Center for Templated Synthesis and Assembly at the Nanoscale
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The University of Wisconsin Nanoscale Science and Engineering Center (NSEC) addresses grand challenges associated with directed assembly of nanoscale materials into functional systems and architectures through the use of self-assembly, chemical patterning, and external fields. Science-media-public interactions, and environmental health and safety research are integral components of the Center. The NSEC operates an ambitious and unique education and outreach program aimed at cultivating the next generation of nanoscale science and engineering experts with diverse and interdisciplinary backgrounds.

Our vision is to foster transformative and interdisciplinary research in directed assembly to revolutionize nanomanufacturing and the discovery and control of new materials and material architectures, to investigate the interaction between science, the media, and the public, to incorporate societal and environmental implications into the research enterprise, and to educate teachers, students, and the general public about and increase the diversity of participants in nanoscale science and engineering.

Over the past seven years, the UW NSEC has become a fertile ground for collaboration, interdisciplinary research, and discovery that has truly changed the nature and scope of research at the University of Wisconsin, particularly at the interface of chemistry and engineering. The Center is characterized by its high productivity, its impact on technology and fundamental science, its success in incorporating underrepresented groups into scientific pursuits and the intellectual environment that it has created for well over a hundred undergraduate and graduate students, faculty, and industrial and academic collaborators. The activities of the NSEC have been crafted to evolve further the mission of the center on all fronts, including technology, innovation, discovery, societal implications, public engagement, and education at all levels. The NSEC includes four Thrusts, Societal Implications research, and a focused education and outreach group.

Thrust 1: *Directed Assembly of Block Copolymer Materials* Current research in Thrust 1 focuses on the grand challenges facing block copolymer lithography and directed assembly: 1) to pattern at 22 nm resolution with the ability to be scaled to less than 10 nm, 2) to enable 2 to 3x resolution enhancement over exposure tools that may be used to create lithographically defined chemically patterned surfaces for directed assembly, and 3) to be easily integrated into existing manufacturing processes. To meet these challenges, fundamental research in Thrust 1 includes: 1) strategies for resolution enhancement that do not sacrifice essential process attributes such as perfection and registration, 2) manufacturability, in terms of inexpensively replicating and reusing chemical nanopatterns, and meeting the stringent constraints for specific applications such as bit patterned media, or nanowire array field effect transistors, and 3) the synthesis and assembly of new block copolymer materials to achieve smaller domain dimensions and higher functionality than poly(styrene-b-methyl methacrylate) P(S-b-MMA), the model polymer used in the majority of past studies. Recent highlights in Thrust 1 are: 1) showing that non-regular, device-oriented structures can also be directed to assemble on chemically nanopatterned surfaces such that the density of features in the assembled pattern is multiplied by a factor of two or more compared to the chemical pattern, 2) synthesizing new types of polymer brushes with distributions of a third polar monomer which is capable of anchoring to an oxide surface or crosslinking with itself to create surfaces with controlled wetting behavior on a range of substrates, and 3) a new massively parallel patterning technique called molecular transfer printing (MTP).

Thrust 2: Thrust 2: Sequence-Directed Assembly of Organic Nanostructures. Research in Thrust 2 has revolved around investigations of the design, directed assembly and functional properties of organic

nanostructures synthesized from a class of -peptides. Current research in Thrust 2 seeksxnon-natural amino acids called to advance the opportunity presented by this unique class of materials as a broadly useful organic scaffold or platform for nanoscience. To this end, Thrust 2 is (i) elucidating design-rules that underlie sequence-directed-peptide nanostructures into nano-assembly of assemblies, including β-peptide nanosheets, nanotubes and nanofibers, (ii) exploring the utility of nanostructures to direct the assembly of broad classes of inorganic crystals; (iii) performing single molecule force spectroscopy measurements to provide fundamental insights into the intermolecular forces responsible for directed -peptide nanostructures, (iv) developing powerful new βassembly of computational methodologies (with input from Thrust 3) to understand the β-peptide nanostructures; (v) developing fundamental collective properties in β-peptide nanostructuresβinsights into the sequence-directed interactions of that lead to biological activity, including potent antimicrobial activity; and (vi) exploring the role of sequence control of assembly processes using poly-β-lactams with controlled peptides prepared via ring-opening polymerization of polymer composition and residue order (random vs. block). The above research topics, when combined, will lead to transformative contributions to the understanding of ways in which nanoscopic chemical patterns can be harnessed to direct assembly processes.

