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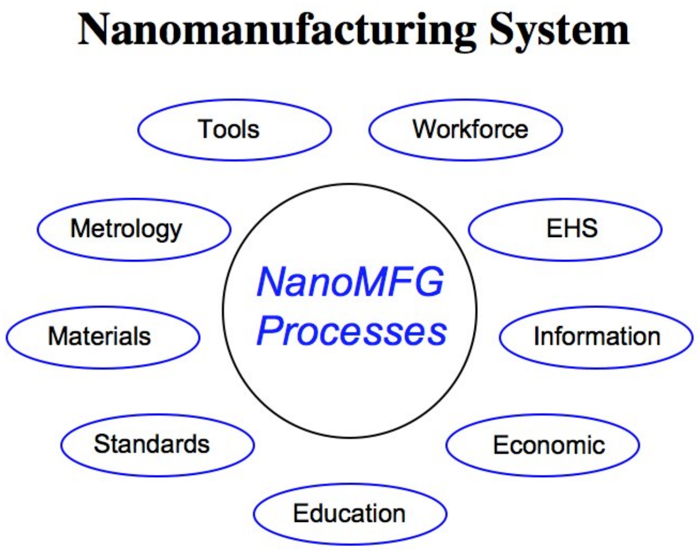
I thank the committee for the opportunity to discuss innovation and manufacturing. It is an honor to be here and speak directly and plainly about this vitally important topic.

Innovation is the raw fuel of the American economy. Manufacturing is the engine.

I speak to you today on behalf of the National Nanomanufacturing Network. Nanomanufacturing is the use of new techniques and tools that generate and manipulate nanomaterials for reproducible commercial-scale manufacturing. As I will discuss today, research and development (R&D) in nanomanufacturing exemplifies what we must pursue in 21st century manufacturing innovation. The National Nanomanufacturing Network (NNN), funded by the National Science Foundation (NSF), operates as an open-access network of centers, leaders, experts, and stakeholders from the nanomanufacturing research, development and education community. The network's mission is to serves as a catalyst to advance nanomanufacturing in the U.S. by facilitating collaboration, roadmapping, and prioritization activities on critical enabling areas of nanomanufacturing, and by information sharing through its nanomanufacturing database and information resource, InterNano. The NNN includes a core of four contributing NSF Nanoscale Science and Engineering Centers focused specifically on nanomanufacturing, as well as nanomanufacturing centers from the Department of Energy (DOE) and the National Institute for Standards and Technology (NIST), and many other contributors from academia, industry and government. More details about the ongoing activities of the NNN are described below. My comments today are the distillation of ideas from many experts who contribute to NNN activities.

Nanotechnology Research and Nanomanufacturing

The U.S. investment in nanotechnology through the National Nanotechnology Initiative has resulted in enormous advancements in our ability to make, control and utilize nanomaterials whose characteristic features are 1-100 nanometers. The last ten years in nanotechnology has been a period of dramatic discovery and exploration. Brilliant scientists and engineers from interdisciplinary teams have created proof-of-concept demonstrations with high performance nanoscale materials and devices. These results are now beginning to impact just about every commercial product sector, including, at the very least, electronics, materials, health, transportation, consumer care products and, especially, energy. However, making transition from proof-of-concept demonstration, to prototype, to manufacturing pilot, to full-scale manufacturing is not trivial. This is especially true in the case of an emergent field like nanotechnology, where, in most cases, we cannot simply adapt old designs of production tools for these new methods. Manufacturing brings to bear a new range of issues: process development and modeling, scale-up, metrology, process control, tooling, workforce, safety, and supply chain. Ultimately, these issues have to be addressed because, without manufacturing, there are no products. Perhaps more than any other previous activity, *nanomanufacturing* requires close cooperative efforts between industry, academia and government. Since a considerable amount of the federal funding in nanotechnology has supported research at universities and government labs, many of the new fundamental discoveries have occurred at those places. Yet product development and manufacturing traditionally occurs in industry. For the U.S. to take full economic and societal advantage of the many nanotechnology breakthoughs it has fostered, the Federal Government needs to help build and support a culture that strives to develop leading-edge manufacturing capabilities through *close collaboration* of industry, academic and government. Creating a culture that thrives on manufacturing excellence is a challenge, but at the same time, an enormous opportunity.



