

## 1. Cover Page

### Title: Soft, Biological and Composite Nanomaterials

Basic Energy Sciences: Scientific User Facilities Division, NSRC

Principal Investigator:  
Millicent Firestone  
Technical Staff Member  
Los Alamos National Laboratory  
Los Alamos, NM 87545  
Phone: 505-665-8554  
Email: firestone@lanl.gov

Officials Signing for Laboratory:  
Tanja Pietrass  
Division Leader  
Materials Physics and Applications Division  
Los Alamos National Laboratory  
Phone: 505-667-8475  
Email: tanja@lanl.gov

Grant Heffelfinger  
Director  
Physical, Chemical and Nano Science Centers  
Sandia National Laboratories  
Phone: 505-845-7801  
Email: gsheffe@sandia.gov

#### Funding Request (by year)

	<b>FY16 (\$K)</b>	<b>FY17 (\$K)</b>	<b>FY18 (\$K)</b>	<b>Total (\$K)</b>
Total	3,855	3,973	4,141	11,969

Human Subjects Use: No  
Animal Subjects Use: No

Signatures:

\_\_\_\_\_  
Millicent Firestone, PI, LANL                      Date

\_\_\_\_\_  
Tanja Pietrass, Division Leader                      Date

\_\_\_\_\_  
Grant Heffelfinger, Director                      Date

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### 3.0 Tabular Budget and Staffing Summary

Total Budget and Level of Effort

Soft, Biological and Composite Nanomaterials

#### Total Operating Budget by Subtask

<b>Requested Funding</b>	<b>FY16</b>	<b>FY17</b>	<b>FY18</b>	<b>Total</b>
	<b>(\$K)</b>	<b>(\$K)</b>	<b>(\$K)</b>	<b>(\$K)</b>
Total	3,855	9,973	4,141	11,969

(Annual budgets cover loaded salaries, small purchases, postdoc salaries, and travel.)

#### Level of Effort

<b>Key Personnel</b>	<b>FY 13 (FTE)</b>	<b>FY14 (FTE)</b>	<b>FY15 (FTE)</b>
Bachand*	0.6	0.6	0.6
Firestone*	0.75	0.75	0.75
Goodwin	0.5	0.5	0.5
Huber	0.5	0.5	0.5
Martinez	0.5	0.5	0.5
Montano	0.5	0.5	0.5
Paxton	0.5	0.5	0.5
Werner	0.5	0.5	0.5
Technicians	3	3	3
Postdocs	2	2	2

\*Thrust Leader and Partner Science Leader

#### Materials and Supplies

<b>Requested Funding</b>	<b>FY16</b>	<b>FY17</b>	<b>FY18</b>	<b>Total</b>
	<b>(\$K)</b>	<b>(\$K)</b>	<b>(\$K)</b>	<b>(\$K)</b>
Total	336	363	390	1,089

## 4.0 Management Plan

### 4.1 Overarching Center Goals

The opportunities presented by nanomaterials are exciting and broad, with revolutionary implications spanning energy technologies, electronics, computing, sensing capabilities and biomedical diagnostics. Deriving the ultimate benefit from these materials will require the controlled assembly of diverse nanoscale materials across multiple length scales to design and achieve new properties and functionality, in other words, nanomaterials integration.

Integration has played a pivotal and revolutionary role in the development of nearly all science and technology. Perhaps the most familiar and dramatic illustration is the development of very large-scale integrated circuits where active and passive devices based on semiconductors, dielectrics, insulators, and metals are monolithically integrated on a single platform for specific applications. Even greater challenges exist as nanomaterials are integrated into new architectures to form functional systems. Interfaces and defects are formed whose structures and properties can dominate the chemical, mechanical, electronic and optical properties of the system. The effects of synthesis and fabrication processes on performance must be investigated and new directed- and self-assembly approaches developed for greater functional control. Combined bottom-up and top-down synthesis and assembly techniques must be optimized and/or invented to allow the intention design of hierarchical materials. Establishing the fundamental principles that underpin the integration of nanomaterials that display unique properties, such as quantum confinement, is of paramount importance to nanoscience and ultimately nanotechnology.

The goal of the Center for Integrated Nanotechnologies (CINT) is to play a leadership role in integration of nanostructured materials to enable novel capabilities and applications through its function as a Department of Energy/Office of Science Nanoscale Science Research Center (NSRC) national user facility. By coupling open access to unique and world-class capabilities and scientific expertise to an active user community, CINT supports high-impact research that no other single institution could achieve – the whole of CINT including its user community is greater than the sum of its parts.

### 4.2 Overarching Thrust Goals

The overarching goal of the SBCN Thrust is the synthesis, assembly, integration and visualization of soft and biomolecular nanomaterials and nanocomposites. In the area of visualization, science efforts focus on both the design and synthesis of nanoscale optical probes for detection and imaging, and the development of techniques for the high-resolution spatio-temporal imaging of objects in complex environments. In the area of synthesis of functional nano-constituents, the Thrust is engaged in the microfluidics-enabled synthesis of nanoparticles (e.g., gold nano-rods, magnetic nanoparticles), bio-templated synthesis of metallic nanoclusters, and engineering and biosynthesis of active biomolecular materials (biomotors, light-transducing membrane proteins). Significant efforts in synthesis of amphiphilic monomers and polymer and their assembly or co-assembly with other amphiphiles (lipid, block co-polymers) to form robust biomimetic / bio-inspired soft nanostructures (e.g., polymersomes, hydrogels, liquid-crystalline phases) for the confinement and spatial organization of both naturally derived (e.g., proteins) and engineered nanoparticles represents a strong area of focus for the Thrust. Efforts in the synthesis of functional nanoconstituents and nanostructured soft matrices enable our efforts in the formation of composites and functionally integrated systems that have utility for energy storage and transduction. Moreover, these efforts involve the fundamental understanding of hierarchical building principles that underpin the structural and functional complexity of biological systems, which will afford the opportunity to create integrated systems that more fully duplicate the complex functional systems observed in Nature.

Program Highlights / selected accomplishments from 2013-2015 are outlined below.

#### Nanoscale Visualization/Imaging

- Demonstrated shape-dependent photoemission from single organometallic halide perovskite NPs ( $\text{CH}_3\text{NH}_3\text{PbI}_3$  nano-wires). Correlated AFM and photoluminescence measurements of single nano-

wires that emit continuously along their lengths. This work is a critical step in advancing our fundamental understanding of how to use perovskites as semiconductor components for solar cells. (<http://science.energy.gov/bes/highlights/2015/bes-2015-05-a/>).

- Combined two CINT-developed technologies, non-blinking quantum dots and 3D single molecule tracking microscopy, to follow individual allergy receptors for several minutes throughout entire mammalian cell volumes.

#### Synthesis of functional nano-constituents

- Optimized and applied the CINT microfluidic synthesis discovery platform™ for real-time monitoring of gold nano-rods (Au-NRs) seed age growth synthesis.
- Developed gold-nanoparticle based lateral flow assay for the detection of virulence factors excreted by *Bacillus anthracis*, the causal agent of anthrax. (R&D100 Award Winner 2014, Federal Laboratory Consortium Excellence in Technology Transfer Award 2015).

#### Integration of nano-components into functional systems

- Devised a cascade synthetic route to form a solvent responsive plasmonic NP hydrogel composite.
- Demonstrated the use of block-copolymer micelles to generate membrane-mimic materials that organize organic chromophores for artificial photosynthetic light harvesting.
- Described the assembly of complex polymer networks under energy-dissipative conditions, where biomolecular machines perform mechanical work to deform and dynamically assemble/reorganize far-from-equilibrium nanostructures (<http://science.energy.gov/bes/highlights/2015/bes-2015-11-a/>)
- Constructed and integrated assembly of DNA-templated metal nanoclusters (NCs), carbon nanotubes (CNT) and bilirubin oxidase and showed utility for enhanced biofuel production. Observed NC mediated enhancement of electron transfer from the CNT to the enzyme, which improved the O<sub>2</sub> reduction thermodynamics and kinetics. (Work was highlighted in Science Daily, EurekaAlert, Los Alamos Daily Post, Santa Fe New Mexican, Nanotechnology News, Phys.Org, Clean Technica, Fuel Cell Works, and Biofuels International).

#### Soft lithography & patterning

- Bio macromolecule-mediated feature enhancement of printed lipid assemblies

### **4.3 Key Personnel**

Millicent Firestone (LANL) who works in coordination with George Bachand (SNL), the Partner Science Leader, leads the Thrust. This structure provides a single point of contact and leadership for the Thrust, but also ensures that activities are well coordinated across the two partner institutions. This management model also helps facilitate connections between the Thrust and other laboratory programs at both Los Alamos and Sandia National Laboratories.

The breadth of our scientific staff provides the foundation that enables us to address a wide range of research activities related to the key integration science issues presented above. Brief descriptions of the principal investigators on our research team are provided below, and more in-depth descriptions of staff and activities are provided in their biographical sketches (Section 8).

George Bachand (SNL) is a bioengineer whose primary role in CINT involves designing and applying biomolecular nano-motors for the active self-assembly of hybrid nano-materials, composites, and devices. He is also active in the study of nanoparticle interactions with prokaryotic and eukaryotic cells.

Millicent Firestone (LANL) is a polymer chemist working on the design of amphiphilic monomers that self-assemble into ordered architectures. The self-assembled amphiphilic mesophases are captured through polymerization and used to prepare nanostructured composites. In concert with her synthetic activities she is an expert in applying X-ray and neutron scattering techniques to the study of soft matter.

Peter Goodwin (LANL) is a spectroscopist with expertise in the area of single-molecule characterization and high-resolution optical imaging.

Dale Huber (SNL) possesses broad solution synthesis expertise applied to the preparation and assembly of a wide range of both organic and inorganic materials for CINT, including nanoparticle synthesis via controlled nucleation and growth, in-situ polymerization of monolayers and films on particles and microsystem surfaces.

Jennifer Martinez (LANL) is a chemist that uses the tools of biology to develop new materials such as fluorescent or catalytic metal nanoclusters or genetically encoded polymers.

Gabriel Montañó (LANL) expertise is in the area of development and characterization of membrane and membrane-protein assemblies, including the use of spectroscopic and atomic force microscopy methods for their study. He is also active in the study of energy transfer assemblies and processes, in large part inspired by or incorporating natural photosynthetic systems.

Walter F. Paxton (SNL) research interests include developing new strategies for the efficient integration of functional molecules, including transmembrane proteins, into synthetic matrices using self-assembly and self-organization.

James Werner (LANL) research interests include the development and deployment of advanced optical methods to image and track single molecules and nanomaterials in both two and three dimensions. These methods provide capabilities critical for study of molecular recognition, multi-component assembly phenomena, and multi-scale structure and dynamics.

Postdoctoral appointees (2.0 FTE) contribute significantly to the success of the research program. For example, SBCN post-doc Ian Henderson published six peer-reviewed papers over the past three years in several high-impact journals (*Angew. Chem.*, *Nanoscale*, and *Chem. Mater.*). Eva Rose M. Balog, also a SBCN postdoctoral appointee, aided in capabilities development in genetically encoded optical polymers and computationally designed and stimuli-responsive peptide assemblies. Her work yielded numerous high impact articles in *J. Amer. Chem. Soc.*, *Nanoscale*, *ACS Biomater.*

The breadth of expertise and research interests within the Thrust provides benefit to a diverse set of users from the external scientific community

#### **4.4 Facility Resources**

The other key components of the SBCN thrust are capabilities and facilities. The SBCN thrust benefits from the forefront synthesis, characterization, fabrication, and computational capabilities available at CINT, which include a 96,000 ft<sup>2</sup> Core facility at SNL and a 36,500 ft<sup>2</sup> Gateway facility at LANL, as well as other major non-CINT facilities at LANL and SNL.

Of particular importance to the SBCN thrust is the optical microscopy laboratory containing both commercial and custom constructed instrumentation for spectroscopy and imaging of nanomaterials. Several lasers are available for scanning confocal microscopy including continuous-wave visible (lasers for single photon measurements and a tunable pulsed laser for multi-photon experiments). This laboratory is also equipped to perform single-molecule atomic force microscopy in combination with single molecule fluorescence imaging, and is able to perform single-molecule tracking in two- and three-dimensions, a differentiating capability within the NSRC. Fluorescence characterization techniques such as time-correlated single photon counting, single pair fluorescence resonance energy transfer, and fluorescence correlation spectroscopy are also available.

Structural characterization of soft materials on the molecular to nanoscale is available within the Thrust through the recent acquisition of a commercial, laboratory scale instrument for conducting both small- and wide-angle X-ray scattering (Bruker Nanostar)

In addition, the SBCN thrust possess significant infrastructure to support the solution phase and microfluidic synthesis of colloidal nanoparticles, small molecule synthesis, of monomers, polymerizations, and micro-

contact printing of materials. Facilities for the biosynthesis and genetic engineering of biomolecules are also available. Additional details of the facilities and instrumentation to SBCN efforts are outlined in section 11.0.

#### 4.5 Resources and connections across CINT

All of the thrusts in CINT benefit from cross-thrust interactions, which often are the enabling components for addressing key questions in nanoscience integration. The Theory and Simulation of Nanoscale Phenomena (TSNP) Thrust provides expertise in theory, simulation, and modeling critical for designing individual nanoscale components, understanding assembly and composite formation, as well as, predicting performance characteristics of materials and integrated systems. For example, the TSNP Thrust (A. Frischknecht, G. Grest, M. Stevens) have been working with D. Huber (SBCN) exploring of the self- and directed-assembly of mixed polymer brushes into nanoscale domains. These studies lay the groundwork for planned efforts in modeling biological /biomimetic membranes nanoparticle – interactions. TSNP thrust (S. Tretiak) with J. Martinez (SBNC) has studied the optical coupling of assembled nanoclusters. The Nanophotonics and Optical Nanomaterials (NPON) Thrust have worked with J. Werner and P. Goodwin to develop new luminescent semiconductor quantum dots to enable the study of complex soft and /or biological materials. In addition, NPOM also supports important characterization tools, such as ultrafast transient absorption spectroscopies, that are used by the SBCN Thrust Users. Study of the interactions of biological assemblies with nanostructured hard materials such as metallic foams developed in the Nanoscale Electronics and Mechanics (NEM) Thrust is another example of interactions between thrusts that target studies in materials integration.

#### 4.6 Laboratory Complementary Resources and Inreach

Basic Energy Sciences research programs (sponsored by the BES Materials Sciences and Engineering (MSE) Division or Chemical Sciences, Geosciences, and Biosciences (CGB) Division) at both Los Alamos (LANL) and Sandia National (SNL) Laboratories are synergistic with the activities in SBCN thrust. For example, the BES-MSE funded program at Sandia on “*Active Assembly of Dynamic and Adaptable Materials*”, G. Bachand (PI), W. Paxton (Co-I), and M. Stevens (TSNP, Co-I) studies the basic underlying scientific issues of active protein transport and assemble of nanomaterials, an activity related to CINT activities on development of multi-scale, multidimensional, hybrid nanomaterials. The Sandia BES-MSE effort title, “*Molecular Nanocomposites*” involves the efforts of D. Huber, Amalie Frischknecht (TSNP), and M. Stevens (TSNP) and is focused on the assembly of active and responsive nanocomposites that perform biomimetic behaviors. This work is closely related to CINT’s theme of integration across multiple length scales, and is an example of close collaboration between theory and experiment. In addition, the BES supported Energy Frontier Research Center (EFRC) title, “*Photosynthetic Antenna Research Center (PARC)*,” led by Professor Robert Blankenship at Washington University St. Louis takes advantage of G. Montaño’s expertise on photosynthetic light harvesting systems. The EFRC in turn benefits through the CINT user program to access unique characterization tools and clean room facilities that enable advanced methods of creating and investigation natural and artificial light-harvesting systems.

Aside from BES-funded programs, other efforts within the laboratories are synergistic with CINT. For example, At LANL, J. Werner is supported by the National Institutes of Health for optical studies of intracellular signaling pathways. This work leverages instrumentation and capabilities developed in CINT and offer an avenue of bringing in new biomedical users to SBCN/CINT. LDRD funded project from both LANL and SNL aid in the development of new capabilities that are eventually transitioned into CINT, providing new resources that serve our external user community. For example, a LANL LDRD program titled, “*Genetically encoded materials: libraries of stimuli-responsive polymers*” led by J. Martinez, developed the underlying capability of genetically encoded polymers. More recently, a current LANL-LDRD project titled, “*Chemical signatures of detonations born fro extreme conditions (U)*”, Firestone (co-I) which seeks to understand carbon condensate signatures formed during the detonation of high explosives, information of high value to U.S. intelligence, and international treaty monitoring and verification organizations, is currently being leveraged to provide our users with access to novel nanocarbons that can only be formed under through extreme synthetic conditions achievable only at facilities offered at Los Alamos.

Finally, SBNC scientific users are able to access capabilities within the broader communities of Los Alamos and Sandia National Laboratories. For example, SBNC thrust members (e.g. Martinez) have actively facilitated

experiments with their users at the National High Magnetic Field Laboratory (NSF user facility) and the Laboratory for Ultrafast Materials and Optical Science (LUMOS).

#### **4.7 Distinguishing Characteristics of the Thrust**

The SBCN thrust possess the following unique capabilities:

- Spatio-temporal imaging of biomolecular and nanoscale objects in complex environment
- DNA-mediated synthesis of fluorescent and catalytic nanocluster
- Design, engineering, and synthesis of biomolecular elements (e.g., biological nano-motors, pumps, light-harvesting systems) for integration in composite materials
- Microfluidics Discovery Platform™ to study the controlled synthesis of nanoparticles, nanorods, and other materials
- Collective expertise in the self-assembly of amphiphilics (monomer, polymers, biomolecules) that generate soft nanostructured matrices, characterization using X-ray scattering and their use as integration platforms for the preparation of composites
- Biomolecules-mediated feature introduction or modification of micro-contact printed patterns



## **5.0 Abstract**

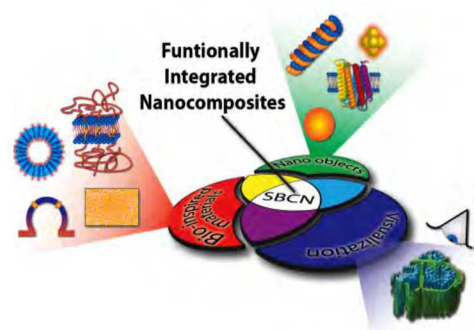
The SBCN thrust in CINT is engaged in fundamental nanoscience, studying the organizational principles of self-assembly and applying them for the preparation and characterization of biomimetic and bioinspired soft nanostructures. The integration of biomolecular nanoconstituents (e.g., proteins) and inorganic nanoparticles into the soft nanostructured matrices are used to generate functionally integrated systems that are broadly applicable in areas including energy store, transduction, sensing, and information processing. The organizational principles needed to prepare complex networks necessitate a deep understanding of coordinated interactions among molecular / nanoscale components across multiple length scale and multiple dimensions. This knowledge is enabled by SBCN's effort in developing optical probes and techniques for the visualization of complex, hierarchically-structured soft materials. The objectives of the thrust are accomplished by a robust internal science program coupled a diverse community of scientific users.

## 6.0 Narrative: Soft, Biological and Composite Nanomaterials

### 6.1 Background and Significance

Since its creation in 2001, the National Nanotechnology Initiative (NNI) has spurred the development of a wide range of nanoparticles and nanostructures with properties previously unattainable in bulk phase materials. The National Research Council (NRC) evaluated the progress of the NNI and outlined several priority research areas, including the need to advance our understanding of how predefined components (molecules, particles, etc.) can spontaneously organize into functional structures. Ultimately, the goal will be to use self-assembly with patterning as an approach for advanced manufacturing of materials by combining nanomaterials into multicomponent, complex systems or devices (i.e., integrative nanoscale manufacturing). Full realization of nanotechnology's potential, however, requires continued effort in fundamental nanoscience, including: (i) reliable, high-throughput synthesis of individual nanoparticles, (ii) matrices for functionally combining nanoscale components, (iii) integrative fabrication of nanoscale building blocks, and (iii) advanced characterization tools that probe structure and functional dynamics across a broad range of time and length scales.

In the area of solution-phase synthesis and assembly of nanoscale materials the SBCN thrust has efforts in the large-scale production of naturally-derived, functional nanoparticles, including transport nanomotors, light-driven proton pumps, light-gated ion transporters, rotary actuators. This effort is complemented by unique capabilities in the production of engineered nanoparticles such as biomolecule-mediated synthesis of emissive metal nanoclusters, high explosives detonation nanocarbons, and microfluidic synthesis of plasmonic nanoparticles. In addition to advancing the synthesis and evaluation of the fundamental properties of individual nanoparticles, the thrust maintains significant efforts in the development of hierarchically-structured soft materials for the assembly of the nanoconstituents into functional composites. In this area, bio-derived (lipid) matrices, artificial biomembranes, genetically-engineered responsive polypeptides, wholly synthetic block copolymer constructs (vesicles), and blends of lipids and polymers are all being investigated and strategies for the spatial localization of nanocomponents are being pursued. Rational design of nanocomposites with complex functionality, however, requires the ability to organize nanoconstituents over a full range of length scales (spanning nano  $\rightarrow$  macro). SBCN addresses this materials challenge by incorporating soft lithography and patterning to complement our established and robust efforts in bottom up self-assembly. Drawing from our noted strengths, we seek to advance the state-of-the-art nanoscience beyond the synthesis and fabrication of simple homogeneous building blocks (nanoconstituents) and composites and seek to create integrated systems which combine multiple functional components. Achievement of multi-scale assembly of disparate nano-objects will serve to fulfill, for example, our vision of hybrid materials for the controlled manipulation of light. That is, by controlling the spatial arrangement of the individual nanocomponents within a responsive matrix dynamic tuning of their spatial proximity and therefore active regulation of the macroscopic properties of the material is possible. For example, the spatial organization of nanoscale emitters (gQDs / nitrogen-doped nanocarbons) and plasmonic (metal) nanoparticles doped or *in-situ* synthesized within a hierarchically-structured soft matrix will offer a means for achieving super-radiance, plasmon assisted lasing and the dynamic control over photon emission or light interaction ("color tuning"), all component materials that could ultimately be integrated to form next generation nanophotonic device.



Core activities that comprise the SBCN thrust

Finally, the interaction between the individual nanocomponents and the structured soft materials in which they reside ultimately determines the properties of the integrated system. A fuller understanding of these complex interactions requires the development of visualization tools that are ideally suited for probing hierarchically-structured soft materials. The synthesis of novel optical probes, in conjunction with, the development and application of 3D tracking techniques that combine optical imaging with spectroscopy is

paramount for obtaining both spatial and temporal information. These activities define the core expertise within the thrust and provide unique capabilities for our user community and supports and strengthens our work in self- and directed-assembly of nanoscale materials.

## 6.2 Progress Report

The Soft, Biological, and Composite Nanomaterials (SBCN) Thrust of the Center for Integrated Nanotechnologies (CINT) contains two major efforts: (1) the development and application of methods for visualizing soft materials, and (2) the synthesis of soft nanostructured materials, hybrids, and composites that can be used for energy storage, transduction, and sensing. The thrust has nurtured initiatives that integrate efforts across SBCN and CINT.

### 6.2.1 Nanoparticle–Soft Materials Interactions.

Nanoscience integration relies on the ability to bring disparate classes of materials together to form functional assemblies on multiple length scales. The ability to create multi-scale soft materials and composites requires both the reliable synthesis of the individual functional nanoconstituents (e.g., plasmonic metal nanoparticles, emissive semiconductor nanoparticles / metal nanoclusters, nanocarbons, proteins) and means to characterize the interactions between the nanoparticles and matrix they reside in. Research efforts within the SBCN thrust have addressed both of these opportunities by using a microfluidic synthesis discovery platform™ to optimize both the production of Au nanorods and advanced characterization tools for the imaging of nanoparticles embedded in complex soft matrices.

**6.2.1.1. Microfluidic synthesis of nanoparticles.** Gold nanoparticles (Au NPs) have attracted a tremendous amount of interest as optical reporters because of their plasmon resonant absorptions, which span from the visible to NIR and can be varied systematically with particle morphology. Anisotropic NPs such as Au nanorods (NRs) have shown utility in chemical sensing, bioimaging, theranostics, and surface-enhanced spectroscopy.[1-3] Seed-mediated growth is a popular route for the preparation of Au NRs, yet little is known about how seed aging influences NR synthesis.[2, 4, 5] To address this opportunity, Huber and coworkers developed a method to monitor the yield of NRs as a function of seed age using the CINT Microfluidic Synthesis Discovery Platform.™ [6] The platform consists of a custom-fabricated microfluidic chip interfaced with computer control of fluidic flow, reaction temperature, and real-time optical monitoring. In these experiments, a seed solution of Au NPs ages until injection and then is mixed with a growth solution on a microfluidic chip fitted with real-time UV-visible spectroscopy (Figure 1A). The yield of rods, calculated by monitoring the longitudinal plasmon resonance, diminishes rapidly as seeds age but recovers if new seeds are injected (Figure 1B). An immediate 30x dilution of seeds effectively arrests aging, permitting continuous synthesis of Au NRs with high yield (Figure 1C). Off-chip experiments revealed that seeds critical for NR growth are less than 1.1 nm in diameter and that they are quickly lost to Ostwald ripening during aging. *The immediate seed dilution approach afforded by microfluidic synthesis offers a means for continuous Au NR synthesis.* Going forward, we are investigating the on-chip synthesis and dilution of seeds to consistently produce the highest rod yield possible. This will involve the design of a more intricate chip as well as more advanced fluid control that will enable CINT and user science.

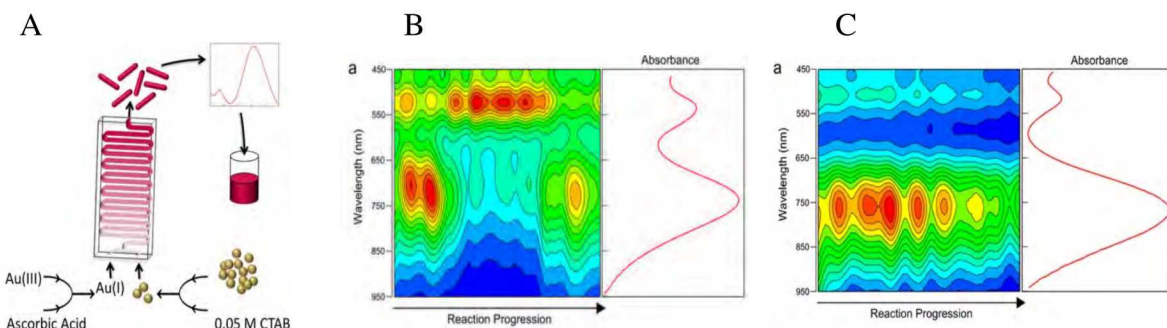


Figure 1. (A) Schematic of microfluidic experiments. (B) 3D graph of visible absorption during in situ seed aging. The longitudinal plasmon resonance (near 750 nm) of the rods drops rapidly as seeds age but recovers when freshly prepared seeds are injected near the end of the experiment. (C) 3D graph of visible absorption using pre-diluted seeds. Yield of rods is constant, as dilution dramatically slows aging of the seeds.

