2008 FLC Award for Excellence in Technology Transfer
Section 1 – Submission Cover Sheet

Laboratory Name: Sandia National Laboratories

If submitting more than one nomination in this category, please indicate how many others are being submitted: Sandia National Laboratories will submit four nominations total in the category Excellence in Technology Transfer.

Title of Nominated Technology Transfer (10 words maximum):
Self-Assembling Process for Fabricating Tailored Thin Films

Summary:
In the space below, write a brief (450 words maximum) summary of the nomination that describes: the transferred technology, the technology transfer process used, and the benefits of the transfer effort. **Please write this paragraph in non-technical terms for a non-scientific audience.**

Many of today's technologies and products, including semiconductor devices, consumer electronics, and optical coatings, depend on the ability to produce high-quality thin films. This nominated technology is a simple, economical nanotechnology coating process for the development of nanoparticle thin films with architectures and properties unattainable by any other processing method.

The self-assembling process for fabricating tailored thin films resolves several problems that conventional coating processes suffer from, such as significant cost, logistics, and environmental, safety and health issues. Large-footprint, expensive capital equipment and highly paid systems operators will be replaced by less expensive equipment and personnel. Also, unlike conventional coatings, these coatings may be applied on or near production lines, thereby reducing the manufacturing timeline. The expensive sputtering targets and toxic chemical vapor deposition chemicals used in current processes will be replaced by environmentally benign and OSHA-compliant chemistries. The supportability of components is also significantly enhanced by the ability to repair coatings in the field, thereby reducing the required spare parts.

The initial transfer of this technology has been to Lockheed Martin. It was through Lockheed Martin that significant applications for industry and the Department of Defense were identified. Additional transfer opportunities to the Department of Energy and NASA, have been identified. Various companies and industries have notified Sandia that they are evaluating how to adapt this technology to meet their current and future needs. These discussions cover a diverse range of applications, including thermal control films for architectural windows, chemical and biological sensors, information storage, and lead solder replacement.

Lockheed Martin has a multi-year "Shared Vision" program that is dedicated to collaborative engagements with Sandia. The program provides the environment to discover, development, and implement high-impact opportunities such as this self-assembling technology. The program provides a means to get promising projects started quickly, as well as business and technical oversight to ensure appropriate technical progress and business relevance.

The innovation of this technology transfer effort lies in the seamless flow from the fundamental understanding of materials and processing to lab-scale production, and from identification of practical applications to final large-scale production. Prior to the collaboration with Lockheed Martin, Sandia developed and demonstrated the fundamentals of the self-assembly technology for deposition of generic optical and electrical coatings; it required close collaboration among the team members from both organizations to identify, develop, and demonstrate the feasibility of applying this technology to several specific applications, such as reflective and anti-reflective coatings on weapon sensor windows.

In 2007, the technology was honored with an *R&D 100 Award*, which annually recognizes the 100 most technologically significant products and advancements in the world. The foundation techniques for this coating process received a Sandia National Laboratories *2007 Laboratory Directed Research and Development Award for Excellence*.

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RECEIVED:	**SUBMISSION NUMBER:**

NOMINEE INFORMATION INSTRUCTIONS:

- List the names (including Mr., Ms., Miss, Mrs., Dr., etc.) and job titles of nominees below.
- Designate one nominee as the primary contact who will be responsible for disseminating information from the FLC to the rest of the team.
- If the address is a PO Box, also include the street address.
- If the project leader is not the primary contact, please provide their information below the primary contact section and designate them as the project leader.
- If any nominee(s) has a different address than the primary contact, provide this information.

Nominee/Primary Contact: Ms. Dorothy Stermer
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NOMINATOR INFORMATION INSTRUCTIONS

- List the names (including Mr., Ms., Miss, Mrs., Dr., etc.) of the nominators below.
- If the nominator holds more than one of the positions listed below (e.g. FLC Representative and ORTA Representative) it is only necessary to list the name of the nominator in the entry of the second position.
- If the address is a PO Box, also include the street address.

THE FLC STRONGLY RECOMMENDS THAT ALL LISTED NOMINATORS HAVE AN OPPORTUNITY TO REVIEW AND APPROVE THE FINAL NOMINATION BEFORE IT IS SUBMITTED FOR JUDGING!!!