Strides in Nanomanufacturing R&D

Nanomanufacturing R&D is focused on the creation of new processes and tools to produce and utilize nanomaterials at a commercially-relevant scale. Nanoscience research has resulted in the discovery and development of new techniques to make and manipulate nanomaterials that are so out-of-the box and revolutionary that it is difficult for the manufacturing community to quickly reposition and take advantage. A few recent examples include:

- The production of carbon-nanotube-based transparent conducting electrodes -- replaces indium tin oxide for displays and solar cells, during a time when the worldwide indium resources are becoming increasingly scarce.
- The use of diblock copolymers for nanoscale patterning -- utilization of molecular self-assembly for magnetic data storage, electronics, energy conversion and energy storage applications.
- Self-alignment processes -- utilizing natural molecular interactions for device integration at the nanoscale and enabling low cost roll-to-roll manufacturing processes.
- Plasmonic lithography -- producing nanostructures with smaller critical dimensions by using surface plasmons to circumvent the diffraction effects that limit conventional optical lithography.

- Scalable processes for the production of carbon nanotubes and graphene -- impacting many applications from electronics to structural materials to thermal management materials.
- Synthetic processes producing monodisperse nanoparticles with designer surface ligands -- impacting many applications from efficient lighting to solar cells to disease diagnosis and therapy.

More examples are discussed at the end of this written testimony. The key point here is that nanomanufacturing introduces many new disruptive, rather than evolutionary, process technologies. In most cases, these innovations were not on any industrial roadmap. As a consequence, there are gaps in the value chain--such as the lack of availability of suitable production scale tools, feedstock suppliers and trained workforce--that hinder commercial implementation. The companies, and nations, that figure out how to manufacture products from these recent innovations will reap the greatest benefits. It is both a challenge and an opportunity.

A Strategic Long View of Nanomanufacturing

The Nation needs to embrace a strategic long view to advance manufacturing science and engineering. The fast progress we observe in nanomanufacturing R&D serves as an important reminder. It is a reminder that we must continue to innovate in manufacturing, that manufacturing holds many yet unsolved challenges, that manufacturing is an area that needs continual research, and that we must train and sustain a workforce driven to continue advancing our national capabilities in manufacturing. This can only be accomplished effectively with strong public-private partnerships with equally vested industry, academic and government stakeholders. To complement the recent strides in fundamental research, pre-competitive joint-development projects are needed to take promising nanomanufacturing processes to scalable manufacturing. If well managed and adequately supported, manufacturing prototype and pilot projects will create critical knowledge to help enable the considerably expensive jump to full-scale manufacturing. This includes process development and modeling, application prototyping, tool design and development, manufacturing informatics, sustainable manufacturing design and manufacturing-by-design method development. Doing so will translate into numerous societal benefits including jobs, economic security, intellectual progress and sustainability.

Nanomanufacturing Support by the National Nanotechnology Initiative

The Federal Government has steadily ramped up its support in nanomanufacturing R&D in the National Nanotechnology Initiative (NNI) funding[1]. In total, the NNI's actual nanomanufacturing funding level was $75.6M (4.4% of NNI total) in 2009, with an added $28.5M (5.5%) of 2009 ARRA funding. The estimated funding is $96.7M (5.4%) in 2010 and proposed funding is $101.4M (5.7%) in the 2011 budget request. Historically, the NSF, NIST and DOD were the early leaders in creating funding programs to to address the distinct issues associated with nanomanufacturing. Now DOE, NIH and other agencies have joined suit, recognizing the essential role that nanomanufacturing plays in progress. Advancing

[1] "The National Nanotechnology Initiative: Research and Development Leading to a Revolution in Technology and Industry: Supplement to the President's FY 2011 Budget," Subcommittee of Nanoscale Science, Engineering, and Technology (NSET), Committee on Technology, National Science and Technology Council. Available from the National Nanotechnology Coordination Office (NNCO), www.nano.gov

manufacturing in the U.S. is a *mission* and should be increasingly supported, with long-term strategic management, by the mission-based agencies. NIOSH has made substantial efforts to provide guidance on controls for nanomanufacturing worker safety, and the EPA has a growing base of activities in nanoparticle environmental, health and safety. The topic of *Sustainable Nanomanufacturing* is one of three NNI Nanotechnology Signature Initiatives planned for the 2011 budget**Error! Bookmark not defined.**. This initiative, which involves contributing efforts by NIST, NSF, DOE, EPA and NIH, at a level of $23M, will focus on the long-term development of flexible "bottom up" nanomanufacturing methods that can be applied broadly to applications including, solar energy harvesting, communications and computation, waste heat management and recovery, and energy storage.

