macromolecules* relies on concerted experimental and theoretical approaches to explore the use of non-equilibrium processes, such as the use of flow and other fields, for nanoscale assembly and manipulation of nanoparticles and macromolecules, including DNA, under severe confinement. Recently the group has developed new quantitative understandings of nanoconfined polymers, and this work was translated into a working integrated system for genomic analysis. The heart of the system centers on the use of nanoslits (rectangular channels bearing a high aspect ratio) demonstrated to significantly elongate long DNA chains under suitable buffer conditions. This robust single molecule display was enabled for “single molecule barcoding” by new labeling and imaging approaches, producing the first working nanoscale system for whole genome analysis.

Thrust 4: *Research in the Societal Implications of Template Synthesis and Assembly at the Nanoscale* is a one-of-a-kind partnership with the Holtz Center for Science and Technology Studies and the La Follette School of Public Affairs at UW that is developing an integrated, multidisciplinary understanding of nanoscale science and engineering as it moves out of the laboratory and into society. Building on a successful citizens consensus conference in April 2005, Thrust 4 is pursuing an expanded dialogue with policymakers and the public about nanotechnology’s implications for social and environmental policy. Thrust 4 is also a major partner in the Center for Nanotechnology in Society (CNS), led by Arizona State University, a new NSF-funded research center to probe the potential for Real Time Technology Assessment to integrate societal considerations into the organization and conduct of nanoscale science and engineering research. Thrust 4 research under CNS auspices will focus on questions of (1) freedom, privacy, and security; (2) the enhancement of human biology; and (3) nanotechnology research related to the human brain and cognitive functioning.

Thrust 1 examines situations and processes in which the self-assembly of mesoscopic materials and the resulting nanostructures can achieve a state of thermodynamic equilibrium. Thrust 2 considers synthetic routes that are also governed by thermodynamic equilibrium and nanoscale templates, but this time at the level of individual atoms and chemical reactivity. Thrust 3 is concerned with nanoscale self-assembly far from equilibrium, driven by the influence of external fields and severe confinement. Thrust 4 considers social influences on and implications of the development, design, reception, and uptake of self-assembling nanotechnological systems.

Each group integrates the five essential elements required for forefront research in nanoscale science and engineering: synthesis, theory, structural characterization, property evaluation, and applications. An aggressive Seed program operates in a manner to foster innovation and promote growth and evolution into new, unexplored areas of opportunity. Seed funds are primarily used to support promising clusters of individuals in emerging areas of nanoscale science and engineering and its societal implications. The established Thrusts and Seed projects share a common view, namely the precise synthesis of nanoscale elements, their assembly into nanostructured systems through the use of templates, self-organization and confinement, and the creation of materials, devices, and processes with hitherto unattainable functions. The way in which the center has been conceived is such that each Thrust is capable of operating in a self-sufficient manner, but multiple cross-Thrust activities and interactions that capitalize on a multidisciplinary environment are essential for successful completion of the research.

NSEC education and outreach activities are designed to educate teachers, students, and the general public about nanoscience. Programs for teachers include summer fellowships, professional development workshops offered through the Madison Metropolitan School District, and the development of an online nanotechnology course for high school teachers. NSEC supports programs directed toward K-12 students including projects that help build diversity within the scientific community. The SciEncounters program partners with the local Boys and Girls clubs to excite teenagers about science and engineering. The NSEC is affiliated with the ILAB program to develop instruments for blind and visually impaired high school and college students to work independently in the laboratory. NSEC programs for the general public include the SPICE (Students Participating in Chemical Education) program and a collaboration with the Discovery Center Museum. An additional partnership with the UW's Business School assesses the commercial potential and possible pathways to commercialization of technologies under development in the NSEC.

The NSEC activities include the establishment of a Graduate Fellowship Program to recruit the most talented young scientists and engineers to the interdisciplinary field of nanoscale science and engineering and to foster a community of diversity. We have also established links to international laboratories on three continents that support living expenses of our students while they participate in substantive collaborative co-supervised research projects.

The shared experimental facilities of the proposed NSEC includes nanopatterning and surface sensitive characterization of materials, and leverages existing state-of-the-art instrumentation, human resources, and user networks of three organizations of national and international reputation at UW: the NSF sponsored Synchrotron Radiation Center (SRC), the NSF sponsored MRSEC, and the Center for NanoTechnology (CNTech). Supporting infrastructure is also provided by the Wisconsin Center for Applied Microelectronics (WCAM) and the UW Materials Science Center (MSC). The shared facilities serve internal and external users in academia and in industry.

For further information about this project link to **www.nsec.wisc.edu** or email **nealey@engr.wisc.edu**