6.2.1.2. *Synthesis of nanomaterials for transformative biodetection and imaging.* Fluorescent nanoclusters (NCs), composed of only several atoms (2–144 atoms) and with physical dimensions close to the Fermi wavelength of an electron (ca. 0.5 nm for Au and Ag), are the link between the elements and NPs.[7-9] Au and Ag noble metal NCs exhibit fluorescence emission spanning the UV to NIR and are attracting significant interest because of their tunable photophysical properties and biomediated synthesis. Previously, Martinez, Goodwin, and Werner established the core capability of solution-based synthesis, characterization, and

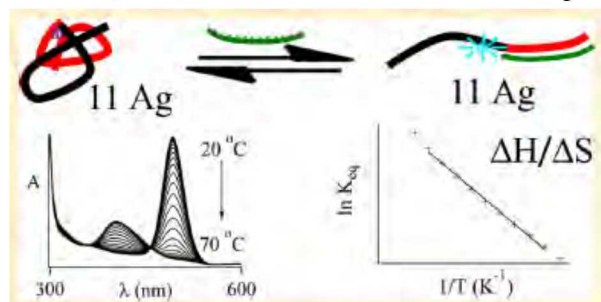


Figure 2. DNA-templated NCs are both chromophores and ligands that modulate analyte–sensor interactions.

application of metal nanoclusters within CINT.[10-23] Work advancing the *in situ* synthesis of the NCs within DNA has led to NCs that exhibit distinct narrow excitation and emission profiles commensurate with common laser lines. The work of CINT users studying Ag NCs and their DNA template has yielded a new DNA detection method, finding that a Ag NC can modulate its emission while remaining a size-selected cluster, with hybridization (Figure 2).[13] Thus, this work demonstrates that a NC can function in two modes: (1) as an optical (chromophore) reporter; and (2) as a ligand that modulates analyte–sensor interactions. Work carried out jointly between SBCN and TSNP thrusts in CINT has examined the assembly of NCs through DNA hybridization. DNA, with its defined base pairing and persistence length, is an ideal molecular ruler for understanding the coupling between fluorophores. We recently have developed both highly stable and bright Ag NCs that are amenable to assembly only recently.[17] As evidenced by large red shifts in emission characteristics, D3-AgNC and our small molecule protected clusters undergo a series of steps from monomer to dimer to larger aggregates upon concentration changes.[11] To understand the steps in coupling, assembled dimers of NCs (via design of extended toehold regions within the D3-DNA, AgNC template) have been prepared and characterized.[11] Dimers possess unusually strong dipole coupling (greater than the coupling strengths of the organic oligomers).[24] Because this is DNA, the effect is readily reversible with temperature and can be used for the sensitive detection of bioanalytes in sensing or imaging.

More recently, with CINT user Professor Atanassov from the University of New Mexico (RA2015A0006), we showed that DNA–Au NCs coupled with carbon nanotubes (or graphene) and bioelectrocatalytic enzymes (bilirubin oxidase) form functional assemblies that enhance electron transfer and lower the overpotential of electrocatalytic oxygen reduction.[25] These DNA–NC assemblies offer enormous potential for the development of cathodes in enzymatic fuel cells. *This work has established DNA-Au NCs not only are as useful fluorescent reporters for imaging and detection but also can serve as electron transfer mediators.*

6.2.1.3. *Spatiotemporal imaging on the nanoscale.* The development of methods for tracking 3D molecular motion is an enabling technology spanning many fields, from fundamental cellular biology (e.g., biomolecular trafficking) to probing the dynamic organization of nanomaterials. Previously, the Werner and Goodwin laboratories within SBCN/CINT developed a fluorescence microscope capable of following the motion of individual fluorescent NPs (e.g., quantum dots [QDs]) as they diffuse in 3D at rates comparable to protein trafficking in cells ( $\mu\text{m/s}$ ).[26-30] The approach uses a custom-built confocal microscope with a unique spatial filter geometry and active feedback 200 times per second. Although semiconductor QDs have been used successfully in numerous single-particle tracking (SPT) studies because of their high photoluminescence efficiency, photostability, and broad palette of emission colors, conventional QDs exhibit fluorescence intermittency or “blinking,” which causes ambiguity in particle trajectory analysis and limits tracking duration. Recently, with CINT users Diane Lidke and Bridget Wilson of the University of New Mexico Pathology Department and in collaboration with the NPON thrust (Jennifer Hollingsworth), we demonstrated the use of nonblinking “giant” QDs (gQDs) to study allergy receptor dynamics before and after antigen stimulation in live cells.[30],[31] We note that the IgE-FcεR1 receptor complex is a primary

component of the allergic response and an ideal model system for studying complex biochemical signal transduction cascades.[27] Using the nonblinking QDs, we observed a 7-fold increase in the probability of observing IgE-FcεRI for longer than 1 min compared to commercially available QDs. The increase in tracking duration for the gQDs allows the observation of multiple changes in diffusion rates of individual IgE-FcεRI receptors occurring on long (>1 min) time scales, which we quantified using a time-dependent diffusion coefficient and hidden Markov modeling.[30] This work demonstrates the utility of using nonblinking gQDs as a tool for live cell 2D and 3D SPT studies, especially in cases in which changes in cellular dynamics occur on a time scale of several minutes. We note that following 3D molecular dynamics for long (minute) time periods in live cells requires both a photostable nonblinking probe (such as gQDs) and a means of tracking the motion in 3 dimensions, which is possible only by using two previous CINT-developed technologies, SPT and gQDs. This work was featured on the frontispiece of *Advanced Functional Materials* in August of 2014 (Figure 3). *By combining two CINT-developed technologies, 3D single molecule tracking microscopy with nonblinking QDs, new opportunities for studying long time scale functional dynamics is possible.*

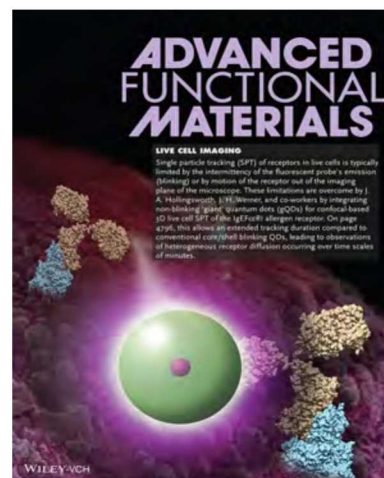


Figure 3. Frontispiece from *Advanced Functional Materials*.

**6.2.1.4. Super-resolution imaging of fluorescence dynamics in QD clusters.** Functional QD devices (e.g., photovoltaics or solid state lighting) use collections of QDs, whereas much of our photophysical understanding of QDs comes from isolated, individual particles. To begin to understand ensemble QD photophysics relevant to functional devices, we are using super-resolution fluorescence microscopy correlated with scanning electron microscopy to study energy transfer dynamics in small ( $n \sim 3$ ) clusters of CdSe/ZnS core-shell QDs in collaboration with external CINT users Professor Alan Van Orden and graduate student Duncan Ryan (Department of Chemistry, Colorado State University).[32] The super-resolution optical images (Figure 4, left column) were reconstructed from the centroid positions of diffraction-limited optical microscopy image sequences of isolated QD clusters using a multicolor through objective total internal reflection (or Hi-Lo) microscope system for single-molecule localization-based microscopy (e.g., PALM- or STORM-type imaging) constructed by Werner and co-workers.[33] Although a number of laboratories have built such systems, to the best of our knowledge, the single-molecule localization-based super-resolution imaging at CINT is unique among the Nanoscale Science Research Centers. These co-registered images enable correlating cluster structure with cluster emission. For clusters exhibiting high energy transfer efficiency, energy transfer within the cluster is evidenced by a “hot spot” indicating a region of dominant emission (Figure 4C) that presumably localizes the position of the terminal energy acceptor within the cluster. *Correlation of the super-resolution optical and SEM images provides better understanding of energy transfer in QD clusters.* SEM imaging provides the complete structure and context for interpreting the distribution of localizations and where the intensity levels fall within that distribution. Moreover, because energy transfer models depend intimately on the interparticle spacing, SEM images could be used to extract transfer rates from the exact geometry

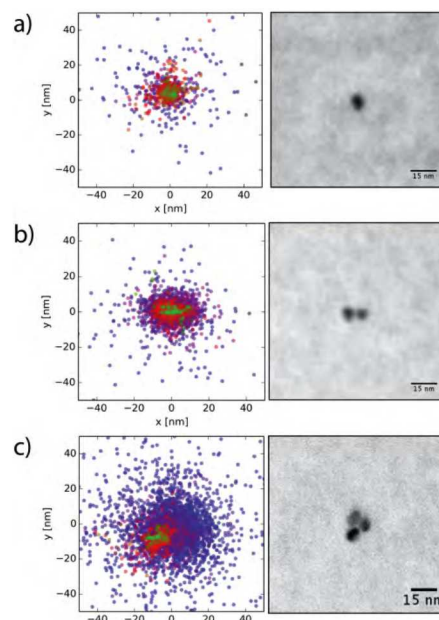


Figure 4. Pairs of correlated super-resolution optical (left) and SEM (right) images of a single QD (a), a dimer cluster showing low energy transfer efficiency (b), and a trimer cluster exhibiting high energy transfer efficiency. The color scales in the optical images indicate the emission intensity (blue, red, green = low, medium, high) comprising each localization fit (point). All of the optical and SEM images are displayed using the same lateral scale. The scale bars in the SEM images are 15 nm.

of a cluster and include the contributions from every particle (in contrast to considering only nearest neighbors or single donor-acceptor pairs), leading to a better understanding of QD cluster photophysics in device-relevant geometries and densities.

### 6.2.2. Functional Nanostructured Soft Materials.

One goal in nanoscience is the development of materials and strategies for harnessing the exceptional properties of individual nanoconstituents to form functional materials, composites, and, ultimately, devices. To bridge the gap between nanoparticulate materials being scientifically interesting and technologically useful approaches for stabilizing the individual NPs without loss of their functionality have been primarily achieved through simple admixing NPs within polymers to create composites with the additive value of the individual components. The next frontier, however, lies in the development of multiscale assembly that achieves the precise positioning of NPs (defined geometry and distance between NPs) over extended length scales. To address this opportunity, the SBCN thrust has a significant effort in the design and solution-based synthesis of structured, dynamic soft materials for active scaffolding to organize functional nanoparticles.

**6.2.2.2. Block copolymers as artificial biomembranes.** Amphiphilic block copolymers are an important component of the thrust's portfolio on nanostructured dynamic materials. Unlike naturally derived lipid-based materials, polymer-based vesicles (polymersomes) exhibit enhanced membrane stability and can be chemically tailored, thus offering enormous potential in the area of biomimetic materials for soft nanotechnology. For example, they are ideal candidate materials for biosensors/biologically sensitive field-effect transistors that require operation in demanding environments. Previously, Paxton and coworkers reported on the response of polymersomes composed of poly(ethylene oxide-*b*-butadiene) (PEO-PBD) to transmembrane pH gradients.[34] This work found the ion permeability of PEO-PBD vesicles to be comparable to that of lipid vesicles. Membrane permeability of PEO-PBD can be tuned through control of the molecular weight (i.e., membrane thickness). Temporal stability of the pH gradients, up to pH of 6, for PEO-PBD was also found to be capable of maintaining gradients for several weeks. The ability to partition acid-ionizable species inside PEO-PBD vesicles was further demonstrated. The use of the pH gradients to drive spatially confined chemical reactions inside the high-pH interior of the vesicle was also proven. For example, fluorescein diacetate, uncharged at low pH, passes through the PEO-PBD membrane into the region of high pH located in the polymersome interior, where it becomes emissive as it hydrolyzes in the more alkaline environment (Figure 5). Thus, pH-gradient vesicles can act as artificial lysosomes, facilitating the collection and digestion of materials that can be hydrolyzed in alkaline environments. Collectively, these studies suggest the use of polymersomes as nanoreactors for harnessing chemical transformations that are carried out under normally unfavorable conditions.

Mechanical stability of PEO-PBD vesicles was also studied. Here, the physical agitation of suspensions of 200-nm polymersomes drove their fusion into giant (>1  $\mu\text{m}$ ) vesicles in dilute aqueous NaCl solutions, a process

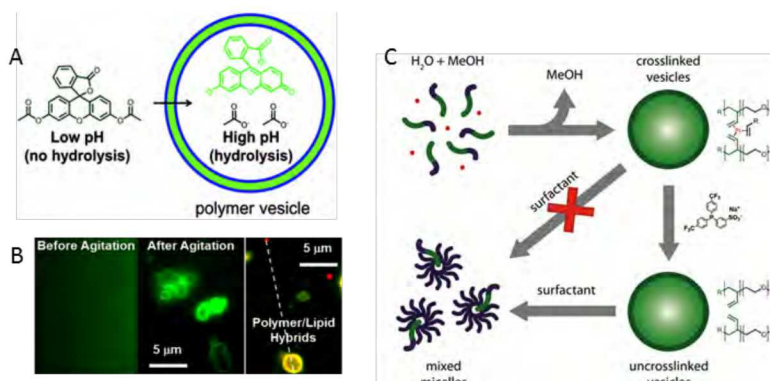


Figure 5. (A) Schematic of pH gradient-driven flux of fluorescein diacetate from low pH to high pH. (B) Mechanically activated fusion polymer vesicles by themselves or with lipid vesicles in dilute salt solutions form polymer/lipid hybrid vesicles (yellow) from polymer (green) and lipid (red) vesicles. (C) Formation and disassembly of Pt-crosslinked PEO-PBD. Vesicles prepared from MeOH/H<sub>2</sub>O suspensions containing PEO-PBD and Karsedt's catalyst by evaporating off the organic solvent. Noncovalently crosslinked vesicles are resistant to surfactant dissolution (i.e., Triton X-100). The metal-ligand crosslinks can be removed with competing ligand (p-DANPHOS), and the polymer vesicles can be subsequently destabilized into smaller structures with the addition of surfactant.

that does not occur with lipid-only vesicles.[35] This unusual effect is attributed to the interaction of the salt with the PEO chains, which reduces steric resistance to fusion. *The ability to use mechanical agitation to prepare hybrid lipid/polymer membranes is important, because it offers a facile approach for the preparation of hybrid assemblies possessing the robustness of a synthetic polymer with the fluidity of biological membranes, materials characteristics amenable for the co-encapsulation and organization of both natural and engineered functional nanoparticles.*

**6.2.2.3. Spatial localization of nanoparticles during network polymer formation.** Synthetic protocols that combine production of a durable, structured scaffold concomitant with *in-situ* formation of nanoparticles offer the greatest potential for controlling particle matrix interactions, achieving spatially organized nanoparticles all while reducing the number of synthetic steps in nanocomposite formation. Firestone and co-workers sought to adapt the principles of cascade syntheses; an approach used in natural products chemistry to combine multiple reactants and / or catalysts in a single “pot” for the execution of multiple sequential or tandem reaction steps to generate a complex target. To this end, a multistep cascade synthesis of a self-supporting, hierarchically structured, solvent responsive Au NP composite was developed (Figure 6).[36] The composite was spontaneously prepared from a self-assembled noncovalent lamellar lyotropic mesophase

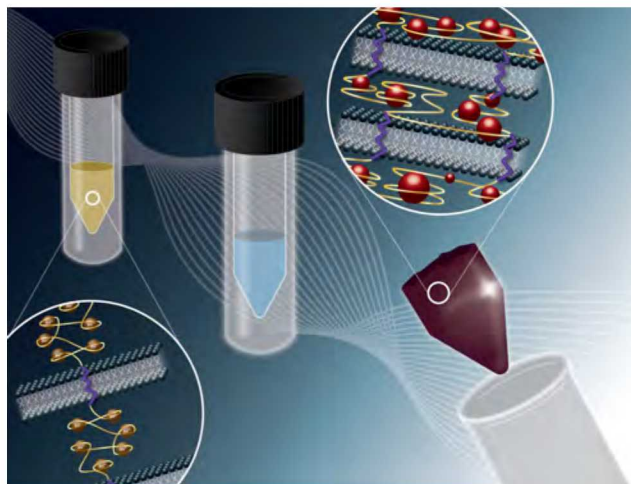


Figure 6. Schematic of cascade synthesis of a Au NP–network polymer composite. Cover inset image *Nanoscale* 2016.

composed of amphiphiles that support the reactive constituents, a mixture of hydroxyl- and acrylate-end-derivatized PEO-PPO-PEO and  $[\text{AuCl}_4^-]$ . [36],[37] The reaction scheme begins with the autoreduction of aqueous  $[\text{AuCl}_4^-]$  by PEO-PPO-PEO, which leads to the production of both the Au NPs and a transition metal redox cycle that serves to catalyze the atom transfer radical polymerization/crosslinking of the acrylate-end-derivatized PEO-PPO-PEO. Optical spectroscopy and transmission electron microscopy (with Katherine Jungjohann, CINT, NEMS) were used to monitor reduction of  $[\text{AuCl}_4^-]$ , formation of large aggregated Au NPs, and oxidative etching into a final state of dispersed spherical Au NPs with in a multilamellar structured network polymer hydrogel. Attenuated total reflectance/Fourier transform IR spectroscopy and thermal analysis confirmed acrylate crosslinking and production of a chemical gel. X-ray scattering (small-angle and wide-angle) monitored the evolution of the multilamellar structured mesophase during reaction and the presence of semicrystalline PEO confined within the water layers. The Au NP hydrogel composite could be reversibly swollen with water with full structural recovery and without loss of the well-entrained Au NPs. Optical spectroscopy showed a 10 nm shift in the surface plasmon resonance between the swollen and contracted states attributed to the solvent-mediated modulation of the internal NP packing arrangement. *This is the first report of the formation of a monolithic material prepared through cascade synthesis that transforms not only the reactants but the supporting scaffold into a functionally integrated nanostructure.*

**6.2.2.4. Biomacromolecule-assisted patterning of lipid assemblies.** Surface supported lipid membranes provide a fluid 2D matrix in which nanoconstituents can be assembled and organized. Montañó and coworkers developed biomacromolecule-mediated patterning of lipids using an endotoxin, lipopolysaccharide (LPS), a component of bacterial cell walls.[38, 39] In this method, microcontact printing is used to create an elastomeric stamp carrying the desired geometric pattern. The stamp is then “inked” with an octadecyltrichlorosilane and transferred onto a hydrophilic surface (Figure 7B, left panel). DOPC liposomes containing a small amount of dye are added to the substrate and spontaneously form uniform, continuous patterns of lipid bilayers (light green features in Figure 7B, left panel) and lipid monolayers (dark green

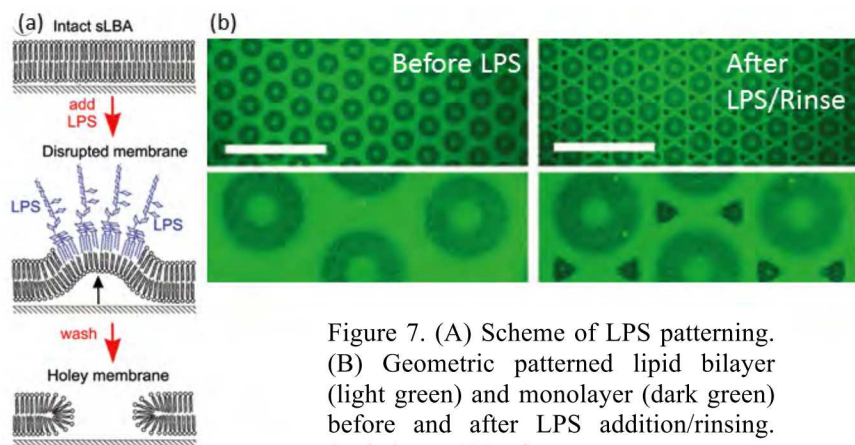


Figure 7. (A) Scheme of LPS patterning. (B) Geometric patterned lipid bilayer (light green) and monolayer (dark green) before and after LPS addition/rinsing. Scale bar = 100 micron.

“doughnuts” (Figure 7B). The LPS approach also allows for serial membrane modification, repair, and/or adjustment of composition. *Unlike traditional mechanical patterning approaches, using a biomacromolecule, such as LPS, to pattern is an inexpensive solution-based approach and is scalable.* Lastly, various serotypes (strains isolated from different organisms) of LPS can generate holes at different temperatures, offering a path forward for creating mixed-lipid compositions by exploiting the LPS temperature dependence. Future efforts will continue to explore the diversity of biomacromolecule-mediated patterning and the application of this approach to 3D-ordered arrays for nanophotonic materials. *Using biomacromolecules to pattern or augment features in lipid assemblies represents an important “bridging” technology for successfully interfacing bottom-up self-assembly with top-down lithography.*

**6.2.2.5. Protein-driven assembly of nanostructures.** The use of biomolecular motors to perform active assembly provides unique opportunities for the creation of far-from-equilibrium soft nanostructures. Motor proteins such as kinesin have been studied as “assemblers” of nonequilibrium, supramolecular composites and as “molecular shuttles” in nanofluidic systems. [40–43] Kinesin motor proteins are adsorbed onto solid surfaces (e.g., glass, Si, Au), forming a planar monolayer. Microtubule filaments, along with attached cargos, are able to glide across this protein monolayer at rates as high as  $5 \mu\text{m s}^{-1}$  through the consumption of fuel (ATP) by the motors (Figure 8). A significant challenge to the use of kinesin (and other motor proteins) is the inability to impart stability and control in *ex vivo* environments. CINT has developed the capability for engineering kinesin (and other biomolecular motors) to address issues of both control (e.g., on/off switch) and stability, as well as to incorporate “chemical handles” on motors to enable integration.[44–48] In addition, a number of functionalization schemes to enable the attachment of cargo (e.g., NPs to microtubules) have been achieved and have been used to establish a means of actively assembling nanocomposite structures[49–52].[53–56] For example, Bachand and Paxton used this transport system to actively assemble networks of block copolymer nanotubes.[49] Amphiphilic block copolymers typically assemble into a narrow range of morphologies in solution (i.e., micelles, supported bilayers), limiting their use in the creation of nanocomposites. To overcome these limitations, active transport by kinesin motors was used to assemble mesoscale networks (hundreds of microns to tens of millimeters in total size) that were composed of block copolymer nanotubes (30–50 nm in diameter).[49] Here, the motors catalyze the hydrolysis of ATP and produce sufficient force to deform polymersomes and subsequently extrude polymer nanotubes

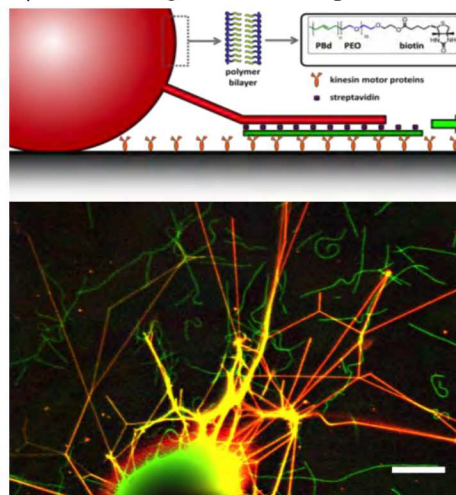


Figure 8. (Top) Schematic illustration of biomolecular motors extruding polymer nanotubes from a source polymersome. (Bottom) Fluorescence micrograph of polymer nanotube network (red/yellow) and microtubules (green).



forming large networks. We further showed that the addition of a fluidizer (lipid) adjusted the size and morphology by lowering the barrier height required to extrude nanotubes.

Professor H. Hess (Columbia University) demonstrated for the first time that CINT's biomolecular motors experience "wear." [56] Here, the chemomechanical energy transduction of kinesin motors is accompanied by protein friction, which induces molecular wear where tubulin dimers are removed molecule-by-molecule by kinesin motors. The molecular wear resulted in continuous shortening of microtubule shuttles during transport and was nonlinearly dependent on the surface density of the kinesin motors. Specifically, the rates of shortening were significantly greater when the motor density was above the mushroom-to-brush transition. [56] *This knowledge is critical to understanding the limitations of biomolecular nanomachines and also motivates efforts to improve the robustness of biomolecular-powered nanosystems through enhanced self-repair mechanisms.*

### 6.3 Future Work

#### 6.3.1. Multilength scale fluidics for optimized synthesis of nanoparticles.

Building on our prior efforts in microfluidics for NP synthesis [6] and real-time characterization, we will work to fabricate and test multilength scale (millimeters to nanometers) fluidic devices. A specific area of investigation during this funding period will be droplet-generating chips used in NP and/or genetically encoded polypeptide synthesis (section 6.2.2.4). Efforts in this area have been hampered by the inability to precisely control the size and shape of the small orifices used to generate droplets with sizes ranging from 10  $\mu\text{m}$  to 100  $\mu\text{m}$ . [57-59] The limitation in small-droplet production arises primarily from restricted flow due to excess backpressure in the channels of reduced dimension (<100  $\mu\text{m}$ ). [60] Multiscale fabricated fluidic platforms will offer a means to address this limitation through tapering the internal channel structure/dimensions. A multilength scale fluidic device featuring massively parallel micron to submicron channel structures will also permit tunable flow focusing and systematic variation in droplet sizes and will increase throughput. Traditionally, however, creation of nanoscale or multiscale fluidic structures has required different (and incompatible) fabrication techniques, making it impractical to combine varying length scales into a single device. SBCN's planned efforts for introducing capabilities for 2D and 3D soft matter fabrication will allow us to address this limitation by combining a wide range of length scales into unique single devices. By combining 3D printing, laser cutting, and two-photon nanolithography, we will create features from nanometers to multiple millimeters in a single device. This can be achieved in a number of ways. Nanoscale features will be printed using our planned institutional investment in the Nanoscribe™ instrument. The Nanoscribe uses a tightly focused laser to perform two-photon photolithography in a near diffraction limited voxel. [61] The Nanoscribe™ can conveniently fabricate parts that are nanopatterned, containing, for example, nanoscopic orifices, but micron-scale overall. This allows the parts to be integrated into a microfluidic system that is fabricated using 3D printing and/or laser cutting, and this system can then be integrated into a larger-scale millifluidic device. The coupling of microfluidic parts to millifluidic packages in a simple and convenient approach has been recently demonstrated at CINT (Figure 9). *We expect this new capability to enable a wide range of new fluidic approaches to materials synthesis and characterization, allowing unprecedented control and tuning of shear and flow over many orders of magnitude.*

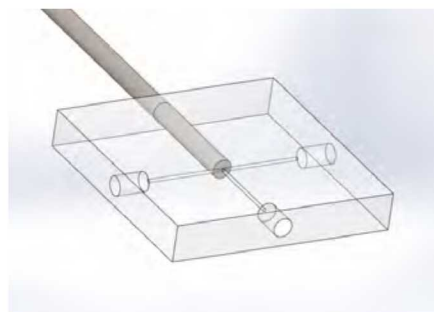


Figure 9. 3D rendering of the integration of nanoscale- patterned pores/channels into a micro- or millifluidic platform. Economical, disposable droplet- generating chips.