Now, after this rather long introduction, I will address the specific questions posed by the committee.

What is the National Science Foundation (NSF) doing to foster innovation in manufacturing through research and development in nanomanufacturing? In your opinion, are NSF's current research programs sufficient? If not, why not?

Ultimately, it is my opinion that the NSF has some well-designed programs supporting nanomanufacturing, it is primarily the low overall level of support limits the impact and speed that such activities could have on the Nation's competitiveness and economy.

The NSF is placing a growing emphasis on nanomanufacturing R&D, with $22.4M (5.4% of NSF NNI share) estimated in 2010 from the National Nanotechnology Initiative budget and proposing $32.2 (8.0%) in 2011. Currently NSF supports nanomanufacturing R&D within the following listed programs or activities. The first three are specifically focused on nanomanufacturing, whereas the others contain only a subcomponent of activity on nanomanufacturing.

- Four Nanoscale Science and Engineering Centers (NSECs) specifically dedicated to nanomanufacturing:
  - Center for Hierarchical Manufacturing (CHM) – University of Massachusetts at Amherst and partner institutions; CHM is also the administrative hub of the National Nanomanufacturing Network
  - Center for High-Rate Nanomanufacturing (CHN) – Northeastern University and partner institutions
  - Center for Scalable and Integrated NanoManufacturing (SINAM) – University of California Berkeley and partner institutions
  - Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems (Nano-CEMMS) – University of Illinois Urbana Champaign and partner institutions
- The National Nanomanufacturing Network -- collaborative activities and information sharing among a network of U.S. centers, experts and stakeholders, including the four NSECs listed above;
- The Nanomanufacturing program within the NSF Engineering Directorate;
- SBIR/STTR program, for small companies, frequently working in collaboration with universities;

- The Nanoelectronics Research Initiative (NRI) -- a program cooperatively funded with the Semiconductor Research Corporation, research based on fundamental research needs of the semiconductor device manufacturers, all large companies;
- The GOALI program for joint university-industry projects;
- NSF manufacturing research programs, generically, within in the Engineering Directorate, some of which have nanomanufacturing relevance;

The proposed 2011 NSF investment plans to emphasize areas several program topics that will have substantial nanomanufacturing impact:

(1) New tools for measuring and restructuring matter for production purposes;
(2) Hierarchical manufacturing of nanosystems by assembling nanoscale components into new architectures and fundamentally new products;
(3) Manufacturing by design by using new computer principles, computer simulations, and nanoinformatics;
(4) Hybrid nanomanufacturing, including nanobiotechnology and nanostructured catalysts.

One overall goal for 2011 is to strengthen support across the National Nanomanufacturing Network in order to advance innovation and to implement research results through partnerships with industry, medical institutions and other government agencies. In my opinion, the NNN effort should be strengthened and expanded *significantly* to provide the physical and intellectual infrastructure needed to spur industrial nanomanufacturing. This includes new centers on complementary nanomanufacturing themes and stepping up the support to existing nanomanufacturing centers to provide shared-use facilities and professional staff specifically dedicated to nanomanufacturing development with industry partners. As identified in NNN roadmapping workshops, rapid progress could be made by strengthening R&D activity, in a set of well-chosen, well-focused manufacturing test bed development projects involving close university-industry collaborations.

Overall, more co-funded projects are needed to enable universities and industry to work collaboratively on advanced nanomanufacturing issues. The NRI program, listed above, accomplishes this to a limited degree, but only in the nanoelectronics area. More analogous efforts are needed for other industry areas, including materials, energy, health, communications, and others. One new program currently under development to take steps in this direction is the "*Industry Inspired Fundamental Research*" (IFR) program. This is a joint effort between the NSF and 28 member companies of the Industrial Research Institute (IRI). These are mainly large companies. The emphasis here is to develop co-funded fundamental research projects at universities on focused scientific topics that will have a direct impact on the success of American industry. This partnership model should serve to simultaneously train the future workforce and advance knowledge that can be directly implemented in industry. If well managed and amply funded, it should prove to be successful. In such case, its funding should be augmented.

It is often stated that the most effective way to transfer new technology from universities to industry is by way of people. Graduating students who carry with them the ideas developed in an environment rich with research activities, innovation culture, and a genuine understanding of industry needs are ideally suited to quickly transform ideas into products in industry. Student involvement in university-industry projects will have a significant impact on the speed by which new innovations can be implemented in industry.