Thrust 3:

Thrust 4: *Environmental Health and Safety Implications of Nanomaterials* Research in Thrust 4 focuses on investigating the biological effects and environmental fate of engineered nanoparticles, with a particular emphasis on understanding how the initial surface chemistry and subsequent environment-induced chemical transformations impact uptake and biological activity in a zebrafish embryo model. Current research in Thrust 4 advances our understanding of how nanomaterials and subsequent alterations in the environment influence their biological activity in the zebrafish embryo model. To this end, Thrust 4 is (i) investigating how the surface chemistry of engineered nanoparticles is impacted by environmental degradation (weathering), (ii) investigating how weathering of nanoparticles impacts their biological activity in the zebrafish embryo, and (iii) investigating the extent to which these effects are modified for nanoparticles modified with synthetic polymers and biopolymers. Biological effects observed in the zebrafish embryo are correlated with nanomaterial properties to identify what properties of nanomaterials control the resulting biological responses. To maximize synergy with Thrusts 1-3, Thrust 4 focuses largely on polymer-modified nanoparticles. This research reduces the uncertainty in predicting adverse biological effects of nanomaterials from knowledge of their structures, and facilitates design of environmentally benign nanomaterials and nanocomposites.

Societal Implications: *Science-Media-Public Interactions* The societal implication projects focus on online information environments and their potential for effective public communication and engagement. We conduct basic research on communication effects and public opinion that will help us build an in-depth, empirical understanding of the psychological processes through which lay audiences make sense of complex information conveyed through the Internet. This research is especially useful to the work conducted by our education and outreach-focused colleagues. In parallel, we are developing partnerships with local and regional newspapers and online news outlets to create and test new ways of online public participation. Activities considered include online lectures with real-time online discussions, web casts, and other forms of communication settings that test the applicability of our research findings to real-world settings. We rely heavily on the other Thrusts when we develop questionnaires that tap cutting-edge scientific developments as they emerge in the marketplace, and as we develop online material. This includes issues, such as energy, toxicology, and other key nanotechnology issues.

SEEDs: The NSEC also supports an ambitious SEED program to identify new research areas within the scope of the center that offer possible high technological payoff while opening new scientific areas. Successful outcomes of past, current and future projects include growth into larger research efforts that

may be the foundation of new Thrusts (e.g. Thrust 4), incorporation into existing Thrusts, procurement of external funding such that the activity continues in an area synergistic with NSEC activities, or delineation of pathways for continuation of NSEC objectives after 2014.

Broader Impacts: *Impact of NSEC on Teaching, Training, and Learning* - One of the primary goals of the UW-Madison NSEC is the training of current and future generations of nanoscience and technology researchers. Through NSEC support, an average of 50 graduate student researchers and seven postdoctoral scholars conduct research with NSEC faculty members each academic year. The NSEC supports graduate students and post docs whose research focus is nanoscience education. The outcome from their work is disseminated broadly as it impacts classrooms nationwide. Since its inception, the NSEC has trained eighteen graduate students and post docs who are currently working in or have accepted faculty positions at academic institutions. The NSEC international program provides international research opportunities for NSEC students and post docs to spend two weeks to one semester conducting research with one of the many NSEC international partners. Through NSEC support, the REU in Nanotechnology Program has provided opportunities for 71 undergraduate students to conduct summer research. The efforts of NSEC faculty have led to the creation of nine new nanoscience and technology courses and the modification of 21 other courses to incorporate outcomes of NSEC research in course curriculum. The NSEC has presented over 87 workshops and short courses and 598 seminars. Through an NSEC supported RET program, teacher participants have created 15 middle and high school lessons that have been combined into a teacher workshop which was presented to 60 middle school teachers. The center has developed educational technologies such as tactile models of nanoscale surfaces to teach a diverse audience about nanoscience and engineering concepts. NSEC students, postdocs, faculty, and staff gain experience in communicating science to the K-12 community and general public through participating in our varied education and outreach programs.

Outreach to Pre-College Institutions - The UW-Madison NSEC's mission embraces and promotes the long standing tradition of the Wisconsin Idea of reaching beyond its doors to provide educational opportunities and training to K-12 students, K-12 teachers, and the general public. The NSEC is continuing its innovative efforts to enhance science, technology, engineering and math education to a diverse audience of students, educators and the public. SCI ENCountErs, a collaboration with the Boys and Girls Club of Dane County, is a highly successful after-school program that excites middle school students with discovery based hands-on science activities. NSEC will provide training through a series of workshops for club staff members with the successfully implement the program to expand the SCI ENCountErs program to Boys and Girls Clubs throughout Wisconsin. The NSEC will continue its successful and productive collaboration with the Discovery Center Museum, a nationally ranked children's science museum, in Rockford, IL with the development of two nanoscience informal science exhibits that will be disseminated nationally thought the NISE Net. The NSEC has authored a series of highly evaluated nanoscience webquests that engage and excite middle and high school students about the potential impacts of nanoscale science and engineering. The webquests are disseminated nationally through the Middle School National Science Digital Library.

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