#### 6.3.2. Soft nanostructures for heterogeneous component integration.

Beyond the synthesis and fabrication of simple homogeneous (a single type of nanoparticle) composites, we seek to create integrated systems that combine multiple functional nanoconstituents. This work requires the development of internally structured soft materials that can precisely position heterogeneous components such as proteins with inorganic nanoparticles. Another research objective will involve responsive (dynamic)

soft matrices that can drive structural reorganization and give rise to associated macroscopic changes. Lastly, thrust efforts also seek to introduce soft fabrication strategies that will effectively combine self-assembly with lithography and patterning to achieve assembly of disparate materials from the nano- to micro-length scales. One approach to constructing functional nanocomposites involves the development of hybrid natural/synthetic systems in which, for example, natural “molecular machinery” (i.e., proteins, enzymes, etc.) is integrated into reconfigurable synthetic systems that are biomolecule- (i.e., protein) compatible (i.e., artificial biomembranes). The result would be a class of composite materials that are able to extend the use of naturally derived molecules beyond what evolution has intended and at the same time permit their application in nonbiological environments. The ability to harness the functionality of proteins outside of the cell could lead to the development of bio-based systems useful for advancing alternative/renewable energy storage or production. An additional avenue of investigation will involve NP–biomolecule hybrid materials. This component of the thrust will build on Montañó, Paxton, Martinez, and Firestone’s efforts to design and synthesize a range of bio-derived, wholly synthetic and hybrid biocompatible soft matrices for stable cointegration of membrane and soluble proteins and their complexes with inorganic nanoparticles to produce hetero-component composites.

*6.3.2.1. Network polymer–hetero-nanoconstituent composites.* Stimuli-responsive nanostructured network polymers that mimic natural cellular environments yet possess chemically distinct domains that can support the cointegration of multiple functional constituents will be studied. These materials will be prepared from multi-component amphiphile-water quaternary mixtures (i.e., complex fluids) whose composition and properties are readily tuned to allow for the incorporation of a wide range of soluble and membrane proteins.[62, 63] [64-70] Prior studies have further demonstrated successful integration of a range of functional guests including small molecules (chromophores), inorganic NPs (Au, gQDs, nanodiamond), and light-transducing integral membrane proteins derived from photosynthetic bacteria (e.g., photosynthetic reaction centers [RCs] from purple nonsulfur bacteria and bacteriorhodopsin [bR; light-induced proton pump]).[36, 63, 68, 71-73] We shall work to adapt the cascade synthesis approach developed by Firestone and co-workers to prepare Au NP–network polymer composites. Co-integration of the light-transducing membrane protein (e.g., RCs) will be accomplished by re-constitution via exploitation of the thermo-inverted phase transition (low viscosity at reduced temperatures and physical gelation upon heating) of the complex fluids. The complex fluid composition will be modified to contain reactive components that will lead to both the *in situ* generation (and spatial localization) of Au NPs and polymerization / crosslinking to form a composite co-integrating RCs and Au NPs in a network polymer. The cointegration of Au NPs with a light-transducing protein is expected to lead to synergistic electrochemical interactions between them (Figure 10). That is, we anticipate that by achieving precise positioning and optimized packing density of a layer of *in situ*–formed Au NP at the protein-doped membrane interface, charge generated by the light transducing proteins will be coupled efficiently into the conductive (Au NP) layer. The preparation of an integrated Au NP–membrane protein polymer composite will yield a simple protein-based electronic device. Beyond achieving sufficient packing density of the Au NPs for electronic transport, vectorial alignment of the reconstituted proteins will also be required. That is, directional electron transfer (RC) or proton pumping (bR) will necessitate uniaxial positioning of the proteins within the bilayer, which may be achieved via electrostatic adjustment of the molecular amphiphiles to promote a defined orientation, by a.c. electric field poling (dipolar alignment of the protein) and/or through lithography and patterning. Lastly, the monomers and initiator comprising the complex fluids will be modified making them amenable to two-photon polymerization for top-down patterning in 3D using our newly acquired Nanoscribe™ instrument. *It is anticipated that*

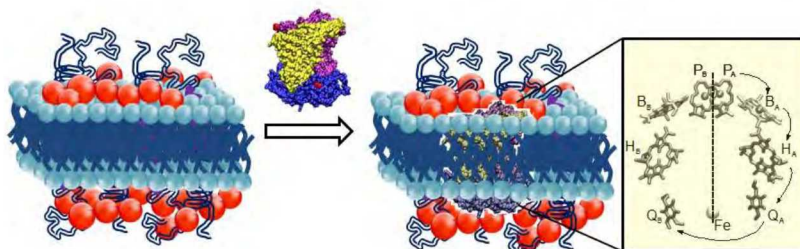


Figure 10. Preparation of a Au NP–polymer composite with reconstituted photosynthetic reaction center proteins that will form a bioelectronic device.

*this work will offer a facile, inexpensive path forward to overcome limitations in harnessing the properties of multiple functional nanocomponents and will serve as an ideal material for efforts producing a multiscale and multidimensional assembly of nanoscale building blocks.*

### 6.3.2.2 Protein-based polymersomes/block copolymer composites.

We will investigate local chemical or physical environment (stimulus) generated by an integrated transmembrane or soluble protein within self-assembled polymer vesicles (polymersomes). Several modes of stimulus-induced phenomena will be studied: (1) shape-changing vesicles, (2) intramembrane electrophoresis, and (3) autoelectrophoretic propulsion. Shape-changing vesicles

will be prepared using thermoresponsive amphiphilic poly-NIPAAm containing membrane-bound urease that catalyzes exergonic hydrolysis of urea and is thus capable of localized heating (Figure 11). Localized heating will produce stresses in the thermoresponsive membrane, inducing morphological changes in the polymer chains. Arrangement of ion transport proteins (e.g., bR) in PEO-PBD vesicles will exploit the protein-generated electrochemical gradient for electro-osmotic “recruitment” of charged components to the polymer vesicles. As previously predicted[74] and demonstrated for bimetallic NRs[75], the generated local electric fields will induce autoelectrophoresis. Preparation of these composites will require addressing the following materials issues: (1) radially asymmetric bR containing polymersomes, and (2) axially asymmetric bR containing an asymmetric distribution of oriented bR. Such structures, in principle, are capable of self-propulsion by an ion-drag mechanism upon photoirradiation. *This effort will yield a new class of hierarchical materials—those with catalysts that generate a stimulus that acts on the supporting matrix.*

Luminescent solar concentrators have the potential to be used as transparent solar energy harvesters that can be coupled to photovoltaics for increased output. Specifically, biomimetic membranes consisting of organized photonic components (e.g., chlorophyll, bacteriochlorophyll, QDs) will be ordered within dynamic membranes, yielding efficient light harvesting and energy transfer in two and three dimensions (Figure 12). This work will first use amphiphilic block copolymers such as poly(ethylene oxide)-block-

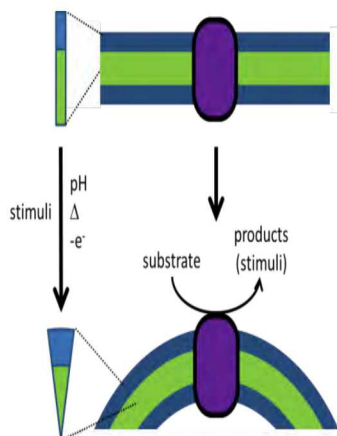


Figure 11. Schematic representation of composite consisting of a localized biotic (enzyme) catalyst, urease, catalyzing an exothermic chemical reaction bound to an abiotic poly-NIPAAm-conjugate vesicle (pH responsive). The catalytic reaction produces localized pH and heat changes altering the shape parameter of the individual polymers (left), and, by extension, the morphology of the synthetic membranes they comprise (right).

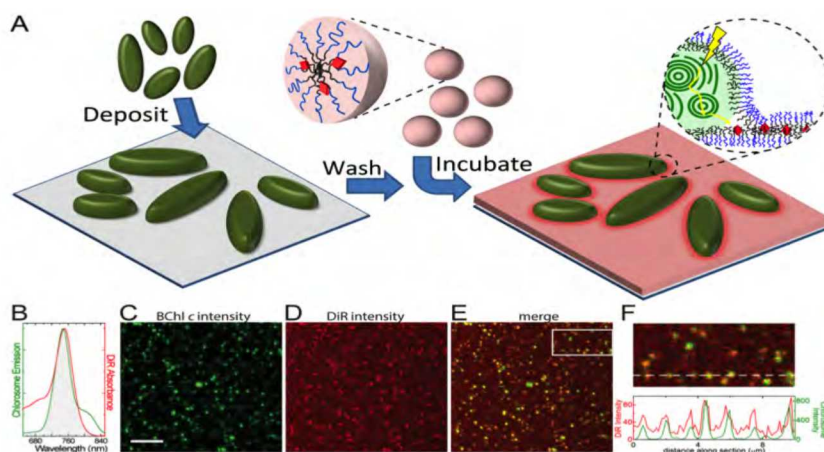


Figure 12. 3D energy transfer in a spatial-energetic polymer landscape. (A) Representation of the assembly process. PCNs are drop cast on hydrophilic glass and immobilized. Sample is backfilled with PEO-b-PBD micelles containing DiR acceptor chromophores to form a continuous bilayer film between and around the deposited PCNs. With selective excitation in to BChl c, emission from DiR is observed, demonstrating energy transfer. (B) Spectral overlap of PCN emission (green) and DiR absorbance (red). (C–E) Fluorescence images showing the distribution and location fluorescence intensity from PCNs (C), DiR (D), and the merged image (E). (F) Magnified view of the boxed area in (E) along with the intensity profile of the PCN and DiR components along the indicated line. The scale bar in (C) represents 5  $\mu\text{m}$

polybutadiene (pEO-b-PBD) as an insertion platform for the nanoconstituents. High-efficiency light harvesters, such as artificial chlorosome constructs previously developed by our group, will be extraneously coupled to the polymer membranes to enhance spectral coverage (Figure 12).[76] polymeric chlorosome nanocomposites (PCNs; energy transfer donors) contain the energy transfer acceptor. These constructs result in 3D films that demonstrate efficient light harvesting and supramolecular energy transfer rates >55%, showing the feasibility of our design. The advantage of such an approach is that extraneous components are modular and thus have the potential to be added, removed, or coupled into a system at will. 3D architectures will be based on the integration of multiple nanocomposites. Patterning of membranes will exploit our recent technology of using a natural biological amphiphile (LPS) to induce highly ordered/in registry membrane modifications in lipid bilayer assemblies[38, 39], not readily achievable using traditional lithography. *Herein, we will seek to extend such approaches to organize photonic nanoconstituents in desired spatial registries for emergent functional response.*

**6.3.2.3. Genetically encoded optical polymers.** Together with our users [L. Sklar, UNM; C. Strauss, LANL; E. Balog, University of New England; C. Kiss, LANL].[77-82] we are establishing a core capability in the development of genetically encoded polymers (GEPs). For the next funding period, we will leverage preliminary work on stimuli-responsive genetically encoded polymers where we created large ( $10^8$ ) diverse libraries of GEPS and identified cellular reactive polymers, to now create libraries of optically active polymers and sort for those that exhibit defined optical or adaptive response (e.g., for application in solid state lighting/ electrochromic displays). GEPs are polypeptides that are programmed at the DNA level and synthesized by microorganisms, a biosynthetic approach that allows large libraries to be generated (more rapidly than traditional synthetic approaches).[80] The large library is then screened en masse (over days) for a target function or physical property (Figure 13). Here, for example, electrochemical and/or optical properties are dictated by the chemical modification to the polypeptide backbone (i.e., covalent attachment of optical moieties).[77-79, 82] Because sorting can be carried out under a range of environmental conditions (e.g., the conditions under which the polymer is to be used), this discovery landscape allows for rapid generation of functional polymeric materials that are optimized for a target application. To achieve these goals, we will focus on developing GEP libraries using microemulsion synthesis and sorting. Briefly, libraries of elastin-like polymers (the “springs”) will be coupled to structural blocks composed of coils of 20 amino acids (the “rods”) that induce block-to-block assembly through short- and long-range order, ion pairing, or folding. Further encoded will be the ability to coordinate (metals) or append organic (oligomers) moieties. We will use amino-, carboxyl-, thiol-, alkyne-, or hydrazide-functionalized metal-ligand or oligophenylene vinylene appended to amine, thiol, fGly[83] or unnatural amino acids (UAA)[84] containing residues. The photophysical properties of the transition metal and lanthanide complexes provide a facile means of tuning the optical properties across the visible-NIR region. In addition, this procedure will permit redox potential variation (by tens to hundreds of millivolts in the range of 0–2 V vs NHE) through modification of substituent groups, metals, and ancillary ligands. Emulsion droplets, created in high-throughput fluidic devices (see section 6.2.1), will be used to synthesize and then sort each of the polymers for a defined photophysical effect under controlled environmental conditions (e.g. pressure, light excitation, or applied potential).[85-89] We anticipate that this new capability will allow us and our user community to rapidly generate macromolecules exhibiting a wide range of optical properties applicable to organic light-emitting diodes, electrochromic materials, or optical biomarkers.

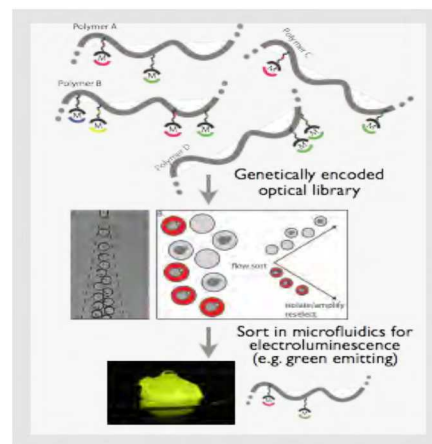


Figure 13. Biologically compatible and optoelectronic GEPs for optoelectronics. GEP libraries can be synthesized and sorted for those with ideal function (e.g., green luminescence) following application of stimuli (e.g., defined electrical potential) within a microfluidic device.

### 6.3.3. Active motor-driven assembly of multidimensional materials.

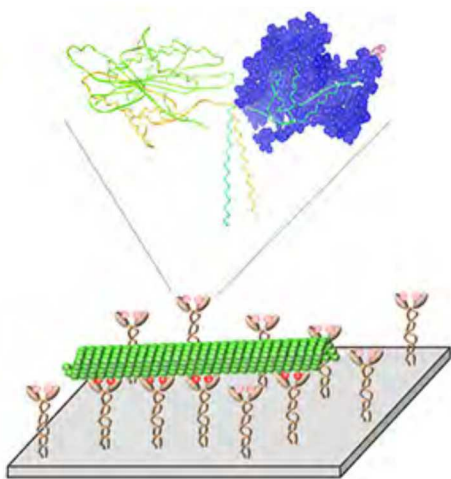


Figure 14. Characterizing the collective behavior of kinesin nanomotors in the gliding of microtubules across a surface using smFRET. Core activities that comprise the SBCN thrust. Core activities

Our capability in biomolecular nanomotors will be expanded to include site-specific labeling with unnatural amino acids (UAAs) such as *p*-(propargyloxy)-phenylalanine. Transformative advances in synthetic biology now permit the incorporation of nonbiological functional groups into proteins. The bio-orthogonal chemistries offered by UAAs will be used to alter, modulate, and characterize the function of proteins.[84, 90] For example, the catalytic efficiency of an enzyme could be enhanced by selectively incorporating UAAs into the active protein.[91-93] This approach can be used for the selective placement of unique chemical moieties to aid the study (structure-function) of nanomotors at the single molecule level.[94, 95] Fundamental studies on individual nanomotors will focus on understanding how they coordinate their function and collectively enable molecular transport. We anticipate that this information will advance the design and development of “smart” materials and systems. Initially, UAAs will be applied to kinesin nanomotors. Amino acids close to the microtubule binding domain will be targeted in order to introduce site-specific moieties amenable to labeling the protein with a fluorescent dye, making it applicable to single-molecule fluorescence resonance energy transfer (smFRET) experiments (Figure 14). Post modification of the

UAA site with an optical reporter group will be achieved by using Cu-catalyzed alkyne-azide cycloaddition to an azide-derivatized dye. Working with CINT user Professor Henry Hess (Columbia) and Werner/Goodwin, we will perform smFRET assays. These studies will characterize the number of kinesin nanomotors bound to a microtubule and their temporal variation. In addition, these studies will provide insights regarding collective dynamics of nanomotors and microtubule gliding. The mechanism underlying the “molecular wear” phenomena recently reported by the Hess group will also be studied[56] In conjunction with these studies, continued efforts on nanomotor transport (efficient chemomechanical energy conversion) to actively assemble hybrid composites that span multiple length scales (e.g., nano to meso) and enable self-healing properties will continue.[40] Specifically, approaches to move beyond planar (2D) surface constructs and generation and implementation of 3D platforms for active assembly of multiscale and multidimensional hybrid materials will be conducted. The soft lithography/patterning work will build on our recent efforts with CINT user Virginia VanDelinder. Here photolithography and replica molding produced a multilayer PDMS–microfluidic device for the active assembly through controlled delivery of biomolecular and NP building blocks while minimizing the photo-induced inactivation of kinesin nanomotors.[96, 97] Using a similar approach, UAA active assembly of NPs (e.g., QDs) into novel 3D composites will be pursued. Motor transport and assembly of these will be characterized with high spatial and temporal resolution using our 3D optical tracking microscope (Werner). *This will not only further CINT’s capability in biomolecular synthesis but will also aid in advancing our visualization (single-molecule tracking/imaging) efforts.*

### 6.3.3. Visualization of soft materials

**6.3.3.1. Spatiotemporal imaging on the nanoscale.** smFRET has emerged as a powerful tool for studying biomolecular conformation and conformational dynamics.[98] However, most smFRET studies to date examine molecules immobilized on a surface (for increased observation time) or molecules rapidly diffusing through a small, nearly diffraction-limited probe volume in solution, providing only a brief snapshot of molecular conformation.[98] To overcome these problems of traditional smFRET, our laboratory recently expanded our 3D single-molecule tracking microscope to simultaneously monitor two colors (a fluorescence donor and acceptor) such that one can follow a single FRET-labeled biomolecule in 3D while simultaneously monitoring its conformation and conformational dynamics.[26, 27, 30, 31, 99] This new two-color 3D

tracking instrument may have a large impact on the study of intrinsically disordered proteins (IDPs), in particular those IDP systems that fold upon binding a target biomolecule.[100] This new instrument should be able to follow the conformation of individual IDPs before, during, and after binding a target (as shown schematically in Figure 15). Our initial focus is on the folding dynamics of small acid-soluble proteins (SASPs) that are intrinsically disordered but fold into a helix turn helix motif upon binding DNA.[101] We hypothesize that SASP folding upon binding will be better described by a conformational selection mechanism of interaction (where proper folding precedes DNA binding, as depicted in Figure 15) than by an induced fit mechanism (where proper folding follows binding to DNA). *We emphasize that unlike smFRET on immobilized samples, 3D tracking smFRET is amenable to studies directly inside living cells, which we propose to perform by introducing FRET-labeled SASPs directly into live cells by electroporation.*

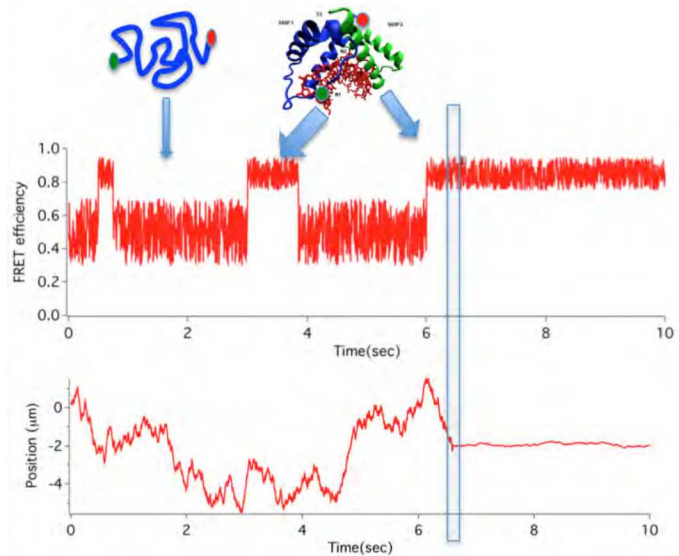


Figure 15. Illustration of how 3D tracking FRET could be used to discern the folding / unfolding of proteins while correlating these events with binding of docking to larger species.

#### 6.3.3.2. A nanoscale view of complex biological processes.

Goodwin, Werner, and Martinez will work to advance CINT capabilities in applying super-resolution fluorescence imaging to monitor the conformation, structure and molecular composition of polymers (including biopolymers such as DNA and polypeptides). In particular, we will use super resolution fluorescence *in-situ* hybridization (SR-FISH) analysis of molecularly combed chromosomal DNA fragments such that we can analyze a controlled and uniform linear deposition of large numbers of aligned DNA fragments (Figure 16) on a solid substrate.[102] DNA combing has proven to be an extremely useful tool for a wide range of genomic studies including optical mapping[102] and the study of DNA replication.[103] Our immediate interest in the development of this capability is our expectation of its utility for high-throughput analysis of telomere conformation.

Telomeres (a repetitive TTAGGG sequence at the end of chromosomes) acts as a molecular clock, with sequences  $\sim 10^4$  base pairs (bp) long at birth shortening with each cell division (except in the germ line and stem cells where length is maintained by telomerase). Telomeres shield chromosome ends from exonucleolytic attack and inappropriate end-joining. In addition to well-known roles in aging and cancer, a surprising long list of diseases is associated telomere dysfunction. Organs most often affected are heart, lung, liver, bone marrow, and retina [104] Our understanding of telomere structure and function is incomplete and subject to scientific debate. Combining CINT strengths in single-molecule and super-resolution fluorescence imaging with the expertise of our New Mexico Consortium (NMC) collaborator, E.H. Goodwin, in telomere biology, we will develop a capability in telomere imaging and use it to answer a central question in this field – *Is telomere function in mammals manifested through a single end-capping structure or multiple structures?* In addition to exploring these fundamental biology questions of interest to CINT users, the

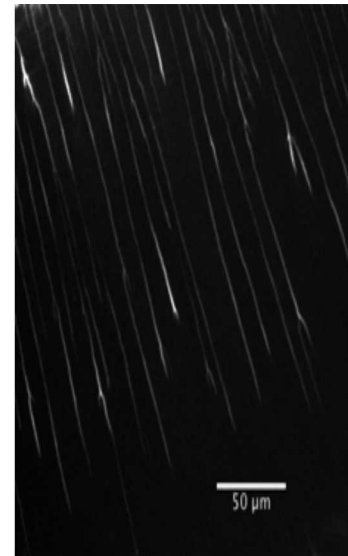


Figure 16. Image of molecularly combed  $\lambda$ -DNA fragments (48,502 base pairs in length). Scale bare is 20 micron

*techniques developed and supported here can be applied to other systems where ordered polymer structure is important (such as LCDs or organic LED displays).*

#### **6.4 Summary**

Future efforts within the SBCN thrust will build on our existing strengths in the synthesis, assembly, and imaging of soft nanomaterials. The proposal describes specific research activities and planned capabilities development for the next 3 years that will position the thrust to achieve more far-reaching goals in these aforementioned areas, including the establishment of a Soft Materials Fabrication Laboratory within CINT. In the area of functional nanoconstituent synthesis, the thrust strives to achieve reliable, high throughput syntheses of inorganic nanoparticles and emulsion droplets by fabricating a multilength scale fluidic platform. In the field of visualization of nanoscale materials, continued efforts aim to improve the photophysical properties of fluorescent metal nanoclusters for use as optical reporters for imaging and biodetection. Advances in imaging of nanoscale materials will build upon our world-leading capabilities in probing the dynamics of nanocomponents in complex environments through further expansion in multimodal characterization. That is, while 3D single molecule/particle tracking and super resolution fluorescence microscopy yields information on nanoparticle dynamics within complex matrices (trajectories), greater structural details will be provided through the coupling of complementary techniques, such as electron microscopy, atomic force microscopy and X-ray scattering. It is anticipated that integration of these techniques onto a single platform will yield structure and structural dynamics over the Ångstrom to micron length scale.

A second area of focus, outlined within the proposal, is the development of strategies (principles and materials) that will enable the hierarchical assembly of individual nanoconstituents in order to harness their collective or emergent behaviors. Considerable capabilities and expertise reside within the thrust for the synthesis of structured soft materials that serve as platforms for the spatial organization and controlled orientation of encapsulated nanocomponents. Devising approaches that combine bottom up, self-assembly with top-down patterning and lithography for the integration of nanomaterials to create larger-scale systems that are multifunctional and exhibit synergistic or emergent properties will become a major emphasis of the SBCN thrust activities during the next 3 years. The introduction of capabilities for top-down lithographic patterning are essential for achieving long-range ordering and reducing defects that are inherent to self-assembled soft materials. Soft lithography and patterning will also be used for directed self-assembly aiding in the realization of more precise positioning and orientation of nanoscale components encapsulated within the soft nanostructures. In summary, the work planned by the SBCN thrust for achieving multiscale and multidimensional assembly of nanoscale building blocks is critical for realizing the promise of integrative nanoscale manufacturing of new devices for the next generation photonic (e.g., solid-state lighting, lasing, color tuning), electronic (i.e., beyond silicon electronics) and energy storage technologies.

## 7.0 Publications

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102. Michalet, X., et al., *Dynamic molecular combing: stretching the whole human genome for high-resolution studies*. Science, 1997. **277**(5331): p. 1518-23.
103. Pasero, P., A. Bensimon, and E. Schwob, *Single-molecule analysis reveals clustering and epigenetic regulation of replication origins at the yeast rDNA locus*. Genes Dev, 2002. **16**(19): p. 2479-84.
104. Holohan, B., W.E. Wright, and J.W. Shay, *Cell biology of disease: Telomeropathies: an emerging spectrum disorder*. J Cell Biol, 2014. **205**(3): p. 289-99.