I would like to emphasize an important and relevant observation: From their inception in the late 1990s, NSF nanotech funding program solicitations for group and center research projects required that research be performed by *interdisciplinary teams*. Looking back, this was a visionary strategy. It is my opinion that, over time, this emphasis on interdisciplinary research *transformed* U.S. science and research in a substantially beneficial way, since almost all the great advancements in nanotechnology have occurred due to the synergy between distinct, but complementary, disciplines. One may argue that without such a required push, there would have been far less progress in nanotechnology overall. The notion of interdisciplinary "boundary spanners" as catalyst for innovation is well known, and in the recent nanotechnology progress we have observed this in action. We see from this recent experiment that suitable incentives can transform research effectiveness.

Are there areas of nanomanufacturing research and development that are not currently being addressed by the Federal Government that should be addressed?

Currently, there is not enough support for tool and instrumentation development, in the form of longer-term continuing projects. Without the development of manufacturing tools that enable the utilization of new nanomanufacturing processes, we cannot benefit from the huge research investment already made in nanotechnology research. This type of research is best done through jointly-funded industry-university projects, so that the manufacturing science learned can be directly implemented in a new wave of process tools. For example, there are several nanomanufacturing processes that could be implemented in a roll-to-roll platform to substantially lower the production cost. The knowledge gained and the tools developed here could be leveraged into several distinct product areas including batteries, solar cells, water filtration membranes and many other technologies. The same is true for a variety of other emergent processing methods.

There is currently not enough support for nanoinformatics, where cyberinfrastructure, data mining tools, modeling tools, and automated data gathering are utilized to accelerate progress in discovery, development, design and manufacturing. Nanoinformatics will be a critical factor in cost- and time-efficient design of nanomanufacturing processes and products. Associated with this is the collection and curation of data that manufacturers can use for evaluation and design. There should be more support for pilot projects that advance nanoinformatics.

There should be a stronger emphasis and support for the development of international documentary standards and standard reference materials for metrology and tool calibration. Nanomaterials certification standards, nanomanufacturing process specification language (PSL) standards, and reference standards for nanomanufacturing process control are vital. Standards will impact nanomanufacturing capabilities in environments ranging from the single production facility to the global supply chain network.

In general, there are not enough funding opportunities for industry and academia to work together collaboratively on to pilot new manufacturing methods based on promising laboratory discoveries. By getting valuable test data, the industrial engineers can make go/no-go decisions and design for scale up, and university scientists and engineers can gain new knowledge regarding the underlying fundamentals. To be effective and serious, it is important that for such projects to be successful, all the stakeholders must have “skin in the game” and co-invest the project. I am shocked by the stark comparison I see when observing the close industry-university ties in countries like Ireland, Japan and China. In other countries such as these, I have seen the equivalent of technical community college students, PhD students and industry scientists all working together under the same roof. We have very few examples like this in the U.S., and but that can change if we create a favorable environment. Proximity and shared mindsets matter significantly. Especially with regards to closing the cultural gaps that currently exist between community colleges, universities, and industry in the U.S.

The development of new manufacturing education curricula should be an integral part of such activities, with the natural involvement of industrial engineering programs. There should be a strong emphasis on innovation education and manufacturing engineering principles. The principles underlying both continue to evolve, especially considering the complexities of a new field such as nanomanufacturing. We need the education and research in science-based manufacturing process-property models, scale-up principles, design-of-experiment methods, data-rich statistical techniques and design-for-manufacturing methods. These all contribute to manufacturing excellence as measured by quality, cost, process reproducibility, property optimization, process flexibility and extensibility.

What role does the manufacturing industry play in shaping the Federal Government’s nanomanufacturing research and development agenda? In your opinion, are Federal Government programs focused on nanomanufacturing responsive to the needs of the manufacturing industry and other stakeholders? If not, why not?

I will mostly defer to my industrial colleagues on this issue, but from my nanotechnology perspective, there have been several valuable industry inputs toward the development of the National Nanotechnology Initiative priorities. The semiconductor industry (through the SIA and the SRC) helped to identify areas of priority for integrated circuit chip manufacturers. Similarly the Council for Chemical Research and the American Forest & Paper Association provided input for nanotechnology priorities through the development of their respective 2020 roadmaps.

As discussed above, the companies of the Industrial Research Institute (IRI) are working with the NSF to create an Industry-inspired Fundamental Research program to jointly fund research driven by industry needs. This program could fund “collaboratory” style university research projects focused on tackling scientific problems that would advance future generations of manufacturing capabilities. More joint interactions of this type would be desirable. Fast “skunkworks”-style projects and facilities, co-funded by the federal government and industry, would result in test data that would advance the development of new manufacturing capabilities. In the case of nanomanufacturing, the centers already established by research agencies could be leveraged for this purpose.

The NIST Technology Innovation Program (TIP) is one good example in which industry and universities can work together towards the development of nanomanufacturing processes and techniques. The Department of Energy’s Energy Efficiency and Renewable Energy (EERE) nanotechnology program, similarly has projects based on an industry need: the creation of better materials for energy efficiency and more energy efficient nanomanufacturing processes for sustainable manufacturing. Augmenting both TIP and EERE would be beneficial.

Lastly one should not neglect the support and involvement of the small and medium sized companies. The SBIR/STTR programs are one mechanism, but it is important that these companies also have the opportunity to benefit from all of the programs discussed above. Small companies are a rich with innovative ideas, but they often lack the manufacturing experience and resources possessed by large companies. Small-company/large-company partnerships can be very beneficial to success.

Are nanotechnologies developed through Federally-funded research and development being transitioned effectively to use by manufacturers? If not, why not?

In some, but not all, cases. One barrier to successful technology transition is the huge "impedance mismatch" in priorities between fundamental researchers and manufacturing experts. The best ways to improve this is to incentivize a change in the culture and support innovation education. As observed in the impact of the NSF requirement for interdisciplinary team research in nanotechnology over the last decade, we see that that mindsets can be changed, and rather quickly, over a period of only a few years. To do so requires the right incentives. Funding of projects with requirements for university-industry partnership, innovation education, or small-company/large-company partnerships, are all activities that over time, emphasize new priorities that change mindsets in beneficial ways.

Another barrier to success is the lack of sufficient data to make informed go/no-go decisions for the implementation of new technologies. Too many of the breakthroughs are only at the proof-of-concept level. When there is far too much uncertainty in the properties, performance and reproducibility of a new nanomaterial or property, it is an enormous economic risk to jump in with both feet. Supporting the development of the most promising nanotechnologies, in the form of pilot projects or manufacturing test beds, can produce reliable test data and build confidence for further investment and development.

In your opinion, is there a need for better coordination and prioritization of Federally-funded manufacturing research and development?

Supporting manufacturing innovation overall should be a priority for the Federal Government. Why? Countries that do not manufacture products are poor, typically. We do not want to head in that direction. With home-grown U.S. research breakthroughs, such as those in nanotechnology, we have a rich foundation of innovations from which we can build manufacturing excellence. Better coordination for manufacturing R&D is needed, indeed, but it can be built upon existing or emerging programs that are already successful, but underfunded. In the case of nanomanufacturing, the National Nanomanufacturing Network and industrial organizations that the NNN works with (eg. IRI, SRC, AF&PA) can assist the process substantially, since these organizations have already started roadmapping activities with key stakeholders and have identified priority activities that represent the "low hanging fruit" as well as long view strategic action that can advance U.S. manufacturing. In the case of nanomanufacturing, each research agency already has engaged in manufacturing R&D prioritization at some level, as discussed in a few examples mentioned above. For manufacturing in general, it is important to have a complementary set of roadmapping exercises, some tightly focused on specific themes and some broad, so as to identify the needs, challenges, opportunities and desired outcomes. As is currently happening the case of nanomanufacturing, through such roadmapping efforts the key priorities will emerge. To leverage resources efficiently, the Federal Government should consider the creation of an interagency initiative focused on manufacturing innovation. As I have already emphasized several times, a vibrant national manufacturing enterprise system, rich in innovation, requires synergistic participation of industry, academia and government.

More Information on the National Nanomanufacturing Network

The mission of the National Nanomanufacturing Network (NNN) is to serve as a catalyst for progress in nanomanufacturing in the U.S., through the facilitation and promotion of nanomanufacturing workshops, roadmapping, inter-institutional collaborations, technology transition, test beds, and information exchange services. The NNN operates as an open-access network of centers, leaders, experts, and stakeholders from the nanomanufacturing research, development and education community. It is a partnership between academia, industry and government that is built to foster and serve nanomanufacturing communities of practice. The core foundation of the NNN consists of the four NSF nanomanufacturing NSECs—the Center for Hierarchical Manufacturing (CHM), the Center for High-Rate Nanomanufacturing (CHN), the Center for Scalable and Integrated NanoManufacturing (SINAM), and the Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems (Nano-CEMMS)—as well as the DOE Center for Integrated Nanotechnologies (CINT) at Sandia National Laboratories and the NIST Center for Nanoscale Science and Technology (CNST) and other affiliations. InterNano is the information arm of the NNN—a digital library clearinghouse of timely information on nanomanufacturing and a web platform for collaboration. It should be noted that each center described above is funded independently. The NSF funding for the NNN's cooperation and information sharing activities is provided as a portion of the grant for the Center for Hierarchical Manufacturing.