**7.2 Publications from Previous Support**

NSRC High Impact Journals	SBCN Publication Count			
	2013	2014	2015	Total
ACS Nano	0	0	1	1
Advanced Functional Materials	1	1	0	2
Advanced Materials	0	0	0	0
Angewandte Chemie International Edition	0	1	0	1
Applied Physics Letters	0	0	0	0
Chemistry of Materials	0	0	2	2
Journal of the American Chemical Society	0	0	1	1
Nano Letters	1	0	1	2
Nanoscale	0	0	1	1
Nature	0	0	0	0
Nature Chemistry	0	0	0	0
Nature Communications	0	0	0	0
Nature Materials	0	0	0	0
Nature Nanotechnology	0	0	1	1
Nature Photonics	0	0	0	0
Nature Physics	0	0	0	0
Physical Review Letters	0	0	0	0
Proceedings of the National Academy of Sciences USA	0	0	0	0
Science	0	0	0	0
Small	0	0	0	0
<b>TOTAL:</b>	2	2	7	11

**SBCN****2013 Publication total: 16***CINT science: 1**CINT user science (internal): 4**CINT user science (external): 11***2014 Publication total: 25***CINT science: 8**CINT user science (internal): 8**CINT user science (external): 9***2015 Publication total: 26***CINT science: 8**CINT user science (internal): 2**CINT user science (external): 16*

*Note: CINT Scientist authors are indicated in red; CINT User authors are indicated in green (external) and orange (internal).*

### Citations for 2013 (16) total

#### CINT Science (1)

Shepherd, D.P., Li, N., Micheva-Viteva, S., Munsky, B., Hong-Geller, E., **Werner, J.H.** (2013) "Counting small RNA in pathogenic bacteria" Analytical Chemistry: 85, 4938-4943

#### CINT User Science - Internal (4)

**Alexandrov, B.S.**, Phipps, M.L., Alexandrov, L.B., Booshehri, L.G., Erat, A., Zabolotny, J., Mielke, C.H., **Chen, H.T.**, Rodriguez, G., **Rasmussen, K.O.**, **Martinez, J.S.**, Bishop, A.R., Usheva, A. (2013) "Specificity and heterogeneity of terahertz radiation effect on gene expression in mouse mesenchymal stem cells" Scientific Reports: 3, 1184. C2012A0078

**Montano, G.A.**, Adams, P.G., **Xiao, X.**, **Goodwin, P.M.** (2013) "Scanning Probe Microscopy of Nanocomposite Membranes and Dynamic Organization" Advanced Functional Materials: 23, 2576-2591

**Xiao, X.**, **Montaño, G.A.**, Edwards, T.L., Allen, A., Achyuthan, K.E., **Polsky, R.**, Wheeler, D.R., Brozik, S.M. (2012) "Surface charge dependent nanoparticle disruption and deposition of lipid bilayer assemblies." Langmuir: 28, 17396. U2008B122

**Xiao, X.**, **Montano, G.A.**, Edwards, T.L., Allen, A., Achyuthan, K.E., Wheeler, D.R., Brozik, S.M. (2013) "Surface charge localized lipid bilayer membrane disruption and nanoparticle deposition" Langmuir: 28, 50

#### CINT User Science - External (11)

**Armijo, L.M.**, Akins, B.A., Plumley, J.B., **Rivera, A.C.**, Withers, N.J., Cook, N.C., Smolyakov, G.A., **Huber, D.L.**, Smyth, H.D.C., **Osinski, M.** (2013) "Highly efficient multifunctional MnSe/ZnSeS quantum dots for biomedical applications" Proceedings of SPIE: 8595, 859517

**Crochet, J.J.**, **Duque, J.G.**, **Werner, J.H.**, Lounis, B., **Cognet, L.**, **Doorn, S.K.** (2013) "Disorder Limited Exciton Transport in Colloidal Single-Wall Carbon Nanotubes". Nano Letters: 12, 5091–5096 C2011B102

**Butler, K.S.**, Lovato, D.M., **Adolphi, N.L.**, Belfon, R., Fegan, D.L., Monson, T.C., Hathaway, H.J., **Huber, D.L.**, Tessier, T.E., Bryant, H.C., **Flynn, E.R.**, and Larson, R.S. "Development of antibody-tagged nanoparticles for detection of transplant rejection using biomagnetic sensors". Cell Transplant: 22, 10, 1943-54. C2011B103

**Hur, S.-M.**, **Frischknecht, A. L.**, **Huber, D. L.**, **Fredrickson, G. H.** (2013) "Self-assembly in a mixed polymer brush with inhomogeneous grafting density composition" Soft Matter: 9, 5341–5354. C2011A1029.

Dumont, E.L.P., Belmas, H., **Hess, H.** (2013) "Observing the mushroom-to-brush transition for kinesin proteins", Langmuir: 29(49), 15142-15145. U2012A0018

**Duzik, A.**, **Thomas, J.C.**, **Van der Ven, A.**, **Millunchik, J.M.** (2013) "Surface reconstruction stability and configurational disorder on Bi-terminated GaAs(001)." Physical Review B: 87: 035313. U2008B054

**Jung, J.**, Sethi, A., Gaiotto, T., Han, J.J., **Jeoh, T.**, **Goodwin, P.M.** (2013) "Binding and movement of

individual Cel7A cellobiohydrolases on crystalline cellulose surfaces revealed by single-molecule fluorescence imaging” Journal of Biological Chemistry: 288, 24164-24172 U2012B0020

Obliosca, J.M., Liu, C., Batson, R.A., Babin, M.C., **Werner, J.H.**, **Yeh, H.C.** (2013) “DNA/RNA detection using DNA-templated few-atom silver nanoclusters” Biosensors: 3, 185-200 U2010A916

**Paxton, W. F.**; **Price, D.**; **Richardson, N. J.** (2013) “Hydroxide ion flux and pH-gradient driven ester hydrolysis in polymer vesicle reactors,” Soft Matter, 9, 11295-11302. (SAND#2013-4575 J) User proposal RA2012A0003

**Petty, J.T.**, Sergeev, O.O., Nicholson, D.A., **Goodwin, P.M.**, Giri, B., McMullan, D.R. (2013) “A silver cluster—DNA equilibrium” Analytical Chemistry: 85, 9868-9876 U2011B34

**Yeager, J.D.**, **Ramos, K.J.**, **Pesce-Rodriguez, R.A.**, **Piraino-Haynes, S.** (2013) “Microstructural effects of processing in the explosive composition A-3” Materials Chemistry and Physics: 139, 1 C2011A1060

### Citations for 2014 (25) total

#### CINT Science (8)

**Goodwin, P.M.**, Bartram, B.D., Gibson, L.L., Wu, M., Dattelbaum, D.M. (2014) “Non-invasive timing of gas gun projectiles with light detection and ranging” Journal of Physics: Conference Series: 500, 14

Henderson, I.M., Adams, P.G., **Montano, G.A.**, **Paxton, W.F.** (2014) “Ionic effects on the behavior of thermoresponsive PEO-PNIPAAm block copolymers” Journal of Polymer Science Part B- Polymer Physics: 52, 7

McGrane, S.D., Moore, D.S., **Goodwin, P.M.**, Dattelbaum, D.M. (2014) “Quantitative tradeoffs between spatial, temporal, and thermoelectric resolution of nonresonant raman thermometry for dynamic experiments” Applied Spectroscopy: 68, 11

Sista, P., Ghosh, K., **Martinez, J.S.**, Rocha, R.C. (2014) “Polythiophenes in biological applications” Journal of Nanoscience and Nanotechnology: 14, 1

Zhang, P., **Goodwin, P.M.**, **Werner, J.H.** (2014) “Fast 3D imaging via confocal line scanning of a Bessel beam using a single galvo mirror” Proceedings of SPIE: 8947

Zhang, P., **Goodwin, P.M.**, **Werner, J.H.** (2014) “Interferometric three-dimensional single molecule localization microscopy using a single high numerical-aperture objective” Applied Optics: 53, 31

Zhang, P., **Goodwin, P.**, **Werner, J.** (2014) “Fast, super resolution imaging via Bessel-beam stimulated emission depletion microscopy” Optics Express: 22, 10

Zhang, P., Phipps, M., **Goodwin, P.**, **Werner, J.** (2014) “Confocal line scanning of a Bessel beam for fast 3D imaging” Optics Letters: 39, 12

#### CINT User Science - Internal (8)

Balog, E.R.M., Ghosh, K., Park, Y.I., Hartung, V., Sista, P., Rocha, R.C., **Wang, H.L.**, **Martinez, J.S.** (2014) “Optical properties of a pH-sensitive and thermoresponsive hydrogel made from a genetically engineered polymer and phenylene vinylene oligomer” Journal of Physical Chemistry Letters C2013A0022

Gao, Y., Roslyak, O., Dervishi, E., Karan, N.S., Ghosh, Y., Sheehan, C.J., Wang, F., Gupta, G., Mohite, A., Dattelbaum, A.M., Doorn, S.K., Hollingsworth, J.A., Piryatinski, A., Htoon, H. (2014) "Hybrid graphene-giant nanocrystal quantum dot assemblies with highly efficient biexciton emission" Advanced Optical Materials: 10.1002 U2013B0037

Ghosh, K., Balog, E.R.M., Sista, P., Williams, D.J., Kelly, D., Martinez, J.S., Rocha, R.C. (2014) "Temperature-dependent morphology of hybrid nanoflowers from elastin-like polypeptides" APL Materials: 2, 021101

Han, J.J., Kunde, Y.A., Hong-Geller, E., Werner, J.H. (2014) "Actin restructuring during salmonella typhimurium infection investigated by confocal and super resolution microscopy" Journal of Biomedical Optics: 19, 1

Kaul, A.M., Ivanovsky, A.V., Atchison, W.L., Petrukhin, A.A., Duday, P.V., Griego, J.R., Salazar, M., Nadezhin, S.S., Tyupanova, O.A., Oro, D.M., Holtkamp, D.B., Rodriguez, G., Tabaka, L.J., Kraev, A.I., Skobelev, A.N., Westley, D.T., Anderson, B.G., Ivanov, V.A., Glybin, A.M., Kuzyaev, A.I., Stone, J.B., Payton, J.R., Goodwin, P.M., McCulloch, Q., Montoya, R.R., Dudin, V.I., Zimenkov, A.A., Randolph, R.B., Fierro, F., Reinovksy, R.E., Rousculp, C.L., Balandina, A.N., Podurets, A.M. (2014) "Damage growth and recollection in aluminum under axisymmetric convergence using a helical flux compression generator" Journal of Applied Physics: 115, 023516 RA2011A1268

Park, Y.I., Postupna, O., Zhugayevych, A., Kyu, W.S., Park, Y.S., Park, B., Park, J., Martinez, J.S., Tretiak, S., Wang, H.L. (2014) "A new pH sensitive fluorescent and white light emissive material through controlled intermolecular charge transfer" Chemical Science: 6, 789-797

Small, L.J., Wolf, S., Spoerke, E.D. (2014) "Exploring Electrochromics: A series of eye-catching experiments to introduce students to multidisciplinary research" Journal of Chemical Education: 91, 12 U2013A0096

VanDelinder, V., Bachand, G.D. (2014) "Photodamage and the importance of photoreception in biomolecular-powered device applications" Analytical Chemistry: 86(1), 721-728

#### CINT User Science - External (9)

Adams, P.G., Lamoreux, L., Swingle, K.L., Mukundan, H., Montano, G.A. (2014) "Lipopolysaccharide-induced dynamic lipid membrane reorganization: Tubules, perforations, and stacks" Biophysical Journal: 106, 11

Armijo, L.M., Kopciuch, M., Olszowka, Z., Wawrzyniec, S.J., Rivera, A.C., Plumley, J.B., Cook, N.C., Brandt, Y.I., Huber, D.L., Smolyakov, G.A., Adolphi, N.L., Smyth, H.D.C., Osinski, M. (2014) "Delivery of tobramycin coupled to iron oxide nanoparticles across the biofilm of mucoidal pseudomonas aeruginosa and investigation of its efficacy" Proceedings of SPIE: 10.1117 C2012A0105

Auge, W.K., Ganguly, K., Goodwin, P.M., Gadomski, A., Gehlert, R.J. (2014) "Lipid distribution in human knee and hip articular cartilage correlated to tissue surface roughness and surface active phospholipid layer presence: evidence of cooperative interfacial lipid delivery mechanisms" Osteoarthritis and Cartilage: 22, 312-313 RA2009A135

Gao, W., Wu, G., Janicke, M.T., Cullen, D.A., Mukundan, R. (2014) "Proton conducting ozonated graphene oxide membrane" Angewandte Chemie International Edition: 53, 14 RA2012A0009

Keller, A.M., Ghosh, Y., Devore, M.S., Phipps, M.E., Stewart, M.H., Wilson, B.S., Lidke, D.S., Hollingsworth, J.A., Werner, J.H. (2014) "3-dimensional tracking of non-blinking 'giant' quantum dots in live cells" Advanced Functional Materials: 24, 30 C2013A0111



Perillo, E.P., De Haro, L., Phipps, M.E., Martinez, J.S., Yeh, H.C., Dunn, A.K., Shepherd, D.P., Werner, J.H. (2014) "Enhanced 3D localization of individual RNA transcripts via astigmatic imaging" Proceedings of SPIE: 8950 U2010A916

Peteanu, L.A., Hong, J., Jeon, S., Kim, J., Devi, D., Wildeman, J., Sfeir, M.Y., Werner, J.H., Shreve, A.P. (2014) "The optical properties of conjugated materials and their aggregates: Towards imaging of films and devices" SPIE Nanoscience and Engineering: 13, 91650 C2011A1006

Vasilev, C., Johnson, M., Gonzales, E., Wang, L., Ruban, A., Montano, G.A., Cadby, A., Hunter, C.N. (2014) "Reversible switching between non-quenched and quenched states in nanoscale linear arrays of plant light harvesting antenna (LHCII) complexes" Langmuir: 30, 8481 U2011A1024

Whitcomb, K.J., Geisenhoff, J.Q., Ryan, D.P., Gelfand, M.P., Van Orden, A.K. (2014) "Photon antibunching in small clusters of CdSe/ZnS core/shell quantum dots" Journal of Physical Chemistry B: 10.1021 C2012B0078

### Citations for 2015 (26 Total)

#### CINT Science (8)

Adams, P.G., Swingle, K.L., Paxton, W.F., Firestone, M.A., Mukundan, H., Montano, G.A. (2015) "Exploiting lipopolysaccharide-induced deformation of lipid bilayers to modify membrane composition and generate two-dimensional geometric membrane array patterns" Scientific Report: 5, 10331

Firestone, M.A., Hayden, S.C., Huber, D.L. (2015) "Greater than the sum: synergy and emergent properties in nanoparticle-polymer composites" MRS Bulletin: 40, 09

Ghosh, K., Balog, E.R.M., Sista, P., Martinez, J.S., Rocha, R.C. (2015) "Multicolor luminescence from conjugates of genetically encoded elastin-like polymers and terpyridine-lanthanides" Macromolecular Chemical Physics: 216, 18

Kelly, J.C., Huber, D.L., Price, A.D., Roberts, M.E. (2015) "Switchable electrolyte properties and redox chemistry in aqueous media based on temperature-responsive polymers" Journal of Applied Electrochemistry: 45, 8

Paxton, W.F., Boussein, N.F., Henderson, I.M., Gomez, A., Bachand, G.D. (2015) "Dynamic assembly of polymer nanotube networks via kinesin powered microtubule filaments" Nanoscale: 7, 25

Paxton, W.F., Sanchez, S., Nitta, T. (2015) "Editorial: Special issue micro- and nanomachines" Transactions on Nanobioscience: 14, 258-259

Watt, J., Huber, D.L., Price, A.D., Roberts, M.E. (2015) "Effect of seed age on gold nanorod formation: a microfluidic, real-time investigation" Chemistry of Materials: 27, 18

Willey, M., Bagge-Hansen, M., Lauderbach, L., Hodgin, R., Hansen, D., May, C., VanBuuren, T., Gustavsen, R., Watkins, E., Firestone, M., Dattelbaum, D., Jensen, B., Graber, T., Bastea, S., Fried, L. (2015) "Measurement of carbon condensates using small-angle X-ray scattering during detonation of high explosives" APS Topical Conference on the Shock Compression of Matter: O1.003

#### CINT User Science - Internal (2)

Kent, M.S., Avina, I.C., Rader, N., Busse, M.L., George, A., Sathitsuksanoh, N., Baidoo, E., Timlin, J.,

Giron, N.H., Celina, M.C., Martin, L.E., Polsky, R., Chavez, V.H., Huber, D.L., Keasling, J.D., Singh, S., Simmons, B.A., Sale, K.L. (2015) "Assay for lignin breakdown based on lignin films: insights into the Fenton reaction with insoluble lignin" *Green Chemistry*: 17, 4830 C2014A0038

VanDelinder, V., Wheeler, D.R., Small, L.J., Brumbach, M.T., Spoerke, E.D., Henderson, I., Bachand, G.D. (2015) "Simple, benign, aqueous-based animation of polycarbonate surfaces" *Applied Material Interfaces*: 10, 5643 C2014B0124

*CINT User Science - External (16)*

Adams, P.G., Collins, A.M., Sahin, T., Subramanian, V., Urban, V.S., Vairaprakash, P., Tian, Y., Evans, D.G., Shreve, A.P., Montano, G.A. (2015) "Diblock copolymer micelles and supported films with noncovalently incorporated chromophores: A modular platform for efficient energy transfer" *Nano Letters*: 10.1021 U2015A0086

Chakraborty, S., Babanova, S., Rocha, R.C., Desireddy, A., Artyushkova, K., Atanasov, P. \*, Martinez, J.S\*. (2015) "A DNA-Hosted Gold Nanocluster Enhances Enzymatic Reduction of Oxygen by Facilitating Efficient Electron Transfer" *Journal of the American Chemical Society*: 137(36), 11678-11687 RA2015A0006

De Haro, L.P., Karaulanov, T., Vreeland, E.C., Anderson, B., Hathaway, H.J., Huber, D.L., Matlashov, A.N., Nettles, C.P., Price, A.D., Monson, T.C., Flynn, E.R. (2015) "Magnetic relaxometry as applied to sensitive cancer detection and localization" *Biomed Tech*: 60, 5 C2014B0127

DeVore, M., Stich, D., Keller, A., Cleyrat, C., Phipps, M., Hollingsworth, J., Lidke, D., Wilson, B., Goodwin, P., Werner, J. (2015) "Time-gated 3D single quantum dot tracking with simultaneous spinning disk imaging" *Review of Scientific Instruments*: 86, 12 C2013A0111

DeVore, M., Stich, D.G., Keller, A.M., Ghosh, Y., Goodwin, P.M., Phipps, E., Stewart, M.H., Cleyrat, C., Wilson, B.S., Lidke, D.S., Hollingsworth, J., Werner, J. (2015) "Three dimensional time-gated tracking of non-blinking quantum dots in live cells" *SPIE BiOS*: 933812-933815 C2013A0111

Dumont, E.L.P., Do, C., Hess, H. (2015) "Molecular wear of microtubules propelled by surface-adhered kinesins" *Nature Nanotechnology*: 10.1038 U2012A0018

Ganguly, M., Bradsher, C., Goodwin, P., Petty, J.T. (2015) "DNA-directed fluorescence switching of silver clusters" *The Journal of Physical Chemistry C*: 119, 49 C2013B0066

Harper, J.C., Carson, B.D., Bachand, G.D., Arndt, W.D., Finley, M.R., Brinker, C.J., Edwards, T.L. (2015) "Laser machined plastic laminates: Towards portable diagnostic devices for use in low resource environments" *Electroanalysis*: 27, 11 C2013B0007

Henderson, I.M., Quintana, H.A., Martinez, J.A., Paxton, W.F. (2015) "Capable crosslinks: Polymersomes reinforced with catalytically active metal-ligand bonds" *Chemical Materials*: 27, 408 U2015A0062

Lamoreux, L., Adams, P., Banisadr, A., Stromberg, Z., Graves, S., Montano, G., Moxley, R., Mukundan, H. (2015) "An optical biosensor for detection of pathogen biomarkers from Shiga toxin-producing *Escherichia coli* in ground beef samples" *Proceeding of SPIE*: 9310, 931004

Moon, J.S., Liang, Y., Stevens, T.E., Monson, T.C., Huber, D.L., Mahala, B.D., Winiarz, J.G. (2015) "Off-resonance photosensitization of a photorefractive polymer composite using PbS nanocrystals"

Journal of Physical Chemistry C: 119, 24 C2008A151

Mukherjee, S., Bowman, D.N., [Jakubikova, E.](#) (2015) "Cyclometalated Fe(II) complexes as sensitizers in dye-sensitized solar cells" Inorganic Chemistry: 54, 2 C2012B0052

Park, Y., [Zhugayevych, A.](#), Postpuna, O., Kyu, S.W., Park, Y.S., Park, B., [Martinez, J.S.](#), Park, J., [Tretiak, S.](#), Wang, H.L. (2015) "A new pH sensitive fluorescent and white light emissive material through controlled intermolecular charge transfer" Chemical Science: 6, 789-797 U2015A0016

Perez del Pino, A., Gyorgy, E., Logofatu, C., Puigmarti-Luis, J., [Gao, W.](#) (2015) "Laser-induced chemical transformation of graphene oxide-iron oxide nanoparticles composites deposited on polymer substrates" Carbon: 10.1016 RA2012A0009

[Vreeland, E.C.](#), Watt, J., Schober, G.B., Hance, B.G., Austin, M.J., [Price, A.D.](#), Fellows, B.D., Monson, T.C., Hudak, N.S., Maldonado-Camargo, L., Bohorquez, A.C., Rinaldi, C., [Huber, D.L.](#) (2015) "Enhanced nanoparticle size control by extending LaMer's mechanism" Chemistry of Materials: 27, 17 C2014B0127

Zhu, F., Men, L., Guo, Y., Zhu, Q., Bhattacharjee, U., [Goodwin, P.M.](#), Petrich, J.W., Smith, E.A., [Vela, J.](#) (2015) "Shape evolution and single particle luminescence of organometal halide perovskite nanocrystals" ACS Nano: 9, 3 U2012B0008

## 8.0 Biographical Sketches

### MILLICENT FIRESTONE

#### Education and Training

University of Chicago, Booth School of Business, Chicago, IL	Leadership training	2010
Northwestern University, Evanston, IL	Chemistry	Ph.D. 1993
University of Arizona, Tucson, AZ	Chemistry	M.A. 1988
Indiana University of Pennsylvania, Indiana, PA	Chemistry	B.S. 1984

#### Research and Professional Experience

2013-present	SBCN Thrust Leader, Center for Integrated Nanotechnologies, Los Alamos, NM
2005-2013	Chemist, Materials Science Division, Argonne National Laboratory, IL
2002-2013	Field Work Program Leader, Argonne National Laboratory, IL
1999-2002	Assistant Chemist, Argonne National Laboratory, IL

#### Selected Publications

- Willey, M.; Bagge-Hansen, M.; Lauderbach, L.; Hodgins, R.; Hansen, D.; May, C.; VanBuuren, T.; Gustavsen, R.; Watkins, E.; Firestone, M.; Dattelbaum, D.; Jensen, B.; Graber, T.; Bastea, S.; Fried, L. “*Measurement of carbon condensates using Small-angle X-ray scattering during detonation of high explosives*”. Shock Compression in Condensed Matter. Accepted / In press.
- Grubjesic, S.; Jungjohann, K.; Brombosz, S. M.; Seifert, Soenke, Firestone, M. A. “*Nature-inspired, cascade synthesis of a gold nanoparticle network polymer composite*”. (2015) DOI: 10.1039/c5nr06594a. Cover article.
- Firestone, M. A.; Hayden, S. C.; Huber, D. L. “*Greater Than the Sum: Synergy and Emergent Properties in Nanoparticle-Polymer Composites*” MRS Bulletin (2015), 40(9), 760-767.
- Adams, P.; Swingle, K.; Paxton, W. Nogan, J.; Lamoureux, L.; Firestone, M. A.; Mukundan, H.; Montano, G. “*Exploiting lipopolysaccharide-induced deformation of lipid bilayers to modify membrane composition and generate two-dimensional geometric membrane array pattern*” Scientific Reports (2015), 5, 1-9.
- Brombosz, S. M.; Lee, S.; Firestone, M. A. “*Installation of a reactive site for covalent wiring onto an intrinsically conductive poly(ionic liquid)*” Reactive & Functional Polymers (2014), 85, 69-76.
- Brombosz, S. M.; Seifert, S.; Firestone, M. A. “*Patterning of a pi-conjugated polyelectrolyte through sequential polymerization of a bifunctional ionic liquid monomer*” Polymer (2014), 55(16), 3370-3377.
- Zaborin, A.; Defazio, J.; Kade, M.; Kaiser, B. L. D.; Belogortseva, N.; Camp, D. G. Smith, R. D.; Adkins, J. N.; Kim, S. M.; Alverdy, A.; Goldfield D.; Firestone, M. A.; Collier, J. H.; Jabri, B.; Tirrell, M.; Zaborina, O.; Alverdy, J. C. “*Phosphates containing PEG polymers prevent lethal sepsis from multi-drug resistant pathogens*” Antimicrobial Agents & Chemotherapy (2014), 58(2), 966-977.
- Ringstrand, B. S.; Seifert, S.; Firestone, M. A. “*Preparation of a solution-processable, nanostructured ionic polyacetylene*” J Poly Sci: Part B Poly Physics (2013), 51(16), 1215-1227.
- Lee, S.; Seifert, S.; Firestone, M. A. “*Multi-length scale evaluation of the temperature-tunable mechanical properties of a lyotropic mesophase*”, Polymer J. Nature (2013), 45(2), 179-187. Cover article
- Lee, S.; Ringstrand, B. S.; Stone, D. A.; Firestone, M. A. “*Electrochemical activity of Glucose Oxidase on a poly(ionic liquid)- Au nanoparticle composite*”, ACS Appl. Mater. Inter. (2012), 4(5), 2311-2317
- Grubjesic, S.; Lee, B.; Seifert, S.; Firestone, M. A. “*Preparation of a self-supporting cell architecture mimic by water channel confined photocrosslinking within a lamellar structured hydrogel*”, Invited for inclusion in a themed issue of biomimetic soft matter, Soft Matter (2011), 7, 9695-9705.

### **Awards and Synergistic Activities**

Co-organizer of LANL workshop on Probing dynamic processes in soft materials using advanced light sources, 2016

LANL representative for second target station and SNS, ORNL, 2015

Appointed Materials Science External Advisory Board for State of Montana Tri-University Graduate Program in Materials Science & Engineering, 2014-Present

Member of the Australian Research Centre for Excellence in Electromaterials Science. Intelligent Polymer Research Institute, 2014-Present

Co-organizer for the 34<sup>th</sup> Los Alamos National Laboratory Center for Non-linear Studies Annual Conference on Mesoscale Science Frontiers. Santa Fe, NM, 2014

LDRD-ER review panel member for chemical sciences, LANL 2013, 2014

Advisory Committee member for University of New Mexico Center (UNM) for Biomedical Engineering, Albuquerque, NM, 2013

MRSEC on-site reviewer, National Science Foundation, UMass Amherst, October 2012

MRSEC review panelist, National Science Foundation, Arlington, VA, June 2008

MRSEC review panelist, National Science Foundation, Arlington, VA, Nov 14-15, 2007

### **Patents**

“Multi-layer micro/nanofluid devices with bionanovalves” (U.S. patent 20130000764) granted 1/03/2013

“Biomimetic Materials for Protein Storage and Transport” (U.S. Patent 8,168,746 ) granted 5/01/2012

“Synthetic Biological Membrane with self-organizing properties” (U. S. Patent 6,537,575) granted 3/25/2003

### **Collaborators**

Dr. J. Alverdy, MD (Department of Surgery, University of Chicago Medical School, Chicago, IL) cell culturing  
Prof. G. Voth (University of Chicago, Chicago, IL) theory and modeling  
Dr. S. Seifert (APS-ANL) X-ray scattering

### **Undergraduate, Graduate and Postdoctoral Advisors**

Ph.D. Advisors: Mark A. Ratner and Tobin J. Marks, Northwestern University

Postdoctoral Advisor: Stephen Sligar, UIUC

Postdoctoral Advisor: Paul Bohn UIUC, now at Notre Dame, Chem. Eng.

### **Scientific Staff Supervised**

Simonida Grubjesic (STA Assistant Chemist, MSD/ANL), Sungwon Lee (Assistant Chemist, MSD/ANL), David Stone (STA Assistant Chemist, MSD/ANL), Laurel Almer (STA, Scientific Associate, MSD/ANL)

### **Postdoctoral Appointees Advised**

Dolly Batra (now at TIAX LLC), Brian Reiss (now at Cabot Electronics), Charles Reedy (now at Nalco Chemical Corp.), Sung Yeun Choi (now at BASF), Chris Burns (now Assistant Prof U. of Louisville), Simonida Grubjesic (STA Assistant Chemist, ANL), Sungwon Lee (Assistant Chemist, ANL), Omar Green, Hermona Pandya (now Lecturer Illinois Benedictine University), Marina Sofos (now at DOE-EERE AAAS Fellow), Greg Becht (now at DuPont), Scott Brombosz, Bryan Ringstrand, Steven Hayden

### **Graduate Students Co-Advised**

Rick Kelly (Chem. Dept. Northwestern University in Prof. Wasielewski group), Sandra Durst (Physics Dept. NIU with Carol Thompson)

**Undergraduates Advised**

Veronika Vajdova (U. of Chicago), Anthony Crisci, (graduate student at UCSB), Cristian González, (UPR-Mayaguez), Mariangel. Ruiz, (UPR- Mayaguez), Liz Rodríguez, (UPR – Mayaguez), Legna Varela (UPR – Mayaguez), Giselle Benitez, (UPR – Mayaguez), LaTisha Wilson (Tougaloo), Kamil Wilson (Tougaloo), Mohammed Mohammed (IL Benedictine)

**GEORGE BACHAND****Education**

SUNY Health Science Center	Immunology	Post-doctoral Training	1998
SUNY Environmental Science & Forestry	Biology	Ph.D.	1997
Elizabethtown College	Biology	B.S.	1992

**Professional Experience**

2011 – Present	Partner Science Leader, Center for Integrated Nanotechnologies, Sandia National Laboratories
2016 – Present	Distinguished Member of the Technical Staff, Physical, Chemical, and Nano Sciences Center, Sandia National Laboratories
2006 – Present	Adjunct Assistant Professor, Department of Cell Biology and Physiology, Health Sciences Center, University of New Mexico
2009	Associate Professor, Department of Environmental and Forest Biology, State University of New York, College of Environmental Science & Forestry
2001 – 2015	Principal Member of the Technical Staff, Physical, Chemical, and Nano Sciences Center, Sandia National Laboratories
1998 – 2001	Research Associate III, Department of Biological and Environmental Engineering, Cornell University
1997 – 1998	Postdoctoral Associate, Department of Medicine, State University of New York, Health Science Center

**Relevant Publications (of 62):**

- VanDelinder, V., Brener, S., and Bachand, G.D. (2016) Mechanisms underlying the active self-assembly of microtubule rings and spools. *Biomacromolecules*, DOI: 10.1021/acs.biomac.5b01684 (2016).
- Lam, A.T., VanDelinder, V., Kabir, A.M.R., Bachand, G.D, Hess, H., and Kakugo, A.T. Cytoskeletal motor-driven active self-assembly in in vitro systems. *Soft Matter* 12, 988-997 (2016).
- Harper, J.C., Carson, B.D., Bachand, G.D., Arndt, W.D., Finley, M.R., Brinker, C.J., and Edwards, T.L. Laser machined plastic laminates: Towards portable diagnostic devices for use in row resource environments. *Electroanalysis* 27, 2503-2512 (2015).
- Paxton, W.F., Bouxsein, N.F., Henderson, I., and Bachand G.D. Dynamic assembly of polymer nanotube networks via kinesin powered microtubule filaments. *Nanoscale* 7, 10998-11004 (2015).
- Bachand, G.D., Spoerke, E.D., and Stevens, M.J. Microtubule-based Nanomaterials: Borrowing from Nature's dynamic biopolymers. *Biotechnol. Bioeng.* 112, 1065-73 (2015).
- Momin, N., Lee, S., Gadok, A.K., Busch, D.J., Bachand, G.D., Hayden, C.C., Stachowiak, J.C., and Sasaki, D.Y. Designing lipids for selective partitioning into liquid ordered membrane domains. *Soft Matt.* 11: 3241-3250 (2015).
- VanDelinder, V., Wheeler, D.R., Small, L.J., Spoerke, E.D., Henderson, I., and Bachand, G.D. Simple, benign, aqueous-based amination of polycarbonate surfaces. *ACS Appl. Mater. Interfaces* 7, 5634-5649 (2015).
- Bachand, M., Bouxsein, N.F., von Hoyningen-Huene, S., Bachand, G.D. Directed self-assembly of 1D microtubule nano-arrays. *RSC Adv.* 4: 51641-54649 (2014).
- Bouxsein, N.F. & Bachand, G.D. (2014). Single filament behavior of microtubules in the presence of added divalent counterions. *Biomacromolecules* 15, 3696-3705 (2014).
- Spoerke, E.D., Connor, B.A., Gough, D.V., McKenzie, B.B., and Bachand, G.D. Microtubule-templated cadmium sulfide nanotube assemblies. *Part. Part. Syst. Charact.* 31,863-870 (2014).
- Bachand, G.D., Bouxsein, N.F., VanDelinder, V., and Bachand, M. Biomolecular motors in nanoscale materials, devices, and systems. *WIREs Nanomed. Nanobiotechnol.* 6, 163-177. (2014).
- VanDelinder, V. and Bachand, G.D. Photodamage and the importance of photoprotection on biomolecular-powered device applications. *Anal. Chem.* 8, 721-728 (2013).
- Spoerke, E.D., Bachand, G.D., Boal, A.K., and Bunker, B.C. Biodynamic assembly of nanocrystals on artificial microtubule asters. *ACS Nano* 7, 2012-2019 (2013).
- Bouxsein, N.F., Carroll-Portillo, A., Bachand, M., Sasaki, D.Y., and Bachand, G.D. A continuous network of lipid nanotubes fabricated from the gliding motility of kinesin powered microtubule filaments. *Langmuir* 29, 2992-

2999 (2013).

Liu, H. and Bachand, G.D. Effects of confinement on molecular motor-driven self-assembly of ring structures. *Mol. Cell. Bioeng.* 6, 98-108 (2013).

Bachand, G.D., Allen, A., Bachand, M., Achyuthan, K., Seagrave, J.C., and Brozik, S.M. Cytotoxicity and inflammation in human alveolar epithelial cells following exposure to occupational levels of gold and silver nanoparticles. *J. Nanopart. Res.* 14, 1-10 (2012).

Bachand, M., and Bachand, G.D. Effects of potential environmental interferents of kinesin-powered molecular shuttles. *Nanoscale* 4, 706-3710 (2012).

#### **Awards and Synergistic Activities**

Sandia National Laboratories Employee Recognition Award, for creating a portable diagnostic device to detect anthrax in low resource environments, and concurrently reducing the risk of theft and misuse of *Bacillus anthracis* (BaDx) (2015)

R&D100 Award, Portable Diagnostic Device for *Bacillus anthracis* Detection (BaDx) in Ultra-Low Resource Environments (2014)

Sandia National Laboratories Employee Recognition Award, W87 MC3730 Detonator Significant Finding Investigation Team (2013)

Mentor, The New Mexico Cancer Nanoscience and Microsystems Training Center (2011-present)

Invited participant, Second Indo-American Frontiers of Engineering Symposium, National Academy of Engineering (2008)

Co-organizer and selected participant, Defense Threat Reduction Agency (DTRA)- sponsored workshop, "Nanotechnology for Chem-Bio Defense 2030" (2007)

Advisor Committee, Post-Doctoral Professional Development Program, Sandia National Laboratories (2007-present)

Selected participant, "Frontiers in Engineering," National Academy of Engineering, Dearborn, MI (2006)

Work featured in *Popular Science* as one of "20 incredible inventions from the near future" (July 2006)

Chair & Lead organizer, Symposium "Hybrid Interfaces & Integrative Nanobiotechnology," American Association for the Advancement of Science Annual Meeting, St. Louis, MO (2006)

Lead organizer, Developing Nano-Bio Interfaces Symposium, Materials Research Society Annual Spring Meeting, San Francisco, CA (2005)

Chair, Defense Advanced Research Projects Agency (DARPA), BioMolecular Motors Workshop (2003)

#### **Collaborators**

Alan Barhorst (Texas Tech University), C. Jeffrey Brinker (SNL), Eva Chi (University of New Mexico), Norman Doggett (LANL), Steven Granick (Ulsan National Institute of Science and Technology), Henry Hess (Columbia University), Elizabeth Hong-Geller (LANL), Julie Lovchik (University of New Mexico), Gabriel Montaño (LANL), Carlo Montemagno (University of Alberta), Aaron Neumann (University of New Mexico), Elba Serrano (New Mexico State University), Andy Shreve (University of New Mexico), Ratnasingham Sooryakumar (Ohio State University), Erik Spoerke (SNL), Jeanne Stachowiak (University of Texas, Austin), Jessica Winter (Ohio State University), Viola Vogel (Swiss Federal Institute of Technology)

#### **Undergraduate, Graduate and Postdoctoral Advisors**

Ph.D. advisor, Prof. John D. Castello, State University of New York, College of Environmental Science and Forestry

Postdoctoral Advisor, Prof. Andras Perl, State University of New York, Upstate Medical Center

#### **Postdoctoral Appointees Advised**

Adrienne Greene (current, SNL), Virginia VanDelinder (current, SNL), Nathan Boussein (former), Haiqing Liu (former, SNL), Lynnette Rios (former, University of New Mexico.), Amanda Carroll-Portillo (former, Sandia Biotech, Inc.), Steve Koch (former, Epic Systems), Andrew Boal (former, Miox Corp.), Susan Rivera (former, Miox Corp.)

#### **PETER GOODWIN**

#### **Education and Training**



Cornell University, Ithaca NY	Applied and Engineering Physics	Ph.D.	1989
Cornell University, Ithaca NY	Applied and Engineering Physics	M.S.	1984
California Institute of Technology, Pasadena CA	Physics	B.S.	1980

### Research and Professional Experience

2010-present	Adjunct Professor, Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM
2005-present	Scientist IV, Center for Integrated Nanotechnologies, LANL
1999-2005	Technical Staff Member, Bioscience Division, LANL
1993-1999	Technical Staff Member, Chemical Science and Technology Division, LANL
1991-1993	Postdoctoral Research Associate, Los Alamos National Laboratory, Los Alamos NM
1989-1991	Postdoctoral Research Associate, IBM Endicott NY

### Selected Publications

- Shape evolution and single particle luminescence of organometal halide perovskite nanocrystals. Zhu, F., Men, L., Guo, Y., Zhu, Q., Bhattacharjee, U., Goodwin, P.M., Petrich, J.W., Smith, E.A. and Vela, J. *Acs Nano*, 2015, 9(3), pp.2948-2959.
- Fast, super resolution imaging via Bessel-beam stimulated emission depletion microscopy. Zhang, P., Goodwin, P.M. and Werner, J.H. *Optics Express*, 2014, 22(10), pp.12398-12409.
- A Silver Cluster–DNA Equilibrium. Petty, J.T., Sergeev, O.O., Nicholson, D.A., Goodwin, P.M., Giri, B. and McMullan, D.R. *Anal. Chem.*, 2013, 85(20), pp.9868-9876.
- Binding and movement of individual Cel7A cellobiohydrolases on crystalline cellulose surfaces revealed by single-molecule fluorescence imaging. Jung, J.; Sethi, A.; Gaiotto T.; Han J.J.; Jeoh T.; Gnanakaran S.; Goodwin P.M. *J. Biol. Chem.* 2013, <http://www.jbc.org/cgi/doi/10.1074/jbc.M113.455758>.
- Non-invasive timing of gas gun-launched projectiles using external surface-mounted optical fiber-Bragg grating strain gauges. Goodwin, P.M.; Marshall, B.R.; Stevens, G.D.; Dattelbaum, D.M. *Rev. Sci. Instrum.*, 2013, 84, 035002, DOI:10.1063/1.4793489.
- Distinct Conformations of DNA-Stabilized Fluorescent Silver Nanoclusters Revealed by Electrophoretic Mobility and Diffusivity Measurements. Driehorst, T.; O'Neill, P.; Goodwin, P.M.; Pennathur, S. and Fyngenson, D.K. *Langmuir*, 2011, 27 (14), 8923–8933.
- Time-Resolved Three-Dimensional Molecular Tracking in Live Cells. Wells, N.P.; Lessard, G.A.; Goodwin, P.M.; Phipps, M.E.; Cutler, P.J.; Lidke, D.S.; Wilson, B.S.; Werner, J.H. *Nano Lett.*, 2010, 10(11), 4732-4737.
- Fluorescence Intermittency and Energy Transfer in Small Clusters of Semiconductor Quantum Dots. Shepherd, D.P.; Whitcomb, K.J.; Milligan, K.K.; Goodwin, P.M.; Gelfand, M.P.; Van Orden, A. *J. Phys. Chem. C*, 2010, 114(35), 14831-14837.
- Three-dimensional tracking of individual quantum dots. Lessard, G.A.; Goodwin, P.M.; Werner, J.H. *Appl. Phys. Lett.*, 2007, 91(22), 2240106-1-3.
- A two-dimensional view of the folding energy landscape of cytochrome c. Werner, J.H.; Joggerst, R.; Dyer, R.B.; Goodwin, P.M. *Proc. Natl. Acad. Sci. USA*, 2006, 103, 11130–11135.

### Awards and Synergistic Activities

- Distinguished Patent Award, “Three-Dimensional Imaging at Nanometer Resolution”, 2010.
- R&D 100 Award, “3D Tracking Microscope”, 2008
- R&D 100 Award, “Rapid Size Analysis of Individual DNA Fragments”, 1997
- LANL Distinguished Performance Award, Human Genome Project Team, 1995
- Letter of appreciation from Deputy Undersecretary of Energy for Counterterrorism and Counterproliferation for contributions to Nuclear Counterterrorism Program , 2015

### Patents

- J. H. Werner, P. M. Goodwin and A. P. Shreve. 3-dimensional imaging at nanometer resolutions U.S. Patent 7,675,045 issued 3/9/2010.
- J. H. Werner, P. M. Goodwin, G. A. Lessard. Apparatus and method for tracking a molecule or particle in three

dimensions. US Patent 7,498,551 issued 3/3/2009.

H. Cai, P. M. Goodwin, R. A. Keller and R. L. Nolan. Quenching methods for background reduction in luminescence-based probe-target binding assays. U.S. Patent 7,202,036 issued 4/10/2007.

W. P. Ambrose, W. K. Grace, P. M. Goodwin, J. H. Jett, R. A. Keller and A. K. Van Orden. High throughput analysis of samples in flowing liquid. U.S. Patent 6,309,886 issued 10/30/2001.

P. M. Goodwin, J. H. Jett, R. A. Keller, A. K. Van Orden, N. P. Machara. Single molecule identification using selected fluorescence characteristics. U. S. Patent 6,049,380 issued 4/11/2000.

R. L. Affleck, W. P. Ambrose, J. N. Demas, P. M. Goodwin, M. E. Johnson, R. A. Keller, J. T. Petty, J. A. Schecker, and M. Wu. Method and apparatus for reducing solvent luminescence background emissions. U.S. Patent 5,827,663 issued 10/27/1998.

R. L. Affleck, W. P. Ambrose, J. N. Demas, P. M. Goodwin, M. E. Johnson, R. A. Keller, J. T. Petty, J. A. Schecker, and M. Wu. Apparatus for reducing solvent luminescence background emissions. U.S. Patent 5,834,204 issued 11/10/1998.

R. L. Affleck, J. N. Demas, P. M. Goodwin, R. A. Keller, J. A. Schecker, and M. Wu. Reduction of diffusional defocusing in hydrodynamically focused flows. U.S. Patent 4,962,037 issued 9/1/1998.

### **Collaborators**

Deborah Fygenon, UC Santa Barbara; Elisabeth Gwinn, UC Santa Barbara; Alan Van Orden, Colorado State University; Martin Gelfand, Colorado State University; Edwin Goodwin, KromaTid, Inc.; Jeffery Petty, Furman University; Wayne Augé, Center for Orthopaedic and Sports Performance Research, Inc.; Santa Fe, New Mexico; Kevin Plaxco, UC Santa Barbara; Javier Vela, Iowa State University; Mircea Cotlet, Brookhaven National Laboratory; Dana Dattelbaum, John Lang, Daniel Garcia, Shawn McGrane, David Moore, Kumkum Ganguly, S. Gnanakaran, Jennifer Hollingsworth, Rashi Iyer, Geoffery Waldo, James Werner (all at Los Alamos National Laboratory)

### **Undergraduate, Graduate and Postdoctoral Advisors**

Ph.D. Advisor: Terrill A. Cool, Cornell University (deceased)

Postdoctoral Advisor: Charles E. Otis

Postdoctoral Advisor: Richard A. Keller

### **Postdoctoral Appointees Advised in last 5 years**

Jaemyeong Jung

Total: 4 postdoctoral students

## DALE HUBER

### Education and Training

02/00 – 02/02                   Biomaterials & Interfaces Dept, Sandia National Labs, Post-doctoral Associate  
10/97 – 02/00                University of Connecticut, Ph.D. in Polymer Science  
10/96 – 09/97                University of Connecticut, M.S. in Polymer Science  
09/91 – 05/95                University of Pennsylvania, B.A. in Chemistry

### Research and Professional Experience

10/05-Present               Principal Member of the Technical Staff, Sandia National Laboratories  
Center for Integrated Nanotechnologies

01/13-Present               Adjunct Associate Professor, University of Texas at Dallas  
Department of Materials Science & Engineering

02/14-Present               Member, University of New Mexico Comprehensive Cancer Center

02/02 – 10/05               Senior Member of the Technical Staff, Sandia National Laboratories  
Nanostructures & Advanced Materials Chemistry Department

### Selected publications:

Simocko, C.K., Frischknecht, A.L., and Huber, D.L., Phase Behavior of Ternary Polymer Brushes. *ACS Macro Letters*, 2016: p. 149-153.

Watt, J., Hance, B.G., Anderson, R.S., and Huber, D.L., Effect of Seed Age on Gold Nanorod Formation: A Microfluidic, Real-Time Investigation. *Chemistry of Materials*, 2015. 27(18): p. 6442-6449.

Vreeland, E.C., Watt, J., Schober, G.B., Hance, B.G., Austin, M.J., Price, A.D., Fellows, B.D., Monson, T.C., Hudak, N.S., Maldonado-Camargo, L., Bohorquez, A.C., Rinaldi, C., and Huber, D.L., Enhanced Nanoparticle Size Control by Extending LaMer's Mechanism. *Chemistry of Materials*, 2015. 27(17): p. 6059-6066.

Firestone, M.A., Hayden, S.C., and Huber, D.L., Greater than the sum: Synergy and emergent properties in nanoparticle-polymer composites. *MRS Bulletin*, 2015. 40(09): p. 760-767.

Price, A.D. and Huber, D.L., Controlled polymer monolayer synthesis by radical transfer to surface immobilized transfer agents. *Polymer Chemistry*, 2013. 4(5): p. 1565-1574.

Price, A.D., Hur, S.-M., Fredrickson, G.H., Frischknecht, A.L., and Huber, D.L., Exploring Lateral Microphase Separation in Mixed Polymer Brushes by Experiment and Self-Consistent Field Theory Simulations. *Macromolecules*, 2012. 45(1): p. 510-524.

Liu, Y., Hudak, N.S., Huber, D.L., Limmer, S.J., Sullivan, J.P., and Huang, J.Y., In Situ Transmission Electron Microscopy Observation of Pulverization of Aluminum Nanowires and Evolution of the Thin Surface Al<sub>2</sub>O<sub>3</sub> Layers during Lithiation-Delithiation Cycles. *Nano Letters*, 2011. 11(10): p. 4188-94.

Huber, D.L., Synthesis, properties, and applications of iron nanoparticles. *Small*, 2005. 1(5): p. 482-501.

Huber, D.L., Manginell, R.P., Samara, M.A., Kim, B.I., and Bunker, B.C., Programmed adsorption and release of proteins in a microfluidic device. *Science*, 2003. 301(5631): p. 352-354.

### Awards and Synergistic Activities

Member, LANSCE—MPAC (Los Alamos Neutron Science Center—Materials Program Advisory Committee) 2007-2013.

Review Panel, NSF Designing Materials to Revolutionize and Engineer our Future (DMREF), 2012.

Review proposals for DOE (BES, EERE), NSF, ACS PRF.

Review manuscripts for: *Science*, *Angewandte Chemie*, *Journal of the American Chemical Society*, *Small*, *Advanced Materials*, *Advanced Functional Materials*, *Advanced Engineering Materials*, *Journal of Applied Physics*, *Journal of Materials Chemistry*, *Langmuir*, *Journal of Magnetism and Magnetic Materials*, *Chem Phys Chem*, *Journal of Nanoparticle Research*, and others.

### Collaborators in last 4 years:

Natalie Adolphi (University of New Mexico), Edward Flynn (Senior Scientific, LLC), Glenn T. Fredrickson

Soft, Biological and Composite Nanomaterials Thrust

(UCSB), Julia W.P. Hsu (UT Dallas), Jeffery T. Koberstein (Columbia U.), J. Ping Liu (UT Arlington), Marek Osinski (University of New Mexico), Dale Schaefer (Univ of Cincinnati), Laurel Sillerud (University of New Mexico), Hugh Smythe (UT Austin), J. Fraser Stoddart (Northwestern U.).

**Graduate Advisor:** Professor Thomas A. P. Seery (University of Connecticut)

**Postdoctoral Advisor:** Dr. Bruce C. Bunker (Sandia National Laboratories, retired)

**Graduate Students Advised:**

Todd Monson, (former, Sandia National Laboratories), Erika Vreeland (Senior Scientific), Jessica Bierner (former, Sandia National Laboratories), Grant Bleier (current, University of New Mexico)

**Post-Doctoral Associates Advised:**

Thomas Phely-Bobin (Entegris, Inc), Benjamin Frankamp (Chemeketa Community College), Judi Lavin (former, Sandia National Laboratories), Nicholas Hudak (Mitre Corp), Andrew Price (10x Technologies), Chester Simocko (Sandia National Laboratories), John Watt (Sandia National Laboratories)

## JENNIFER S. MARTINEZ

### Education and Training

University of California, Santa Barbara	Chemistry	Ph.D.	2002
University of Utah	Chemistry	B.S.	1994

### Research and Professional Experience

2015- present	Research Professor, Center for BioMedical Engineering, University of New Mexico
2014- present	CoDeputy Director of the Institute for Materials Science, Los Alamos National Laboratory.
2011-2014	Mentor within New Mexico Cancer Nanotech Training Center. University of New Mexico
2005-present	Technical Staff Member, MPA-CINT, Los Alamos National Laboratory.
2004-2005	Technical Staff Member, Bioscience Division, Los Alamos National Laboratory.
2002- 2004	Director's Funded Postdoctoral Fellow, Bioscience Division, Los Alamos
1996-2002	Graduate Research Assistant and GOF Fellow, Department of Chemistry, UCSB
1994-1996	Research Associate, Department of Human Genetics, University of Utah.
1990-1994	Undergraduate Research Associate, Department of Biology, University of Utah.

### Selected Publications (of 52)

- Balog, E.R.M., Ghosh, K., Park, Y.-I., Hartung, V., Sista, P., Rocha, R.C., Wang, H.-L., Martinez, J.S. "Optical properties of a pH-sensitive and thermoresponsive hydrogel made from a genetically engineered polymer and phenylene vinylene oligomer" *ACS Biomatsci. & Eng., in review* (2016)
- Chakraborty, S., Babanova, S., Rocha, R.C., Desireddy, A., Artyushkova, K., Atanassov, P. \*, Martinez, J.S\*. "A DNA-Hosted Gold Nanocluster Enhances Enzymatic Reduction of Oxygen by Facilitating Efficient Electron Transfer" *J. Amer. Chem. Soc.*, 137(36), 11678-11687 (2015) \*corresponding authors (highlighted in Science Daily, EurekaAlert, Los Alamos Daily Post, Santa Fe New Mexican, Nanotechnology News, Phys.Org, Clean Technica, Fuel Cell Works, Biofuels International).
- Ghosh, K., Balog, E.R.M., Sista, P., Martinez, J.S.\*, Rocha, R.C.\* "Multicolor Luminescence from Conjugates of Genetically Encoded Elastin-like Polymers and Terpyridine-Lanthanides" *Macromol. Chem. Phys*, 216(18) 1856-1861 (2015)
- Fazelinia, H., Balog, E.R.M., Desireddy, A., Chakraborty, S., Sheehan, C.J. Strauss, C.E.M.\* and Martinez, J.S.\* "Elastomeric polymer arrays through zipper assembly" *Angew Chemie Int., submitted* (2016)
- Phipps, M.L., Lillo, A.M., Shou Y., Schmidt, E.N., Paavola, C.D., Swanson, B.I., Bradbury, A.R.M., Martinez, J.S. "Affinity Ligands From "Helper Cell" Peptide Libraries" *PLOS One, in review* (2016)
- J.K. Sharma, M.L. Phipps, H.-C. Yeh, J.H. Werner, J.S. Martinez "Evolution of highly fluorescent silver nanocluster" *Nanoscale*, 4(14), 4107-4110 (2012)
- Yeh, H.-C., Sharma, J., Shihb, I.-M., Vu, D.M. Martinez, J.S.\*, Werner, J.H.\* "Colorimetric detection of single-nucleotide variations using silver nanoclusters" *J. Amer. Chem. Soc.*, 134(28) 11550-11558 (2012) \*corresponding authors (highlighted in C&EN "Silver nanoclusters spot single-base mutations in DNA" July, 2012)
- Neidig, M.L., Sharma, J., Yeh, H.-C., Martinez, J.S., Conradson, S.D., Shreve, A.P. "Ag K-edge EXAFS analysis of DNA-templated fluorescent silver nanoclusters: insight into the structural origins of emission tuning by DNA sequence variations" *J. Am. Chem. Soc.* 133(31), 11837-9 (2011)
- Sharma, J., Yeh, H.-C., Yoo, H., Werner, J.H., Martinez, J.S. "In-situ generation of aptamer templated silver nanoclusters for label-free protein detection," *Chem. Commun.*, 47, 2294-2296 (2011)
- Yeh, H.-C., Sharma, J., Martinez, J.S.\*, Werner, J.H.\* "Fluorescence enhancement of DNA-silver nanoclusters from guanine proximity," *Nano Letters* 10(8), 3106-3110 (2010) \*corresponding authors

### Awards and Synergistic Activities

AAAS Fellow, February (2013)

Kavli Fellow (2012) (18<sup>th</sup> Kavli German-American Frontiers of Science, US National Academy of Science/Humboldt Fndt)

RnD100 Award, “NanoCluster Beacons” (2011)

Presidential Early Career Award for Science and Engineering (2008)

LANL Outstanding Mentoring Award (2007 and 2012)

Directors Postdoctoral Fellow, LANL (2002)

B.R. Baker Award, Outstanding Chemistry, UCSB (2001)

California SeaGrant Traineeship and Graduate Opportunity Fellow, UCSB

Entrepreneurial and Centel Scholarship, University of Utah

Guest Editor, 2016, APL Materials, Nanoclusters

Adhoc Editor, 2013 MRS Spring Meeting Proceedings (Section N), 2013 MRS Spring Meeting Proceedings

Review Panelist: NIH, Centers of Cancer Nanotechnology Excellence, RFA-CA-14-013 (2015)

Review Panelist: NSF, 2015 HBCU-UP Research Initiation Award (2015)

Review Panelist: USDA/NIFA AFRI Nanotechnology for Agriculture and Food Systems (2008, 2011, 2013)

Review Panelist: DOE Early Career proposals (Synthesis and Processing and Biomaterials) (2012, 2013)

Review Panelist: DOE adhoc program proposal review (2010, 2011, 2012, 2013)

Review Chair: LANL LDRD-ER, “BBB” (2009, 2010, 2011)

Review Panelist: NSF CAREER: Solid State and Materials Chemistry (2011)

Review Panelist: LANL LDRD-ER, “Chemistry and Chemical Sciences” (2008, 2015, 2016)

Review Panelist: NIH SBIR “Bioengineering Sciences and Technology” (2008)

Review Panelist: NIH Special Emphasis Panel, ZRG1 BCMB-S (Nanotechnology) (2007)

Review Panelist: LANL LDRD-ER, “BBB” (2006); Review Panelist: LANL LDRD-ER, “Materials and Methods” (2005)

Review Panelist: LANL LDRD-ER, “Synthetic and Analytical Chemistry” (2004)

#### **Patents (of 8 award or in application)**

Genetically encoded polymer libraries and methods of using them, Full US Patent Application No. 61/932,436, (2015).