The NNN functions as part electronic resource, part community of practice, and part network of experts working on the development of nanomanufacturing. The NNN has made key progress in launching and establishing an effective mechanism for information sharing (InterNano), facilitating and organizing workshops and events with topical focus on critical and emerging nanomanufacturing issues, facilitating and contributing to critical areas of informatics, standards, education and workforce training, and further providing an open platform for archiving information where stakeholders can contribute or access relevant information specific to their needs in the area of nanomanufacturing. Subject to available funding resources, the NNN has a vision of providing the following activities to support nanomanufacturing R&D:

- Facilitate collaborative R&D activities that support the development of nanomanufacturing systems through pilot projects and test beds with industry partnership
- A complementary portfolio of nanomanufacturing education and training activities.
- Share and disseminate best practices (process implementation, tech transfer, EHS, supply chain)

- Leading or assisting technology visioning and roadmapping activities via workshops and working groups, symposia, and summits on nanomanufacturing themes.
- Guide the development, implementation and growth of the InterNano nanommanufacturing information clearinghouse via broad-based informatics.
- Economic analysis of emerging nanomanufacturing processes.
- Federated nanoinformatics efforts linking materials, process, and application databases.

More Information on the Centers Affiliated with the NNN

The collection of centers represented by the NNN provides a complementary portfolio of nanomanufacturing processeses. Detailed information can be found at nanomanufacturing.org and at each center's website.

The **Center for Hierarchical Manufacturing** (CHM) led by the University of Massachusetts Amherst provides methods that use self-assembling diblock copolymers and complementary nanomanufacturing process to control structure from the nanoscale to the macroscale. The center develops processing techniques and modeling methods for nanomanufacturing both in batch and roll-to-roll production formats. These processes have significant impact for the low-cost production of data storage media, nanoelectronics, batteries, solar cells, water filters and communications. The CHM is also the administrative hub of the National Nanomanufacturing Network.

The **NSF Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing** (Nano-CEMMS) headquartered at the University of Illinois concentrates on developing innovative processes that function in ambient (as opposed to high vacuum processes) conditions, are well suited to large-area formats, and with material sets not usually associated with microelectronics. Nano-CEMMS has developed a manufacturing platform that exploits efficient nano-fluidic and ionic transport phenomena to realize a whole new class of products such as semi-transparent flexible solar collectors, flexible-stretchable solid-state lighting and bio-compatible electronics.

The **NSF Center for High-Rate Nanomanufacturing** (CHN) headquartered at Northeastern University provides methods for fast large scale directed assembly and transfer of nanostructures, including carbon nanotubes as on chip wiring interconnects, transparent flexible electronics using carbon nanotubes, wafer-level template-free assembly, and custom made nanostructured carbons of various forms. The CHM also works on the development of best practice guidelines to limit exposures to nanomaterials and fast toxicity screening methods.

The **NSF Center for Scalable and Integrated Nanomanufacturing** (SINAM) led by the University of California Berkeley has developed tools and techniques for plasmonic nanolithography, which provides a high throughput route to pattern nanostuctures having feature sizes below 22 nm. This technology is relevant to semiconductor device manufacturing and other application areas.

The **DOE Center for Integrated Nanotechnologies** (CINT) at Sandia National Laboratory has developed and deployed the Discovery Platform™. These platforms are modular micro-laboratories designed and batch fabricated by CINT to allow easy integration of nanomaterials into microscale structures. They allow easy connections, a range of diagnostic and experimental measurement conditions, and a degree of standardization and reproducibility in nanoscale measurements. Sandia also is home to The National Institute for Nano-Engineering (NINE) is a Public-Private Partnership formed to develop the next generation of technical innovation leaders for the U.S., employing the national strategy of the America COMPETES Act.

The **NIST Center for Nanoscale Science and Technology** (CNST) supports the development of nanotechnology from discovery to production. The Center provides this support through a research program that develops innovative nanoscale measurement and fabrication capabilities, and is accessible via collaboration with CNST scientists and a national nanofabrication facility, the NanoFab, which is a shared-use R&D facility with a suite of tools and processes for nanomanufacturing research.