Fluorescence-enhancement of DNA-silver nanoclusters from guanine proximity. H.-C, Yeh, J. Sharma, J.S. Martinez, J.H. Werner S-18,917, (2010)

Synthesis of fluorescent metal nanoclusters. J.S. Martinez, R. B. Dyer, D. M. Vu, C. Zhong, Y. Bao. U.S. Patent 7,914,588 (2012)

Planar optical waveguide based sandwich assay sensors and processes for the detection of biological targets including early detection of cancers. Martinez, J.S., Swanson, B.I., Shively, J.E. Li, L. U.S. Patent 7,541,196 (2009)

#### **Collaborators**

Scott Anderson, U. Utah; Plamen Atanassov, UNM; Terry Bigioni, Toledo; Andrew P. Shreve, UNM; Larry Sklar, UNM; Anny Usheva, Brown.

#### **Undergraduate, Graduate and Postdoctoral Advisors**

Ph.D. Advisors: Prof. Alison Butler, University of California Santa Barbara

Postdoctoral Advisors: Basil Swanson and Andrew R.M. Bradbury (LANL)

#### **Postdoctoral Appointees Advised (Total number students and PDs advised in last 5 years: 10)**

Eva Balog (U NE); Yuping Bao (Prof. U. Alabama); Saumen Chakraborty (Ol’ Miss); Devin Close (ARUP Laboratory); Anil Desireddy; Leyma DeHaro (Senior Scientific); Koushik Ghosh (Eastman Chemical Company); Harsha Magurudeniya; Jaswinder Sharma (ONL); Prakash Sista (SABIC); Tim Yeh (U. Texas Austin); Hyojong Yoo (Prof. University of Hallym, Korea); Chang Zhong (Applied Biosystems);

#### **Graduate Appointees Advised**

Stoyana Alexandrova (Cambridge University)

### Undergraduates Advised

Emily Funsten (Middlebury College); Oksana Tretiak (UNM); Kirill Balatsky (LANL); Amy Boncella (Colo St. U)

### GABRIEL A. MONTAÑO

### Education and Training

New Mexico State Univ.	Undergraduate	BSc Mol Biol.	1997
Arizona State University	Graduate student	PhD Biochemistry	2002

### Research and Professional Experience

2012- Present     Team Leader of the Programmable Membrane Nanocomposite Integration Focus Area-Center for Integrated Nanotechnologies

2005-Present     Technical Staff Member/ Los Alamos National Laboratory

2002-2005        Intelligence Community Postdoctoral Fellow- Los Alamos National Laboratory

### Publications

Adams, P.G., Swingle, K.L., Paxton, W.F., Firestone, M.A., Mukundan, H., & Montaña, G.A. Exploiting lipopolysaccharide-induced deformation of lipid bilayers to modify membrane composition and generate two-dimensional geometric membrane array patterns. *Sci. Report* 5, 10331.

Adams, P.G., Collins, A.M., Sahin, T., Subramanian, V., Urban, V.S., Vairaprakash, P., Tian, Y., Evans, D.G., Shreve, A.P., & Montaña, G.A. (2015) *Diblock copolymer micelles and supported films with noncovalently incorporated chromophores: a modular platform for efficient energy transfer*. *Nanoletters* 15(4): 2422-2428.

Adams, P.G., Lamoureux, L., Swingle, K.L., Mukundan, H. & Montaña, G.A. *Lipopolysaccharide induced dynamic lipid organizations: lipid tubules, membrane perforations and multi-lamellar stacking*. *Biophys. J.* 106 (11): 2395-407.

Montaña, G.A., Adams, P.G., Xiao, X., & Goodwin, P.M. (2013) *Scanning probe microscopy of nanocomposite membrane assemblies- dynamic organization and mechanics*. *Adv. Funct. Mater. Advanced Functional Materials* 23(20): 2576-2591. (Invited)

Goertz, M.P., Marks, L.E. & Montaña, G.A. (2012) *Biomimetic Monolayer and Bilayer Membranes Made From Amphiphilic Block Copolymer Micelles*. *ACS Nano*: 6(2):1532-40.

### Awards and Synergistic Activities

2014-2017        President, Society for the Advancement of Chicanos and Native Americans in Science (SACNAS)

2013-present     Founder of the Annual Northern New Mexico STEM Symposium

2012-2015        Team Leader of Integration Focus Area at CINT in Programmable Membrane Nanocomposites-

2012-2014        Board of Directors- SACNAS

2003-2005        Intelligence Community Postdoctoral Fellowship- Los Alamos National Laboratory Honor/award

2002-2005        Minority Affairs Committee, Biophysical Society

2001-2002        Achievement Rewards for College Scientists (ARCS) Foundation Fellow, Arizona State

2007                SACNAS 2007 Presidential Award Recipient

1998-2002        Arizona State University Graduate Tuition Scholarship

1995-1997        MARC Fellow Recipient

### Collaborators

Susan Brozik (deceased); Bruce Bunker (Sandia National Laboratories); Eva Chi (University of New Mexico); Dewey Holten (Washington University); Neil Hunter (University of Sheffield); Jon Lindsay (North Carolina State

University); Gabriel Lopez (Duke University); Ronen Polsky (Sandia National Laboratories); John Shelnett (deceased); Andy Shreve (University of New Mexico); Xiaoyin Xiao (Sandia National Laboratories)

**Undergraduate, Graduate and Postdoctoral Advisors**

Robert E. Blankenship- Graduate Advisor, Professor- Washington University  
Andrew P. Shreve- Postdoctoral Advisor, Professor- University of New Mexico

**Postdoctoral Appointees Advised**

Aaron M. Collins, PhD (Asst. Professor-Southern New Hampshire University)  
Peter G. Adams, PhD (Postdoctoral Fellow- University of Sheffield)  
Gregory Uyeda, PhD (self-employed)  
Matthew Goertz, PhD (Senior Project Scientist- Donaldson Company)  
Xiaoyin Xiao, PhD (currently PI- Sandia National Lab)  
Haiqing Liu, PhD- (currently PI-Sandia National Lab)  
Yongming Tian, Graduate Student (Postdoc- New Mexico Institute of Technology)  
Matthew Rush, Graduate Student (Current)

**Thesis Advisees and Sponsored Postgraduate Scholar**

Thesis advisors: Neil Woodbury- Arizona State University, Biodesign Institute  
Vincent Pizziconi- Arizona State University, Dept. of Chemical Engineering



## WALTER F. PAXTON

### Education and Training

Penn State, University Park, PA	Chemistry	Ph.D.	2006
Brigham Young University, Provo, UT	Chemistry	B.S.	2001
Brigham Young University - Idaho, Rexburg, ID	Arts and Sciences	A.A.S.	1998

### Research and Professional Experience

2011-present	Senior Member of Technical Staff, Center for Integrated Nanotechnologies, Albuquerque, NM
2008-2011	Postdoctoral Fellow, Northwestern University, Evanston, IL
2006-2008	Postdoctoral Researcher, Pacific Northwest National Laboratory, Richland, WA

### Selected Publications

- Henderson, I. M., Quintana, H. A., Martinez, J. A., Paxton, W. F., Capable Crosslinks: Polymersomes Reinforced with Catalytically Active Metal-Ligand Bonds. *Chem. Mater.* 27, 4808 (2015).
- Paxton, W. F., Boussein, N. F., Henderson, I. M., Gomez, A., Bachand, G. D., Dynamic Assembly of Polymer Nanotube Networks via Kinesin Powered Microtubule Filaments. *Nanoscale* 7, 10998 (2015).
- Henderson, I. M., Adams, P. G., Montañó, G. A., Paxton, W. F., Ionic effects on the behavior of thermoresponsive PEO-PNIPAAm block copolymers. *J. Poly. Sci. B* 52, 507 (2014).
- Henderson, I. M., Paxton, W. F., Salt, Shake, Fuse – Giant Hybrid Polymer/Lipid Vesicles via Mechanically-Activated Fusion. *Angew. Chem. Int. Ed.* 53, 3372 (2014).
- Paxton, W. F., Price, D., Richardson, N. J., Hydroxide ion flux and pH-gradient driven ester hydrolysis in polymer vesicle reactors. *Soft Matter* 9, 11295 (2013).
- Paxton, W. F., Kleinman, S. L., Basuray, A. N., Stoddart, J. F., Van Duyne, R. P., Surface-Enhanced Raman Spectroelectrochemistry of TTF-Modified Self-Assembled Monolayers. *J. Phys. Chem. Lett.* 2, 1145 (2011).
- Li, D., Paxton, W. F., Baughman, R. H., Huang, T. J., Stoddart, J. F., Weiss, P. S., Molecular, Supramolecular, and Macromolecular Motors and Artificial Muscles. *MRS Bulletin* 34, 671 (2009).
- Paxton, W. F., Spruell, J. M., Stoddart, J. F., Heterogeneous Catalysis of a Copper-Coated Atomic Force Microscopy Tip for Direct-Write Click Chemistry. *J. Am. Chem. Soc.* 131, 6692 (2009).
- Paxton, W. F., Sundararajan, S., Mallouk, T. E., Sen, A., Chemical Locomotion. *Angew. Chem. Int. Ed.* 45, 5420 (2006).
- Paxton, W. F., Kistler, K. C., Olmeda, C. C., Sen, A., St. Angelo, S. K., Cao, Y., Mallouk, T. E., Lammert, P. E., Crespi, V. H., Autonomous Movement of Striped Nanorods. *J. Am. Chem. Soc.* 126, 13424 (2004).

### Awards and Synergistic Activities

- Co-organizer of Micro- and Nanomachines 2014, Volkswagen Stiftung, June 2016
- Guest Editor, IEEE Transactions on Nanobioscience, Spring 2015
- Co-organizer of MRS symposium L: Bioinspired Micro- and Nano-machines, April 2015
- German American Frontiers of Engineering, Invited Participant, April 2015
- Co-organizer of Micro- and Nanomachines 2014, Volkswagen Stiftung, July 2014

### Patents

- “Autonomous Moving Microstructures” (U.S. patent 7,516,759) granted 4/14/2009

### Collaborators (past 48 months)

- Richard P. Van Duyne (Northwestern University)
- Ayusman Sen (Penn State)
- Bryan J. Kaehr (SNL)
- Eric C. Carnes (SNL)
- James H. Werner (LANL)
- Henry Hess (Columbia)
- George D Bachand (SNL)
- Julio Martinez (NMSU)

Soft, Biological and Composite Nanomaterials Thrust

Darryl Sasaki (SNL-CA)  
Michael Betenbaugh (Johns Hopkins)  
Samuel Sanchez (Institute for Bioengineering of Catalonia)  
Gabriel B. Montaña (LANL)

**Undergraduate, Graduate and Postdoctoral Advisors**

Ph.D. advisors: Ayusman Sen and Thomas E. Mallouk, The Pennsylvania State University, Department of Chemistry

Postdoctoral Advisor: Jay W. Grate, Pacific Northwest National Laboratories

Postdoctoral Advisor: J. Fraser Stoddart, Northwestern University, Department of Chemistry

**Postdoctoral Appointees Advised**

Ian M. Henderson (now at Sandia)

**Graduate Students Co-Advised**

Hope A. Quintana (Chem. E. NMSU, now at Sandia)

**Undergraduates Advised**

Jennifer Hsu (MIT), Delisia Price (Houston Community College), Nicholas J. Richardson (Houston Community College)

**Total:** 1 postdoc, 4 students

## JAMES WERNER

### Education and Training

Cornell University, Ithaca NY	Applied Physics	Ph.D.	1998
Cornell University, Ithaca NY	Applied Physics	M.S.	1994
California Institute of Technology, Pasadena, CA	Applied Physics	B.S.	1992

### Research and Professional Experience

2002-present	Technical Staff Member, Los Alamos National Laboratory, NM
2009-present	Adjunct Assistant Professor, University of New Mexico, Department of Physics, NM
1998-2002	Postdoctoral Research Associate, Los Alamos National Laboratory, NM

### Selected Publications

- DeVore, M, Stich, D, Keller, A, Cleyrat, C, Phipps, M, Hollingsworth, J, Lidke, D, Wilson, B, Goodwin, P and Werner, J, "Note: Time-gated 3D single quantum dot tracking with simultaneous spinning disk imaging," *Review of Scientific Instruments* 86, 126102, (2015).
- Keller, AM, Ghosh, Y, DeVore, MS, Phipps, ME, Stewart, MH, Wilson, BS, Lidke, DS, Hollingsworth, JA and Werner, JH, "3-Dimensional Tracking of Non-blinking 'Giant' Quantum Dots in Live Cells," *Advanced Functional Materials* 24, 4796-4803, (2014). (Work featured in frontispiece)
- Zhang, P, Phipps, M, Goodwin, P and Werner, J, "Confocal line scanning of a Bessel beam for fast 3D Imaging," *Optics Letters* 39, 3682-3685, (2014).
- Han, JJ, Kunde, YA, Hong-Geller, E and Werner, JH, "Actin restructuring during Salmonella typhimurium infection investigated by confocal and super-resolution microscopy," *Journal of Biomedical Optics* 19, 016011-016011, (2014).
- Shepherd, D.P., Li, N., Micheva-Viteva, S., Munsky, B., Hong-Geller, E. and Werner, J.H., "Counting Small RNA in Pathogenic Bacteria," **Anal. Chem.**, 85, 4938-4943, (2013). Featured on Cover.
- Yeh, H.C., Sharma, J., Shih, I.M., Vu, D.M., Martinez, J.S. and Werner, J.H., "A Fluorescence Light-Up Ag Nanocluster Probe That Discriminates Single-Nucleotide Variants by Emission Color," **JACS**, 134, 11550-11558, (2012).
- Han, J.J., Kiss, C., Bradbury, A. and Werner, J.H., "Time-Resolved, Confocal Single Molecule Tracking of Individual Organic Dyes and Fluorescent Proteins in Three Dimensions," **ACS Nano**, 6, 8922-8932, (2012).
- Crochet, J.J., Duque, J.G., Werner, J.H., Lounis, B., Cognet, L. and Doorn, S.K., "Disorder Limited Exciton Transport in Colloidal Single-Wall Carbon Nanotubes," **Nano Lett**, 12, 5091-5096, (2012).
- Crochet, J.J., Duque, J.G., Werner, J.H. and Doorn, S.K., "Photoluminescence imaging of electronic-impurity-induced exciton quenching in single-walled carbon nanotubes," **Nat. Nanotechnol.**, 7, 126-132, (2012).
- Sharma, J., Rocha, R.C., Phipps, M.L., Yeh, H.C., Balatsky, K.A., Vu, D.M., Shreve, A.P., Werner, J.H. and Martinez, J.S., "A DNA-templated fluorescent silver nanocluster with enhanced stability," **Nanoscale**, 4, 4107-4110, (2012).
- Yeh, H.C., Sharma, J., Han, J.J., Martinez, J.S. and Werner, J.H., "A DNA- Silver Nanocluster Probe That Fluoresces upon Hybridization," **Nano Lett**, 10, 13308-13313, (2010).
- Wells, N.P., Lessard, G.A., Goodwin, P.M., Phipps, M.E., Cutler, P.J., Lidke, D.S., Wilson, B.S. and Werner, J.H., "Time-resolved three-dimensional molecular tracking in live cells," **Nano Lett**, 10, 4732-4737, (2010).

### Awards and Synergistic Activities

- Los Alamos Distinguished Patent Award (2011)
- R&D 100 Award "NanoCluster Beacons" (2011)
- Los Alamos Postdoctoral Distinguished Mentor Award (2011)
- Best Paper Award, IEEE Conference on Nano/Micro Engineered and Molecular Systems (2011)

Best Paper Award, Single Molecule Session of Photonics West (2009)

R&D 100 Award “3D Tracking Microscope” (2008)

Hertz Foundation Fellowship (1992-1997)

Caltech Carnation Merit Award (1990-91 and 1991-92)

### Patents

Yeh, H.C., Sharma, J.K., Martinez, J.S. and Werner, J.H., “*Probe and Method for DNA Detection*,” **US Patent 8,476,014** (2013).

Werner, J.H., Goodwin, P.M. and Shreve, A.P., “*3 Dimensional Imaging at Nanometer Resolutions*,” **US Patent 7,675,045**, (2010).

Werner, J.H., Goodwin, P.M. and Lessard, G.A., “*Apparatus and method for tracking a molecule or particle in three dimensions*,” **US Patent 7,498,551**, (2009).

### Collaborators

Prof. Yuping Bao (University of Alabama), Prof. Jeff Brinker (University of New Mexico), Dr. Hong Cai (Mesa Biotech), Prof. James Demas (University of Virginia), Prof. Donglei Fan (University of Texas, Austin), Prof. James Freyer (University of New Mexico), Dr. Mark Hildebrand (Scripps Institute of Oceanography), Prof. Diane Lidke (University of New Mexico), Prof. James Ng (University of California, Riverside), Prof. Christine Payne (Georgia Tech), Prof. Linda Peteanu (Carnegie Mellon), Prof. Ayusman Sen (Penn State University), Prof. Andy Shreve (University of New Mexico), Prof. Alan Van Orden (Colorado State University), Prof. Bridget Wilson (University of New Mexico), Prof. Hsin-Chih Yeh (University of Texas, Austin)

### Undergraduate, Graduate and Postdoctoral Advisors

Undergraduate Advisor: Dr. Amnon Yariv, Caltech (advisor for senior thesis and summer research)

Ph.D. Advisor: Dr. Terrill Cool, Cornell University

Postdoctoral Advisors: Dr. Peter Goodwin and Dr. Richard Keller, LANL (1998-2000)

Postdoctoral Advisor: Dr. R. Brian Dyer, Los Alamos National Laboratory (2000-2002)

### Scientific Staff Supervised

W. Kevin Grace (LANL Laser Technologist)

### Postdoctoral Appointees Advised

Dominik Stich (current, LANL), Matt DeVore (Assoc. Prof. Evangel University), Aaron Keller (Assistant Prof., William Jewell College), Douglas Shepherd (Assistant Professor, Physics, UC Denver), Pengfei Zhang, Mircea Cotlet (Brookhaven National Laboratory), Jason Han (MIT Lincoln Labs), Guillaume Lessard (Covidien), Anton Malko (Assoc. Prof, University of Texas, Dallas), Jamshid Temirov (St. Jude’s Research Hospital), Nathan Wells (Aerospace Corporation) Hsin-Chih Yeh (Assistant Prof., University of Texas, Austin)

### Undergraduates Advised

Delon Wilson, (Wayne State University)

### Visiting Faculty

Prof. Linda Peteanu (Carnegie Mellon), Prof. James Demas (U. Virginia), Prof. Tim Causgrove (Texas A&M, Corpus Christi)

## 9.0 Current & Pending Support

### George D. Bachand

<b>Investigator:</b> George D. Bachand	Other Agencies to which this proposal has been/will be submitted: N/A
Support (Current, Pending, Submission Planned in Future or Transfer of Support): <u>Current</u>	
Project/Proposal Title and grand number if appropriate: <i>Active Assembly of Dynamic and Adaptive Materials</i>	
Source of Support: Office of Basic Energy Sciences, DOE	Location of Project: Sandia National Laboratories
Annual Award Amount: \$1,250,000	Total Award Period Covered: 8/02 - present
Annual Award Amount to PI's Research: 195,500	
Person-Months Per Year Committed to Project: 4.8 Pers. Months; Specify: <u>Calendar</u>	
Describe research including synergies and/or overlaps with This Proposal/Award: The work on this project is focused on understanding and exploiting key principles and strategies used by living systems to develop materials whose transport, assembly, configuration, organization, and disassembly can be programmed or "self-directed" in controlled environments.	
<b>Investigator:</b> George D. Bachand	Other Agencies to which this proposal has been/will be submitted: N/A
Support (Current, Pending, Submission Planned in Future or Transfer of Support): <u>Current</u>	
Project/Proposal Title and grand number if appropriate: Synthetic DNA for Highly Secure Information Storage and Transmission	
Source of Support: Sandia National Laboratories, Laboratory Directed Research and Development (LDRD)	Location of Project: Sandia National Laboratories
Annual Award Amount: \$100,000	Total Award Period Covered: 10/14 – 09/16
Annual Award Amount to PI's Research: \$100,000	
Person-Months Per Year Committed to Project: 0.6 Pers. Months; Specify: <u>Calendar</u>	
Describe research including synergies and/or overlaps with This Proposal/Award: This project centers on the development of a method to encrypt and store sensitive information using synthetic DNA. No overlap with this FWP.	
<b>Investigator:</b> George D. Bachand (PI: Spoerke)	Other Agencies to which this proposal has been/will be submitted: N/A
Support (Current, Pending, Submission Planned in Future or Transfer of Support): <u>Current</u>	
Project/Proposal Title and grand number if appropriate: <i>Programmable Nanocomposite Membranes for Ion-Based Electrical Energy Storage</i>	
Source of Support: Sandia National Laboratories, Laboratory Directed Research and Development (LDRD)	Location of Project: Sandia National Laboratories
Annual Award Amount: \$510,000	Total Award Period Covered: 10/13 – 09/15
Annual Award Amount to PI's Research: \$130,000	
Person-Months Per Year Committed to Project: 0.6 Pers. Months; Specify: <u>Calendar</u>	
Describe research including synergies and/or overlaps with This Proposal/Award: This project involves the integration of synthetic channels and biological ion pumps to create, maintain, and dissipate ionic gradients across a membrane as a means of developing novel electrochemical energy storage systems. Work on this project does not overlap with work on this FWP.	
<b>Investigator:</b> George D. Bachand (PI: Ashlee)	Other Agencies to which this proposal has been/will be submitted: N/A
Support (Current, Pending, Submission Planned in Future or Transfer of Support): <u>Pending</u>	
Project/Proposal Title and grand number if appropriate:	

<i>NanoCRISPR: A Revolutionary Therapeutic Platform for Rapidly Countering Emerging and Genetically-Enhanced Biological Threats</i>	
Source of Support: Sandia National Laboratories, Laboratory Directed Research and Development (LDRD)	Location of Project: Sandia National Laboratories
Annual Award Amount: \$3,971,000	Total Award Period Covered: 10/15 – 09/18
Annual Award Amount to PI's Research: \$120,000	
Person-Months Per Year Committed to Project: 2 Pers. Months; Specify: Calendar	
Describe research including synergies and/or overlaps with This Proposal/Award: This project involves the integration of CRISPR technology with “proto-cell” based delivery to develop state-of-the-art medical countermeasures against existing as well as novel, previously-unrecognized, naturally-occurring emerging infectious disease.	

**Millicent Firestone**

<b>Investigator:</b> Name (PI: Name) Firestone (Podlesak)	Other Agencies to which this proposal has been/will be submitted: n/a
Support (Current, Pending, Submission Planned in Future or Transfer of Support): Current	
Project/Proposal Title and grand number if appropriate: Chemical Signatures of Detonation Born from Extreme Conditions (Unclassified title)	
Source of Support: LANL/LDRD-DR	Location of Project: LANL
Annual Award Amount: 1,695,000.00	Total Award Period Covered: 10/1/15 to 9/30/2017
Annual Award Amount to PI's Research: 350,000.00	
Person-Months Per Year Committed to Project: 3 Pers. Months; Specify: Calendar	
Describe research including synergies and/or overlaps with This Proposal/Award: The ability to infer information about high explosive, type and detonation geometry (i.e., implosion vs. explosion) is of high value to U.S. intelligence, and international treaty monitoring and verification organizations. Nuclear detection satellites, seismic monitoring networks, and traditional nuclear forensic investigations provide little or no insight into the dynamics of HE detonation. Post-detonation and real-time signatures of explosive test programs and unique materials identifiers are needed, but can only come from a fundamental understanding of the physical processes that lead to their formation and evolution in time. An interdisciplinary effort to understand how solid carbon forms and evolves during detonation, develop new models to describe its evolution, and link <i>in situ</i> measurements of signature formation with post-detonation characteristics.	
<b>Investigator:</b> Name (PI: Name) Firestone (Firestone)	Other Agencies to which this proposal has been/will be submitted: n/a
Support (Current, Pending, Submission Planned in Future or Transfer of Support): Pending	
Project/Proposal Title and grand number if appropriate: Durable and dynamic polymer templates for the hierarchical assembly of optically active nanoparticles	
Source of Support: LANL/LDRD-ER	Location of Project: LANL
Annual Award Amount: 350,000.00	Total Award Period Covered: 10/1/2016-9/30/18
Annual Award Amount to PI's Research: 100,000.00	
Person-Months Per Year Committed to Project: 2 Pers. Months; Specify: Calendar	
We propose to use polymeric ionic liquids [Poly(ILs)] as novel durable, responsive matrices that are capable of: (a) co-assembling light-emitting quantum dots (QDs) and plasmonic metal nanoparticles (MNPs) into geometrically-defined arrays, hierarchically ordered across the nano/meso to macroscale.	
<b>Investigator:</b> Name (PI: Name) Firestone (Hollingsworth)	Other Agencies to which this proposal has been/will be submitted: n/a
Support (Current, Pending, Submission Planned in Future or Transfer of Support): Pending	
Project/Proposal Title and grand number if appropriate:	

Hybrid Photonic-Plasmonic Materials: Toward Ultimate Control Over the Generation and Fate of Photons	
Source of Support: LANL/LDRD-DR	Location of Project: LANL
Annual Award Amount: 1,650,000.00	Total Award Period Covered: 10/1/2016-9/30/18
Annual Award Amount to PI's Research: 275,000.00	
Person-Months Per Year Committed to Project: 2 Pers. Months; Specify: Calendar	
this proposal is to develop new classes of solid-state functional photonic (semiconductor quantum emitter)-plasmonic (metallic nanostructure) <i>hybrid materials</i> that afford unprecedented control over the generation and fate of the elementary particle of light – the photon.	
<b>Investigator:</b> Name (PI: Name) Firestone (Kathryn Brown)	Other Agencies to which this proposal has been/will be submitted: n/a
Support (Current, Pending, Submission Planned in Future or Transfer of Support): Pending	
Project/Proposal Title and grant number if appropriate: Metal Nanoparticle Directed Catalysis of Carbon Allotropes at Elevated Temperatures	
Source of Support: LANL/LDRD-DR	Location of Project: LANL
Annual Award Amount: 320,000.00	Total Award Period Covered: 10/1/15 to 9/30/2017
Annual Award Amount to PI's Research: 50,00.00	
Person-Months Per Year Committed to Project: 1 Pers. Months; Specify: Calendar	
Describe research including synergies and/or overlaps with This Proposal/Award: Through the study of well-defined carbon allotropes (diamond, graphite, amorphous carbon) with metal nanoparticles acting as either a nucleation point or substrate for epitaxy, we will be able to determine how to better direct hybridization and morphology.	

**Peter Goodwin**

<b>Investigator:</b> Peter Goodwin (PI: Dattelbaum)	Other Agencies to which this proposal has been /will be submitted:
Support (Current):	
Project / Proposal Title and grant number, if appropriate: LANL programmatic work	
Source of Support:	Location of Project: Los Alamos National Laboratory, Los Alamos NM 87545
Annual Award Amount:	Total Award Period Covered:
Annual Award Amount to PI's Research:	
Person-Months Per Year Committed to Project: 6 Per. Months; Calendar	
Describe research including synergies and/or overlaps with this Proposal/Award: LANL programmatic work <i>No overlap</i>	

**Dale Huber**

<b>Investigator:</b> Dale Huber (PI: Dale Huber)	Other Agencies to which this proposal has been/will be submitted: N/A
Support (Current, Pending, Submission Planned in Future or Transfer of Support): Current	
Project/Proposal Title and grant number if appropriate: <i>A Nanocomposite Inductor Core for Pulsed Power Applications</i>	
Source of Support: Sandia LDRD program	Location of Project: Sandia National Laboratories
Annual Award Amount: \$165,000	Total Award Period Covered: 10/15-9/16

Annual Award Amount to PI's Research: \$165,000	
Person-Months Per Year Committed to Project: 3 Pers. Months; Specify: Calendar	
Describe research including synergies and/or overlaps with This Proposal/Award: This one year project seeks to use the basic understanding of magnetic nanoparticles developed in part through this FWP to scale up a synthesis to create a 1/10 scale model of a nanocomposite inductor core for testing as a potential high performance inductor in pulsed power applications. This project utilizes knowledge generated from this FWP to develop a manufacturable material for potential fusion energy applications.	
Investigator: Dale Huber (PI: Fan)	Other Agencies to which this proposal has been/will be submitted: N/A
Support (Current, Pending, Submission Planned in Future or Transfer of Support): Current	
Project/Proposal Title and grant number if appropriate: <i>Adaptive and Reconfigurable Nanocomposites</i>	
Source of Support: Office of Basic Energy Sciences, DOE	Location of Project: Sandia National Laboratories
Annual Award Amount: \$1,400,000	Total Award Period Covered: 10/02 - present
Annual Award Amount to PI's Research: \$250,000	
Person-Months Per Year Committed to Project: 3 Pers. Months; Specify: Calendar	
Describe research including synergies and/or overlaps with This Proposal/Award: To explore the use of energy consuming, switchable, and/or responsive components to create programmable and/or reconfigurable nanocomposites.	

**Jennifer S. Martinez**

Investigator: Jennifer S. Martinez (PI. Sasha Balatsky)	Other Agencies to which this proposal has been /will be submitted: none
Support (Current)	
Project / Proposal Title and grant number, if appropriate: <i>Institute for Materials Science</i>	
Source of Support: LANL	Location of Project: LANL
Annual Award Amount: \$130K	Total Award Period Covered: 2014-2017
Annual Award Amount to PI's Research: 0\$ (Administrative not research)	
Person-Months Per Year Committed to Project: 4 Per. Months; Specify <u>C</u> al., <u>A</u> cad., or <u>S</u> mr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: <i>Project Scope:</i> Administrative <i>Role:</i> CoDeputy Director <i>Synergies/Overlaps:</i> Potential sponsor of conferences with like minded topics to CINT; promotion of LANL science to external community.	
Investigator: Jennifer S. Martinez (Dr. Reginaldo Rocha)	Other Agencies to which this proposal has been /will be submitted: none
Support ( <u>C</u> urrent, <u>P</u> ending, <u>S</u> ubmission <u>P</u> lanned in <u>F</u> uture or <u>T</u> ransfer of <u>S</u> upport): C	
Project / Proposal Title and grant number, if appropriate: <i>Stimuli-Responsive Coordination Polymersomes</i>	
Source of Support: LDRD Location of Project: LANL	
Annual Award Amount: 310K	Total Award Period Covered: 2015-2018
Annual Award Amount to PI's Research: FTE plus materials	



Person-Months Per Year Committed to Project: 0.5 Per. Months; Specify <u>Cal.</u> , <u>Acad.</u> , or <u>Smr</u> : C	
Describe research including synergies and/or overlaps with this Proposal/Award: Program develops synthetic polymers that have programmed assembly and disassembly with metal coordination. CINT <i>may</i> benefit from new stimuli-responsive coordination chemistry that we may incorporate into our genetically encoded polymers.	
<b>Investigator:</b> Jennifer S. Martinez (PI Dima Yarotsky)	Other Agencies to which this proposal has been /will be submitted: none
Support ( <u>C</u> urrent, <u>P</u> ending, <u>S</u> ubmission <u>P</u> lanned in <u>F</u> uture or <u>T</u> ransfer of <u>S</u> upport): C	
Project / Proposal Title and grant number, if appropriate: <i>Transient Thermal Conduction in Nonlinear Molecular Junctions</i>	
Source of Support: LANL Location of Project: LANL/SNL	
Annual Award Amount: \$310K Total Award Period Covered: 2013-2016	
Annual Award Amount to PI's Research: FTE + materials and supplies	
Person-Months Per Year Committed to Project: 0.5 Per. Months; Specify <u>Cal.</u> , <u>Acad.</u> , or <u>Smr</u> : C Describe research including synergies and/or overlaps with this Proposal/Award: There is no overlap with this program. The above project will measure the thermal conduction of molecular junctions, through use of double stranded DNA attached to thermal probes.	
<b>Investigator:</b> Jennifer S. Martinez (PI)	Other Agencies to which this proposal has been /will be submitted: none
Support ( <u>C</u> urrent, <u>P</u> ending, <u>S</u> ubmission <u>P</u> lanned in <u>F</u> uture or <u>T</u> ransfer of <u>S</u> upport): C	
Project / Proposal Title and grant number, if appropriate: <i>Emergent Polymers</i>	
Source of Support: LDRD Location of Project: LANL	
Annual Award Amount: 310K Total Award Period Covered: 2015-2018	
Annual Award Amount to PI's Research: 300K	
Person-Months Per Year Committed to Project: 0.5 Per. Months; Specify <u>Cal.</u> , <u>Acad.</u> , or <u>Smr</u> : <u>Cal</u>	
Describe research including synergies and/or overlaps with this Proposal/Award: Program aims to develop genetically encoded polymers that have emergent properties through rational design. CINT will gain access to the techniques and polymers for application in users science. CINT may leverage conjugation strategies of optical moieties.	
<b>Investigator:</b> Jennifer S. Martinez (Dr. Charlie Strauss)	Other Agencies to which this proposal has been /will be submitted: none
Support ( <u>C</u> urrent, <u>P</u> ending, <u>S</u> ubmission <u>P</u> lanned in <u>F</u> uture or <u>T</u> ransfer of <u>S</u> upport): C	
Project / Proposal Title and grant number, if appropriate: <i>Foldamers: Design of Monodisperse Macro-Molecular Structure by Selection of Synthetic Heteropolymer Sequence</i>	
Source of Support: LDRD Location of Project: LANL	

Annual Award Amount: \$1.2M Total Award Period Covered: 2015-2018	
Annual Award Amount to PI's Research: FTE; 1 postdoc, materials and supplies	
Person-Months Per Year Committed to Project: 0.5 Per. Months; Specify <u>C</u> al., <u>A</u> cad., or <u>S</u> mr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: No overlap with this proposal. Project aims to develop artificial proteins, made of peptoids, that fold into defined 3D shapes. Once stable folded structures are developed, functions such as organophosphate hydrolysis will be developed.	
<b>Investigator:</b> Jennifer S. Martinez (PI)	Other Agencies to which this proposal has been /will be submitted: none
Support ( <u>C</u> urrent, <u>P</u> ending, <u>S</u> ubmission <u>P</u> lanned in <u>F</u> uture or <u>T</u> ransfer of <u>S</u> upport): in submission	
Project / Proposal Title and grant number, if appropriate: <i>Genetically Encoded Photonic Materials</i>	
Source of Support: Office of Basic Energy Sciences, DOE Location of Project: LANL	
Annual Award Amount: 850K Total Award Period Covered: unknown	
Annual Award Amount to PI's Research: unknown unless funded	
Person-Months Per Year Committed to Project: - Per. Months; Specify <u>C</u> al., <u>A</u> cad., or <u>S</u> mr: <u>C</u> al	
Describe research including synergies and/or overlaps with this Proposal/Award: Program will develop de novo design of genetically encoded peptide assemblies coupled to adaptive polymers and photonic materials (nanoclusters). The fundamental studies in this program will be development of Rosetta algorithms to design materials and in situ dynamic studies of their assembly. This program will leverage CINT's capabilities in genetically encoded polymer libraries and 3D microscopy/spectroscopy. Proposed project will leverage a few techniques from CINT (3D tracking, optical polymers selection, super resolution microscopy).	
<b>Investigator:</b> Jennifer S. Martinez (LANL PI unnamed)	Other Agencies to which this proposal has been /will be submitted: none
Support ( <u>C</u> urrent, <u>P</u> ending, <u>S</u> ubmission <u>P</u> lanned in <u>F</u> uture or <u>T</u> ransfer of <u>S</u> upport): P	
Project / Proposal Title and grant number, if appropriate: <i>Greenlock</i>	
Source of Support: outside sponsor Location of Project: LANL	
Annual Award Amount: unknown Total Award Period Covered: unknown	
Annual Award Amount to PI's Research: 25% of a postdoc	
Person-Months Per Year Committed to Project: - 0 Per. Months; Specify <u>C</u> al., <u>A</u> cad., or <u>S</u> mr: C	
Describe research including synergies and/or overlaps with this Proposal/Award: Outside sponsor. No synergies	

Gabriel Montaña

<b>Investigator: Gabriel A. Montaño</b>	Other Agencies to which this proposal has been/will be submitted:
Support (Current, Pending, Submission Planned in Future or Transfer of Support): Current	
Project/Proposal Title and grant number, if appropriate:	
Photosynthetic Antenna Research Center (PARC)	
Source of Support: U.S. Department of Energy Location of Project: Los Alamos National Laboratory	
Annual Award Amount: \$4,000,000 Total Award Period Covered: 08/01/2009-07/31/2014	
Annual Award Amount to PI's Research: \$125,000	
Describe Synergies and/or overlaps with This Proposal/Award:	
Person-Months Per Year Committed to Project: 0.24 Pers. Months; Cal.	
<b>Investigator: Gabriel A. Montaño</b>	Other Agencies to which this proposal has been/will be submitted:
Support (Current, Pending, Submission Planned in Future or Transfer of Support): Current	
Project/Proposal Title and grant number, if appropriate:	
Stimuli-Responsive MetalloSupramolecular Polymersomes	
Source of Support: Los Alamos National Laboratory LDRD program	
Location of Project: Los Alamos National Laboratory	
Annual Award Amount: \$375,000 Total Award Period Covered: 10/2015-09/2018	
Annual Award Amount to PI's Research: \$	
Describe Synergies and/or overlaps with This Proposal/Award: This project is aimed toward the design of polymersomes that exhibit dynamic properties for drug delivery and release	
Person-Months Per Year Committed to Project: 2.0 Pers. Months; Cal.	

<b>Investigator: Gabriel A. Montaño</b>	Other Agencies to which this proposal has been/will be submitted:
Support (Current, Pending, Submission Planned in Future or Transfer of Support): Current	
Project/Proposal Title and grant number, if appropriate:	
Multi-scale Probabilistic Resuspension Modeling of Spores and Radionuclides from Outdoor Surfaces	
Source of Support: Los Alamos National Laboratory LDRD program	
Location of Project: Los Alamos National Laboratory	
Annual Award Amount: \$395,000 Total Award Period Covered: 10/2013-09/2016	
Annual Award Amount to PI's Research: \$ 1650,000	
Describe Synergies and/or overlaps with This Proposal/Award: This project aims to determine driving forces for particle dispersion related to biosecurity applications.	
Person-Months Per Year Committed to Project: 2.0 Pers. Months; Cal.	
<b>Investigator: Gabriel A. Montaño</b>	Other Agencies to which proposal has been submitted:
Support (Current, Pending, Submission Planned in Future or Transfer of Support): Current	
Project/Proposal Title and grant number, if appropriate: SACNAS Bioscience Integrated Organizational Network (BioNet): Promoting Retention and Success In URM Undergraduate Biology Education	
Source of Support: National Science Foundation	
Location of Project: SACNAS	
Annual Award Amount: \$50,000 Total Award Period Covered: 2/2016-03/2017	
Annual Award Amount to PI's Research: \$ 0	

Describe Synergies and/or overlaps with This Proposal/Award: This project goal is to expand opportunities at all institutional levels for URM biology students and to enhance their retention and success rate by offering webinars of instruction and mentoring by URM professionals.

Person-Months Per Year Committed to Project: 0 Pers. Months; Cal.

### Walter Paxton

<b>Investigator:</b> Walter Paxton (PI: Bachand)	Other Agencies to which this proposal has been/will be submitted: N/A
Support ( <u>C</u> urrent, <u>P</u> ending, <u>S</u> ubmission Planned in Future or <u>T</u> ransfer of Support): <u>C</u> urrent	
Project/Proposal Title and grand number if appropriate: <i>Active Assembly of Dynamic and Adaptive Materials</i>	
Source of Support: Office of Basic Energy Sciences, DOE	Location of Project: Sandia National Laboratories
Annual Award Amount: \$1,290,000	Total Award Period Covered: 8/02 - present
Annual Award Amount to PI's Research: 75,000	
Person-Months Per Year Committed to Project: <u>3</u> Pers. Months; Specify: <u>Calendar</u>	
Describe research including synergies and/or overlaps with This Proposal/Award: The work on this project is focused on understanding and exploiting key principles and strategies used by living systems to develop materials whose transport, assembly, configuration, organization, and disassembly can be programmed or "self-directed" in controlled environments.	
<b>Investigator:</b> Walter Paxton (PI: Ashlee)	Other Agencies to which this proposal has been/will be submitted: N/A
Support ( <u>C</u> urrent, <u>P</u> ending, <u>S</u> ubmission Planned in Future or <u>T</u> ransfer of Support): <u>C</u> urrent	
Project/Proposal Title and grand number if appropriate: <i>NanoCRISPR: A Revolutionary Therapeutic Platform for Rapidly Countering Emerging and Genetically-Enhanced Biological Threats</i>	
Source of Support: Sandia National Laboratories, Laboratory Directed Research and Development (LDRD)	Location of Project: Sandia National Laboratories
Annual Award Amount: \$3,971,000	Total Award Period Covered: 10/15 – 09/18
Annual Award Amount to PI's Research: \$120,000	
Person-Months Per Year Committed to Project: <u>3</u> Pers. Months; Specify: <u>Calendar</u>	
Describe research including synergies and/or overlaps with This Proposal/Award: This project involves the integration of CRISPR technology with "proto-cell" based delivery to develop state-of-the-art medical countermeasures against existing as well as novel, previously-unrecognized, naturally-occurring emerging infectious disease.	
<b>Investigator:</b> Walter Paxton (PI)	Other Agencies to which this proposal has been/will be submitted: N/A
Support ( <u>C</u> urrent, <u>P</u> ending, <u>S</u> ubmission Planned in Future or <u>T</u> ransfer of Support): <u>P</u> ending	
Project/Proposal Title and grand number if appropriate: <i>Cyborg Materials: Emergent Phenomena via Integration of Cooperative Biological Function in Stimuli-Responsive Polymer Bilayers and Hierarchical Assemblies</i>	
Source of Support: Early Career Award Proposal, Office of Basic Energy Sciences - DOE, Biomolecular Materials	Location of Project: Sandia National Laboratories

Soft, Biological and Composite Nanomaterials Thrust

Annual Award Amount: \$1,000,000	Total Award Period Covered: 10/16 – 10/21
Annual Award Amount to PI's Research: \$1,000,000	
Person-Months Per Year Committed to Project: 6 Pers. Months; Specify: Calendar	
Describe research including synergies and/or overlaps with This Proposal/Award: We propose to create active materials composed of synthetic polymers that respond to the chemical or physical stimuli <i>generated by</i> biological components (e.g. transmembrane proteins or enzymes). These <i>cyborg materials</i> – functional <i>biotic</i> components integrated into <i>abiotic</i> matrices – would comprise novel systems where protein-mediated changes in local chemistry interact dynamically with the bilayer matrix to produce emergent membrane dynamics phenomena. The efforts of this proposed work are highly synergistic with the efforts of the soft, biological, and composite nanomaterials thrust at CINT.	
Investigator: Walter Paxton (PI)	Other Agencies to which this proposal has been/will be submitted: N/A
Support (Current, Pending, Submission Planned in Future or Transfer of Support): Current	
Project/Proposal Title and grand number if appropriate: A New Paradigm in Chem/Bio Threat Detection: Evaluating Threats Based on Biological Function Rather than Chemical Form	
Source of Support: Sandia National Laboratories, Laboratory Directed Research and Development (LDRD)	Location of Project: Sandia National Laboratories
Annual Award Amount: \$435,000	Total Award Period Covered: 10/15 – 09/18
Annual Award Amount to PI's Research: \$127,000	
Person-Months Per Year Committed to Project: 4 Pers. Months; Specify: Calendar	
Describe research including synergies and/or overlaps with This Proposal/Award: This project involves is for the development of field-effect transistor-based biosensors that use biological membrane proteins integrated into polymer bilayer assemblies on silicon nanowires as the principle sensory element. The project is highly synergistic with the soft, biological and composite nanomaterials thrust at CINT.	

**James Werner**

Investigator: Werner, James	Other Agencies to which this proposal has been/will be submitted:
Support (Current, Pending, Submission Planned in Future or Transfer of Support): C	
Project/Proposal Title and grand number if appropriate:  Three dimensional Molecular Tracking of IgE-Fc(epsilon)RI in Live Cells Grant # R01AI097154	
Source of Support: National Institutes of Health	Location of Project: Los Alamos National Laboratory
Annual Award Amount: 400K	Total Award Period Covered: 8/2012 to 8/2016
Annual Award Amount to PI's Research: 400K	
Person-Months Per Year Committed to Project: 2.0 Pers. Months; Specify: Calendar	
Describe research including synergies and/or overlaps with This Proposal/Award:  Work proposes to enhance the contextual information and temporal resolution of 3D tracking of protein transport in cells. We are proposing to address specific testable hypotheses regarding IgE-Fc(epsilon)RI signaling and down-regulation. As PI, I oversee the project, communicate results to the scientific community, and help with instrument development. Work is complementary to CINT-supported work as it exploits 3D tracking instrumentation used by both.	

<b>Investigator:</b> Werner, James	Other Agencies to which this proposal has been/will be submitted:
Support (Current, Pending, Submission Planned in Future or Transfer of Support): C	
Project/Proposal Title and grand number if appropriate:  Intrinsically Disordered Proteins: New Tools for Old Controversies Grant # 20140307ER	
Source of Support: Laboratory Directed Research and Development (LDRD)	Location of Project: Los Alamos National Laboratory
Annual Award Amount: 370K	Total Award Period Covered: 10/2013 to 10/2016
Annual Award Amount to PI's Research: 370K	
Person-Months Per Year Committed to Project: 2.0 Pers. Months; Specify: Calendar	
Describe research including synergies and/or overlaps with This Proposal/Award:  This research project aims to explore single molecule conformational dynamics of intrinsically disordered proteins, with a particular emphasis on seeing the changes in conformation that occur upon binding (or occur before binding) a protein or DNA partner. As PI, I oversee the project, communicate results to the scientific community, and help with instrument development. Work is complementary to CINT-supported work as it exploits 3D tracking instrumentation used by both.	
<b>Investigator:</b> Werner, James (PI: Hong-Geller, Elizabeth)	Other Agencies to which this proposal has been/will be submitted:
Support (Current, Pending, Submission Planned in Future or Transfer of Support): C	
Project/Proposal Title and grand number if appropriate:  Bet-hedging in pathogens: Targeting bacterial persistence to combat infectious disease	
Source of Support: Defense Threat Reduction Agency (DTRA)	Location of Project: Los Alamos National Laboratory
Annual Award Amount: 600K	Total Award Period Covered: 3/2014 to 2/2017
Annual Award Amount to PI's Research: 75K	
Person-Months Per Year Committed to Project: 1.0 Pers. Months; Specify: Calendar	
Describe research including synergies and/or overlaps with This Proposal/Award:  This research project aims to explore the molecular basis of bacterial persistence and discover treatment strategies that may coax bacteria out of their persistent state. My role in this project involves using time-lapse microscopy to study bacterial growth/death and single molecule fluorescence in-situ hybridization studies to measure bacteria to bacteria heterogeneity in mRNA production. There is no overlap with current CINT projects.	
<b>Investigator:</b> Werner, James (PI: Terwilliger, Thomas)	Other Agencies to which this proposal has been/will be submitted:
Support (Current, Pending, Submission Planned in Future or Transfer of Support): C	
Project/Proposal Title and grand number if appropriate:  Countering Pathogen Interference with Human Defenses Grant # 20160054DR	
Source of Support: Laboratory Directed Research and Development (LDRD)	Location of Project: Los Alamos National Laboratory

Soft, Biological and Composite Nanomaterials Thrust

Annual Award Amount: 1.6M	Total Award Period Covered: 10/2015 to 10/2018
Annual Award Amount to PI's Research: 75K	
Person-Months Per Year Committed to Project: 1.0 Pers. Months; Specify: Calendar	
Describe research including synergies and/or overlaps with This Proposal/Award:  Work is exploring the role of autophagy during influenza infections. My role in the project involves analyzing fluorescence microscopy images during various stages of infection to provide quantitative data for modeling efforts. Work has no overlap with proposed CINT efforts.	
<b>Investigator:</b> Werner, James	Other Agencies to which this proposal has been/will be submitted:
Support (Current, Pending, Submission Planned in Future or Transfer of Support): S	
Project/Proposal Title and grand number if appropriate:  Fast, 3D Imaging Flow Cytometry	
Source of Support: Laboratory Directed Research and Development (LDRD)	Location of Project: Los Alamos National Laboratory
Annual Award Amount: 330K	Total Award Period Covered: 10/2017 to 10/2020
Annual Award Amount to PI's Research: 330K	
Person-Months Per Year Committed to Project: 2.0 Pers. Months; Specify: Calendar	
Describe research including synergies and/or overlaps with This Proposal/Award:  Research aims to use new, fast 3D imaging methods in a flow cytometry format to investigate changes in cellular morphology due to disease (e.g. cancer) or radiation exposure. As program PI, I will direct research, participate in instrument development, and communicate results to the scientific community. Work has potential overlap with future CINT activities.	
<b>Investigator:</b> Werner, James	Other Agencies to which this proposal has been/will be submitted:
Support (Current, Pending, Submission Planned in Future or Transfer of Support): P	
Project/Proposal Title and grand number if appropriate:  Single-Cell Inventories	
Source of Support: Laboratory Directed Research and Development (LDRD)	Location of Project: Los Alamos National Laboratory
Annual Award Amount: 1.6M	Total Award Period Covered: 10/2017 to 10/2020
Annual Award Amount to PI's Research: 1.6M	
Person-Months Per Year Committed to Project: 3.0 Pers. Months; Specify: Calendar	
Describe research including synergies and/or overlaps with This Proposal/Award:  Research will create microfluidic devices for direct, digital counting of mRNA and protein content from single cells. It will be applied to study cell to cell variability in algal lipid production. As program PI, I will direct research, participate in instrument development, and communicate results to the scientific community. Work has potential overlap with future CINT activities in soft lithography.	
<b>Investigator:</b> Werner, James	
Support (Current, Pending, Submission Planned in Future or Transfer of Support): S	
Project/Proposal Title and grand number if appropriate:  FISH and Chips: Counting mRNA and Proteins from Single Cells	

Source of Support: Laboratory Directed Research and Development (LDRD)	Location of Project: Los Alamos National Laboratory
Annual Award Amount: 330K	Total Award Period Covered: 10/2017 to 10/2020
Annual Award Amount to PI's Research: 330K	
Person-Months Per Year Committed to Project: <u>2.0</u> Pers. Months; Specify: <u>Calendar</u>	
Describe research including synergies and/or overlaps with This Proposal/Award:	
<p>Research will create microfluidic devices for the analysis of mRNA and protein content from single cells. It will be applied to study changes in human cellular response to pathogen infection. As program PI, I will direct research, participate in microfluidic platform development, and communicate results to the scientific community. Work has potential overlap with future CINT activities in soft lithography.</p>	



## 10.0 Budget and Budget Explanation

DOE F 4620.1 (04-93) All Other Editions Are Obsolete	<b>U.S. Department of Energy</b> <b>Budget Page</b> (See reverse for Instructions)	OMB Control No. 1910-1400 OMB Burden Disclosure Statement on Reverse				
ORGANIZATION Sandia National Laboratories		Budget Page No: <u>1</u>				
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Millicent Firestone (SBCN Thrust Leader)		Requested Duration: <u>12 (FY2016)</u> (Months)				
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos.	Funds Requested by Applicant	Funds Granted by DOE			
	<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th style="width:33%;">CAL</th> <th style="width:33%;">ACAD</th> <th style="width:33%;">SUMR</th> </tr> </table>	CAL	ACAD	SUMR		
CAL	ACAD	SUMR				
1. Bachand, George (.6 FTE)	7.20		110,120.00			
2. Huber, Dale (.5 FTE)	6.00		83,032.00			
3. Paxton, Walter (.5 FTE)	6.00		61,491.00			
4.						
5.						
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)						
7. ( 3 ) TOTAL SENIOR PERSONNEL (1-6)	19.20		254,643.00			
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. ( 1 ) POST DOCTORAL ASSOCIATES	12.00		91,083.00			
2. ( 1 ) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	12.00		91,083.00			
3. ( ) GRADUATE STUDENTS						
4. ( ) UNDERGRADUATE STUDENTS						
5. ( ) SECRETARIAL - CLERICAL						
6. ( ) OTHER						
TOTAL SALARIES AND WAGES (A+B)		436,809.00	0.00			
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)		159,435.00				
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)		596,244.00	0.00			
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)						
TOTAL PERMANENT EQUIPMENT						
E. TRAVEL						
1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)						
2. FOREIGN						
TOTAL TRAVEL		0.00	0.00			
F. TRAINEE/PARTICIPANT COSTS						
1. STIPENDS (Itemize levels, types + totals on budget justification page)						
2. TUITION & FEES						
3. TRAINEE TRAVEL						
4. OTHER (fully explain on justification page)						
TOTAL PARTICIPANTS ( ) TOTAL COST		0.00	0.00			
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES		88,916.00				
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION						
3. CONSULTANT SERVICES						
4. COMPUTER (ADPE) SERVICES						
5. SUBCONTRACTS						
6. OTHER		22,229.00				
TOTAL OTHER DIRECT COSTS		111,145.00	0.00			
H. TOTAL DIRECT COSTS (A THROUGH G)		707,389.00	0.00			
I. INDIRECT COSTS (SPECIFY RATE AND BASE)						
TOTAL INDIRECT COSTS		554,172.00				
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)		1,261,561.00	0.00			
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES						
L. TOTAL COST OF PROJECT (J+K)		1,261,561.00	0.00			

DOE F 4620.1 (04-93) All Other Editions Are Obsolete	<b>U.S. Department of Energy</b> <b>Budget Page</b> (See reverse for Instructions)	OMB Control No. 1910-1400 OMB Burden Disclosure Statement on Reverse				
ORGANIZATION Sandia National Laboratories	Budget Page No: <u>2</u>					
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Millicent Firestone (SBCN Thrust Leader)	Requested Duration: <u>12 (FY17)</u> (Months)					
A. SENIOR PERSONNEL: PI/PI, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos.	Funds Requested by Applicant	Funds Granted by DOE			
	<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th style="width:33%;">CAL</th> <th style="width:33%;">ACAD</th> <th style="width:33%;">SUMR</th> </tr> </table>	CAL	ACAD	SUMR		
CAL	ACAD	SUMR				
1. Bachand, George (.6 FTE)	7.20		112,980.00			
2. Huber, Dale (.5 FTE)	6.00		85,183.00			
3. Paxton, Walter (.5 FTE)	6.00		63,088.00			
4.						
5.						
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)						
7. ( 1 ) TOTAL SENIOR PERSONNEL (1-6)	19.20		261,251.00	0.00		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. ( 1 ) POST DOCTORAL ASSOCIATES	12.00		93,448.00			
2. ( 1 ) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	12.00		93,448.00			
3. ( ) GRADUATE STUDENTS						
4. ( ) UNDERGRADUATE STUDENTS						
5. ( ) SECRETARIAL - CLERICAL						
6. ( ) OTHER						
TOTAL SALARIES AND WAGES (A+B)			448,147.00	0.00		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)						
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)			611,720.00	0.00		
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)						
TOTAL PERMANENT EQUIPMENT						
E. TRAVEL						
1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)						
2. FOREIGN						
TOTAL TRAVEL			0.00	0.00		
F. TRAINEE/PARTICIPANT COSTS						
1. STIPENDS (Itemize levels, types + totals on budget justification page)						
2. TUITION & FEES						
3. TRAINEE TRAVEL						
4. OTHER (fully explain on justification page)						
TOTAL PARTICIPANTS ( ) TOTAL COST			0.00	0.00		
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES			90,446.00			
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION						
3. CONSULTANT SERVICES						
4. COMPUTER (ADPE) SERVICES						
5. SUBCONTRACTS						
6. OTHER			22,611.00			
TOTAL OTHER DIRECT COSTS			113,057.00	0.00		
H. TOTAL DIRECT COSTS (A THROUGH G)			724,777.00	0.00		
I. INDIRECT COSTS (SPECIFY RATE AND BASE)						
TOTAL INDIRECT COSTS			575,075.00			
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)			1,299,852.00	0.00		
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES						
L. TOTAL COST OF PROJECT (J+K)			1,299,852.00	0.00		

DOE F 4620.1 (04-93) All Other Editions Are Obsolete	<b>U.S. Department of Energy</b> <b>Budget Page</b> (See reverse for Instructions)	OMB Control No. 1910-1400 OMB Burden Disclosure Statement on Reverse	
ORGANIZATION Sandia National Laboratories		Budget Page No: <u>3</u>	
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Millicent Firestone (SBCN Thrust Leader)		Requested Duration: <u>12 (FY18)</u> (Months)	
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos.	Funds Requested by Applicant	Funds Granted by DOE
	CAL    ACAD    SUMR		
1. Bachand, George (.6 FTE)	7.20	116,734.00	
2. Huber, Dale (.5 FTE)	6.00	88,014.00	
3. Paxton, Walter (.5 FTE)	6.00	65,185.00	
4.			
5.			
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)			
7. ( 9 ) TOTAL SENIOR PERSONNEL (1-6)	19.20	269,933.00	0.00
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)			
1. ( 3 ) POST DOCTORAL ASSOCIATES	12.00	96,553.00	
2. ( 3 ) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	12.00	96,553.00	
3. ( ) GRADUATE STUDENTS			
4. ( ) UNDERGRADUATE STUDENTS			
5. ( ) SECRETARIAL - CLERICAL			
6. ( ) OTHER			
TOTAL SALARIES AND WAGES (A+B)		463,039.00	0.00
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)			
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)		632,048.00	0.00
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)			
TOTAL PERMANENT EQUIPMENT			
E. TRAVEL			
1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)			
2. FOREIGN			
TOTAL TRAVEL		0.00	0.00
F. TRAINEE/PARTICIPANT COSTS			
1. STIPENDS (Itemize levels, types + totals on budget justification page)			
2. TUITION & FEES			
3. TRAINEE TRAVEL			
4. OTHER (fully explain on justification page)			
TOTAL PARTICIPANTS ( )		TOTAL COST	
		0.00	0.00
G. OTHER DIRECT COSTS			
1. MATERIALS AND SUPPLIES		92,176.00	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION			
3. CONSULTANT SERVICES			
4. COMPUTER (ADPE) SERVICES			
5. SUBCONTRACTS			
6. OTHER		23,044.00	
TOTAL OTHER DIRECT COSTS		115,220.00	0.00
H. TOTAL DIRECT COSTS (A THROUGH G)		747,268.00	0.00
I. INDIRECT COSTS (SPECIFY RATE AND BASE)			
TOTAL INDIRECT COSTS		597,755.00	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)		1,345,023.00	0.00
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES			
L. TOTAL COST OF PROJECT (J+K)		1,345,023.00	0.00

DOE F 4620.1 (04-93) All Other Editions Are Obsolete	<b>U.S. Department of Energy</b> <b>Budget Page</b> (See reverse for Instructions)	OMB Control No. 1910-1400 OMB Burden Disclosure Statement on Reverse				
ORGANIZATION Sandia National Laboratories		Budget Page No: <u>4</u>				
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Millicent Firestone (SBCN Thrust Leader)		Requested Duration: <u>36 (FY16-18)</u> (Months)				
A. SENIOR PERSONNEL: PI/PI, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos.	Funds Requested by Applicant	Funds Granted by DOE			
	<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th style="width:33%;">CAL</th> <th style="width:33%;">ACAD</th> <th style="width:33%;">SUMR</th> </tr> </table>	CAL	ACAD	SUMR		
CAL	ACAD	SUMR				
1. Bachand, George (.6 FTE)	21.60		339,834.00			
2. Huber, Dale (.5 FTE)	18.00		256,229.00			
3. Paxton, Walter (.5 FTE)	18.00		189,763.00			
4.						
5.						
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)						
7. ( 9 ) TOTAL SENIOR PERSONNEL (1-6)	57.60		785,826.00	0.00		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. ( 3 ) POST DOCTORAL ASSOCIATES	36.00		281,084.00			
2. ( 3 ) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	36.00		281,084.00			
3. ( ) GRADUATE STUDENTS						
4. ( ) UNDERGRADUATE STUDENTS						
5. ( ) SECRETARIAL - CLERICAL						
6. ( ) OTHER						
TOTAL SALARIES AND WAGES (A+B)			1,347,994.00	0.00		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)						
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)			1,840,012.00	0.00		
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)						
TOTAL PERMANENT EQUIPMENT						
E. TRAVEL						
1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)						
2. FOREIGN						
TOTAL TRAVEL			0.00	0.00		
F. TRAINEE/PARTICIPANT COSTS						
1. STIPENDS (Itemize levels, types + totals on budget justification page)						
2. TUITION & FEES						
3. TRAINEE TRAVEL						
4. OTHER (fully explain on justification page)						
TOTAL PARTICIPANTS ( ) TOTAL COST			0.00	0.00		
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES			271,538.00			
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION						
3. CONSULTANT SERVICES						
4. COMPUTER (ADPE) SERVICES						
5. SUBCONTRACTS						
6. OTHER			67,884.00			
TOTAL OTHER DIRECT COSTS			339,422.00	0.00		
H. TOTAL DIRECT COSTS (A THROUGH G)			2,179,434.00	0.00		
I. INDIRECT COSTS (SPECIFY RATE AND BASE)						
TOTAL INDIRECT COSTS			1,727,002.00			
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)			3,906,436.00	0.00		
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES						
L. TOTAL COST OF PROJECT (J+K)			3,906,436.00	0.00		

DOE F 4020.1 (04-93) All Other Editions Are Obsolete		U.S. Department of Energy <b>Budget Page</b> (See reverse for Instructions)			OMB Control No. 1510-1400 OMB Burden Disclosure Statement on Reverse	
ORGANIZATION Los Alamos National Laboratory				Budget Page No: <u>1</u>		
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Millie Firestone (SBCN Thrust Leader)				Requested Duration: <u>12 (FY16)</u> (Months)		
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)				DOE Funded Person-mos.		Funds Requested
				CAL	ACAD	SUMR
						Funds Requested by Applicant
						Funds Granted by DOE
1.	Firestone, Millicent (0.75FTE)	9.00				\$124,177
2.	Goodwin, Peter (0.50FTE)	6.00				\$82,784
3.	Martinez, Jennifer (0.50FTE)	6.00				\$82,784
4.	Montano, Gabriel (0.50FTE)	6.00				\$67,749
5.	Werner, James (0.50FTE)	6.00				\$82,784
6.	OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7.	( 5 ) TOTAL SENIOR PERSONNEL (1-6)					
				33.00		
						\$440,279
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1.	( 1 ) POST DOCTORAL ASSOCIATES	12.00				\$76,911
2.	( 2 ) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	24.00				\$209,360
3.	( ) GRADUATE STUDENTS					
4.	( ) UNDERGRADUATE STUDENTS					
5.	( ) SECRETARIAL - CLERICAL					
6.	( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)						\$726,549
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)						\$318,082
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)						\$1,044,631
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)						
TOTAL PERMANENT EQUIPMENT						
E. TRAVEL				1. DOMESTIC (INCL CANADA AND U.S. POSSESSIONS)		
				2. FOREIGN		
TOTAL TRAVEL						
F. TRAINEE/PARTICIPANT COSTS						
1. STIPENDS (Itemize levels, types + totals on budget justification page)						
2. TUITION & FEES						
3. TRAINEE TRAVEL						
4. OTHER (fully explain on justification page)						
TOTAL PARTICIPANTS ( ) TOTAL COST						
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES						\$225,000
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION						
3. CONSULTANT SERVICES						
4. COMPUTER (ADPE) SERVICES						
5. SUBCONTRACTS- University contract						
6. OTHER						
TOTAL OTHER DIRECT COSTS						\$225,000
H. TOTAL DIRECT COSTS (A THROUGH G)						\$1,269,631
I. INDIRECT COSTS (SPECIFY RATE AND BASE)						
TOTAL INDIRECT COSTS						\$1,323,671
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)						\$2,593,302
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES						
L. TOTAL COST OF PROJECT (J+K)						\$2,593,302

DOE F-4020.1 (04-93) All Other Editions Are Obsolete	<b>U.S. Department of Energy</b> <b>Budget Page</b> (See reverse for instructions)	OMB Control No. 1510-1400 OMB Burden Disclosure Statement on Reverse	
<b>ORGANIZATION</b> Los Alamos National Laboratory		<b>Budget Page No.:</b> <u>2</u>	
<b>PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR</b> Millie Firestone (SBCN Thrust Leader)		<b>Requested Duration:</b> <u>12 (FY17)</u> (Months)	
<b>A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates</b> (List each separately with title; A.6. show number in brackets)	<b>DOE Funded</b> Person-mos.	<b>Funds Requested</b> by Applicant	<b>Funds Granted</b> by DOE
	CAL    ACAD    SUMR		
1. Firestone, Millicent (0.75FTE)	9.00		\$127,902
2. Goodwin, Peter (0.50FTE)	6.00		\$85,268
3. Martinez, Jennifer (0.50FTE)	6.00		\$85,268
4. Montano, Gabriel (0.50FTE)	6.00		\$69,782
5. Werner, James (0.50FTE)	6.00		\$85,268
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)			
7. ( 5 ) TOTAL SENIOR PERSONNEL (1-6)	33.00		<b>\$453,486</b>
<b>B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)</b>			
1. ( 1 ) POST DOCTORAL ASSOCIATES	12.00		\$79,219
2. ( 2 ) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	24.00		\$215,640
3. ( ) GRADUATE STUDENTS			
4. ( ) UNDERGRADUATE STUDENTS			
5. ( ) SECRETARIAL - CLERICAL			
6. ( ) OTHER			
<b>TOTAL SALARIES AND WAGES (A+B)</b>			<b>\$748,346</b>
<b>C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)</b>			<b>\$32,525</b>
<b>TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)</b>			<b>\$1,075,971</b>
<b>D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)</b>			
<b>TOTAL PERMANENT EQUIPMENT</b>			
<b>E. TRAVEL</b>			
1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)			
2. FOREIGN			
<b>TOTAL TRAVEL</b>			
<b>F. TRAINEE/PARTICIPANT COSTS</b>			
1. STIPENDS (Itemize levels, types + totals on budget justification page)			
2. TUITION & FEES			
3. TRAINEE TRAVEL			
4. OTHER (fully explain on justification page)			
<b>TOTAL PARTICIPANTS ( ) TOTAL COST</b>			
<b>G. OTHER DIRECT COSTS</b>			
1. MATERIALS AND SUPPLIES			\$250,000
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION			
3. CONSULTANT SERVICES			
4. COMPUTER (ADPE) SERVICES			
5. SUBCONTRACTS-University Contract			
6. OTHER			
<b>TOTAL OTHER DIRECT COSTS</b>			<b>\$250,000</b>
<b>H. TOTAL DIRECT COSTS (A THROUGH G)</b>			<b>\$1,325,971</b>
<b>I. INDIRECT COSTS (SPECIFY RATE AND BASE)</b>			
<b>TOTAL INDIRECT COSTS</b>			<b>\$1,346,886</b>
<b>J. TOTAL DIRECT AND INDIRECT COSTS (H+I)</b>			<b>\$2,672,857</b>
<b>K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES</b>			
<b>L. TOTAL COST OF PROJECT (J+K)</b>			<b>\$2,672,857</b>

DOE F 4520.1 (04-93) All Other Editions Are Obsolete	<b>U.S. Department of Energy</b> <b>Budget Page</b> (See reverse for Instructions)	OMB Control No. IS10-1400 OMB Burden Disclosure Statement on Reverse			
<b>ORGANIZATION</b> Los Alamos National Laboratory		<b>Budget Page No.:</b> <u>3</u>			
<b>PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR</b> Millie Firestone (SBCN Thrust Leader)		<b>Requested Duration:</b> <u>12 (FY18)</u> (Months)			
<b>A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates</b> (List each separately with title; A.6. show number in brackets)		<b>DOE Funded</b> Person-mos.	<b>Funds Requested</b> by Applicant	<b>Funds Granted</b> by DOE	
		CAL    ACAD    SUMR			
1.	Firestone, Millicent (0.75FTE)	9.00		\$131,739	
2.	Goodwin, Peter (0.50FTE)	6.00		\$87,826	
3.	Martinez, Jennifer (0.50FTE)	6.00		\$87,826	
4.	Montano, Gabriel (0.50FTE)	6.00		\$71,876	
5.	Werner, James (0.50FTE)	6.00		\$87,826	
6.	( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)				
7.	( 5 ) TOTAL SENIOR PERSONNEL (1-6)	33.00		\$467,093	
<b>B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)</b>					
1.	( 1 ) POST DOCTORAL ASSOCIATES	12.00		\$81,595	
2.	( 2 ) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	24.00		\$222,110	
3.	( ) GRADUATE STUDENTS				
4.	( ) UNDERGRADUATE STUDENTS				
5.	( ) SECRETARIAL - CLERICAL				
6.	( ) OTHER				
<b>TOTAL SALARIES AND WAGES (A+B)</b>				\$770,798	
<b>C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)</b>				\$337,454	
<b>TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)</b>				\$1,108,252	
<b>D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)</b>					
<b>TOTAL PERMANENT EQUIPMENT</b>					
<b>E. TRAVEL</b>					
1. DOMESTIC (INCL CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
<b>TOTAL TRAVEL</b>					
<b>F. TRAINEE/PARTICIPANT COSTS</b>					
1. STIPENDS (Itemize levels, types + totals on budget justification page)					
2. TUITION & FEES					
3. TRAINEE TRAVEL					
4. OTHER (fully explain on justification page)					
<b>TOTAL PARTICIPANTS ( ) TOTAL COST</b>					
<b>G. OTHER DIRECT COSTS</b>					
1. MATERIALS AND SUPPLIES				\$275,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS- University Contract					
6. OTHER					
<b>TOTAL OTHER DIRECT COSTS</b>				\$275,000	
<b>H. TOTAL DIRECT COSTS (A THROUGH G)</b>				\$1,383,252	
<b>I. INDIRECT COSTS (SPECIFY RATE AND BASE)</b>					
<b>TOTAL INDIRECT COSTS</b>				\$1,413,188	
<b>J. TOTAL DIRECT AND INDIRECT COSTS (H+I)</b>				\$2,796,440	
<b>K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES</b>					
<b>L. TOTAL COST OF PROJECT (J+K)</b>				\$2,796,440	

DOE F 4620.1 (04-03) All Other Editions Are Obsolete	<b>U.S. Department of Energy</b> <b>Budget Page</b> (See reverse for instructions)	OMB Control No. 1510-1400 OMB Burden Disclosure Statement on Reverse				
ORGANIZATION Los Alamos National Laboratory		Budget Page No: <u>4</u>				
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Millie Firestone (SBCN Thrust Leader)		Requested Duration: <u>36 (FY16-18)</u> (Months)				
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	DOE Funded Person-mos.	Funds Requested by Applicant	Funds Granted by DOE			
	<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th style="width:33%;">CAL</th> <th style="width:33%;">ACAD</th> <th style="width:33%;">SUMR</th> </tr> </table>	CAL	ACAD	SUMR		
CAL	ACAD	SUMR				
1. Firestone, Millicent (0.75FTE)	27.00		\$383,817			
2. Goodwin, Peter (0.50FTE)	18.00		\$255,879			
3. Martinez, Jennifer (0.50FTE)	18.00		\$255,879			
4. Montano, Gabriel (0.50FTE)	18.00		\$209,407			
5. Werner, James (0.50FTE)	18.00		\$255,879			
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)						
7. ( 5 ) TOTAL SENIOR PERSONNEL (1-6)	99.00		\$1,360,860			
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. ( 1 ) POST DOCTORAL ASSOCIATES	36.00		\$237,725			
2. ( 2 ) OTHER PROFESSIONAL (TECHNICIAN, PROGRAMMER, ETC.)	72.00		\$647,110			
3. ( ) GRADUATE STUDENTS						
4. ( ) UNDERGRADUATE STUDENTS						
5. ( ) SECRETARIAL - CLERICAL						
6. ( ) OTHER						
TOTAL SALARIES AND WAGES (A+B)			\$2,245,694			
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)			\$983,160			
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)			\$3,228,854			
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)						
TOTAL PERMANENT EQUIPMENT						
E. TRAVEL						
1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)						
2. FOREIGN						
TOTAL TRAVEL						
F. TRAINEE/PARTICIPANT COSTS						
1. STIPENDS (Itemize levels, types + totals on budget justification page)						
2. TUITION & FEES						
3. TRAINEE TRAVEL						
4. OTHER (fully explain on justification page)						
TOTAL PARTICIPANTS ( )			TOTAL COST			
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES			\$750,000			
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION						
3. CONSULTANT SERVICES						
4. COMPUTER (ADPE) SERVICES						
5. SUBCONTRACTS						
6. OTHER						
TOTAL OTHER DIRECT COSTS			\$750,000			
H. TOTAL DIRECT COSTS (A THROUGH G)			\$3,978,854			
I. INDIRECT COSTS (SPECIFY RATE AND BASE)						
TOTAL INDIRECT COSTS			\$4,083,745			
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)			\$8,062,599			
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES						
L. TOTAL COST OF PROJECT (J+K)			\$8,062,599			



## **10. Budget Explanation**

### **A. Senior Personnel**

George Bachand – (SBCN Partner Science Leader) Provides scientific leadership for Thrust, provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

Millicent Firestone – (SBCN Thrust Leader) Provides scientific leadership for Thrust, provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

Peter Goodwin – (CINT Scientist) Provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

Dale Huber – (CINT Scientist) Provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

Jennifer Martinez – (CINT Scientist) Provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

Gabriel Montano – (CINT Scientist) Provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

Wally Paxton – (CINT Scientist) Provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

James Werner – (CINT Scientist) Provides support for approved CINT user projects and conducts independent research in support of CINT internal science program.

### **B. Other Personnel**

Postdoctoral Associates – Conduct research in support of CINT internal science program and work with users as appropriate to support user projects.

Other Professional – Research technologists supporting laboratory operations and instrumentation usage.

### **G. Other Direct Costs**

1. Materials and Supplies – Laboratory supplies to support CINT Thrust user projects and internal science efforts; Thrust staff travel costs; publication costs.

6. Other (Service Contracts) – Direct costs to provide service and maintenance for lab equipment

## 11. Description of Facilities and Resources

The Soft, Biological and Composite Nanomaterials thrust occupies a total of eight laboratories at the CINT Core Facility at Sandia (5000 ft<sup>2</sup> of research space), including a Biomolecular and Cellular Materials Synthesis Labs, a Self-Assembly Chemistry lab, a Polymer Synthesis lab, two Thin Film Labs, an Optical Interrogation and Manipulation lab, and significant space in the Scanning Probe Lab. The Thrust occupies five laboratories at the CINT Gateway at LANL (4000 ft<sup>2</sup>), including an Optical Microscopy lab, two Nanoscale Self-Assembly labs, and two Biochemical and Bioassembly labs. Instrumentation housed in these laboratories is described below. It is important to note that this Thrust also has access to all of the other extensive CINT capabilities in the Core and the Gateway, including the Clean Room in the Core for performing “top-down” lithographic processing, sophisticated laser and optical characterization facilities in the Gateway, as well as a broad range of characterization and theory/modeling tools housed in other CINT thrusts (as described in the other CINT Research Documents).

### 11.1 Core Facilities

The biomolecular materials labs in the Core are configured to support research activities in molecular biosynthesis and modification of protein- and DNA-based nanomaterials including gene isolation and cloning, site-directed mutagenesis, recombinant protein expression and characterization, fusion protein development, and protein functionalization. Facilities also include an integrated tissue culture lab for prokaryotic/eukaryotic cell culture (BSL1 & 2) and walk-in cold room for temperature sensitive protein purification and manipulation. Specific equipment supporting this area includes high resolution, differential interference microscopy, spinning disk confocal microscopy, total internal reflectance microscopy (TRIF), Olympus FV1000 multi-photon laser scanning confocal microscopy with fluorescence lifetime imaging microscopy (FLIM) capability, Victor3 Multilabel Plate Reader (fluorescence & UV-Vis absorbance), NanoDrop 2000 UV-Vis spectrophotometer, NanoDrop 3300 Fluorospectrometer, 6-ft BakerSterilGard3 biosafety cabinet, Beckman high-speed and ultra-centrifuges, Bio-Rad Multi-Bay DNA Engine thermal cycler, Pharmacia FPLC, and a Microfluidics MPA-110 cell disruption capability.

Four Core labs house facilities for preparing, patterning, and characterizing films based on membranes, self-assembled monolayers, organic polymers, and solution-derived inorganic films. Capabilities include precursor synthesis, isolation, and purification of biological membranes and membrane components, liposome and planar lipid assemblies, spin and dip coating, and microcontact printing. Equipment includes inert atmosphere glove boxes, a Nanofilm spectroscopic imaging ellipsometer, 2 Bruker IFS 66 v/S infrared spectrometer with attenuated total reflectance and polarization modulation capabilities, an Anasazi 90 MHz FT-NMR, 3 UV-visible spectrometers, fluorescence spectroscopy capabilities (200-1700 nm, 100 ps to ms lifetime resolution), 2 HPLC's and various size exclusion and affinity chromatographies for isolation and purification of organics and membrane complexes, a Netsch Jupiter simultaneous DSC/TGA, a quartz crystal microbalance, a holographic optical trapping microscope with force measurement capabilities, and an Asylum MFP-3D-SA Atomic Force Microscope

### 11.2 LANL Gateway Facilities

The Optical Microscopy lab contains commercial instrumentation for multi-photon confocal fluorescence microscopy (Olympus IX81 microscope with an Olympus FV-330 confocal unit) and atomic force microscopy (VEECO Bioscope and VEECO Enviroscope units). Several lasers are available for scanning confocal microscopy including continuous-wave visible (457, 488, 514, 543, 594, and 633 nm) lasers for single photon measurements and a tunable pulsed (710-990 nm) laser for multiphoton experiments. This laboratory is equipped to perform single-molecule atomic force microscopy in combination with single molecule fluorescence imaging, and is also equipped to perform single-molecule tracking in two- and three-dimensions. Fluorescence characterization techniques such as time-correlated single photon counting, single pair fluorescence resonance energy transfer, and fluorescence correlation spectroscopy are also available.

The nanoscale self-assembly labs are equipped with chemical fume hoods, a bio-safety unit, as well as general laboratory supplies to perform a variety of chemical processes. The labs also house equipment for spatial micro-patterning using masked deep-UV light (Hg-lamp with 185-254 nm output). Characterization tools in the lab include a J. A. Woollam V-Vase Spectroscopic ellipsometer, an Olympus IX81 fluorescence microscope optimized for fluorescence recovery after photo-bleaching (FRAP) experiments, a mass spectrometer, a system to measure incident photon to current efficiency (QEX7, PV Measurements, Inc.) and a solar cell I-V measurement system (PV measurements) external solar cell efficiency, and a potentiostat (BAS Instruments) for electrochemical measurements, as well as access to a Rigaku Ultima III X-ray diffractometer. Absorption (Cary 300 uv-vis), infrared (Bruker Equinox 55), and steady state fluorescence spectroscopies are also available. A Small and Wide angle X-ray scattering instrument (Bruker Nanostar) is available for structural characterization of soft materials on the nanometer to Å length scale.

The biochemistry and bioassembly labs contain an integrated cold room, two instrument rooms, a mammalian cell culture facility, a bacterial culture room, and a molecular biology/biochemistry suite. This lab space is a biosafety level II facility, housing chemical and biosafety fume hoods, which is able to culture biothreat surrogates for biosensor testing and mammalian cell culturing. In addition to general laboratory equipment, the lab is set-up to perform phage display (custom peptide, polymers and scFv libraries), genetic engineering (using reverse transcription, the polymerase chain reaction and site-directed mutagenesis), as well as expression, purification, characterization, and functionalization of native and recombinant proteins or peptides. Specialized equipment includes dynamic light scattering (Malvern NanoZetasizer), high throughput microwave peptide synthesis (CEM Liberty) and high performance liquid chromatography (Waters), tandem mass spectrometry (Synapt G2 Micromass, Waters), FPLC (Pharmacia), and high throughput magnetic bead manipulation (King Fisher).