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2008 FLC Award for Excellence in Technology Transfer Section 2 – Submission Narrative

Laboratory Name: Sandia National Laboratories
Title of Nominated Technology Transfer: Self-Assembling Process for Fabricating Tailored Thin Films

PART A – Background and Technology Transfer Process
Address each of the following items on pages 2-1 and 2-2. See the award criteria for details on each item. If a criterion is not applicable, indicate why not and evaluators will make adjustments accordingly. **Criteria that are not addressed will not receive points.**

1. **Description of Technology (5 points)**
2. **Tech Transfer Recipient and Need for Technology (7 points)**
3. **Technology or Technical Expertise (5 points)**
4. **Initiation of Technology Transfer Partnership (10 points)**
5. **Technology Transfer Processes Used/Innovations (5 points)**
6. **Time Frame Challenges (5 points)**
7. **Patents and Publications (3 points)**

1. The transferred technology combines self-assembly and conventional sol-gel processing to develop processes and tools to produce multifunctional composite coatings with tailored properties. It involves chemical synthesis and functionalization of nanoparticles with controlled chemical composition, particle size and shape, and their further assembly into engineered nanoparticle composite films. This technology is a simple, economical nanotechnology coating process that enables the development of nanoparticle thin films with architectures and properties unattainable by any other processing method.

The benefits of this new technology include cost reduction, increased producibility, improved logistics, and the incorporation of new technology solutions not possible with currently available technologies. Coatings produced using this technology will be significantly less expensive than those produced by conventional processes.

2. The initial transfer of this technology has been to the Lockheed Martin Corporation. It was through Lockheed Martin that significant applications for industry and the Department of Defense were identified. Additional transfer opportunities to the Department of Energy and NASA have been identified.

Lockheed Martin has requirements for fabricating optical and electrical coatings on a wider range and type of surfaces than are currently practical by conventional manufacturing processes. Factors influencing these requirements include cost reduction and increased productivity, especially on large and irregular shape products. This new technology will meet Lockheed Martin's needs by dramatically reducing costs and increasing productivity, thereby positioning Lockheed Martin to be more competitive in both the national and international business environment.

This technology resolves several long-term problems that conventional processes suffer from, such as significant cost, logistics, and environmental, safety and health issues. Large-footprint, expensive capital equipment and highly paid systems operators will be replaced by less expensive equipment and personnel. Furthermore, these coatings may be applied on or near production lines, thereby reducing the manufacturing timeline. The expensive sputtering targets and toxic chemical vapor deposition chemicals used in current processes will be replaced by environmentally benign and OSHA-compliant chemistries. The supportability of components will be significantly enhanced by the ability to repair some coatings in the field, thereby reducing the required spare parts.

3. The nominees systematically developed a "tool box" of synthesis, self-assembly, functionalization, modeling/simulation, and processing to produce optical and electrical nanocomposite thin films. Specifically, they developed unique chemical synthetic routes to produce multifunctional monodisperse nanoparticles with controlled composition, size, shape, and surface chemistry, allowing the nanoparticles to readily disperse in commercial solvents. Modeling developed by the nominees helped design, engineer, and evaluate optical and electrical properties and performance. In addition, they introduced multifunctionality into the thin films, such as a "hydrophobic" property that prevents moisture from deteriorating the coating performance.

Lockheed Martin provided facilities and personnel to evaluate and characterize the optical, electronic, and magnetic properties of these new coatings, targeting practical applications. These resources included complete access to a state-of-the-art optical measurement laboratory to determine both constitutive properties and performance characteristics.

The nominees successfully transferred Sandia technology to Lockheed Martin; Sandia is leveraging the technology development to address more Lockheed Martin applications.

4. The partnership for the technology/technical advance was initiated by Lockheed Martin. Following a review of published studies, and recognizing Sandia's position of leadership in advanced nanotechnology, Lockheed Martin scientists met with their Sandia counterparts to discuss technologies of mutual interest. As a direct result of these discussions, a Cooperative Research and Development Agreement (CRADA) was signed between Lockheed Martin and Sandia to develop cutting-edge technologies and high-technology products with reduced costs and increased productivity.

Sandia leveraged research efforts funded through its Laboratory Directed Research and Development (LDRD) program and DOE's Office of Science, Basic Energy Sciences programs to develop multifunctional nanomaterials for microelectronics and optics, as well as structure/property investigations of self-assembled nanomaterials.

The work has been well received by both Lockheed Martin, which identified multiple applications across several business sectors, and Sandia, as evidenced by its selection for the *2007 Laboratory Directed Research and Development Award for Excellence*, the award presented to the most significant technology at Sandia National Laboratories.

5. Sandia partnered with Lockheed Martin to jointly develop this coating technology through a CRADA that was funded by Lockheed Martin and received in-kind funding from both Lockheed Martin and Sandia. Within the past five years, both DOE Office of Science (through Basic Energy Science programs) and Sandia (through LDRD) invested about $5M in R&D on this technology. These research efforts matured the technology to the point that industry was able to assess its viability.

The innovation of this technology transfer effort lies in the seamless flow from the fundamental understanding of materials and processing to lab-scale production, from identification of practical applications to final large-scale production. Sandia had already developed and demonstrated the fundamentals of the self-assembly technology for deposition of generic optical and electrical coatings; it required close collaboration among the team members from both organizations to identify, develop, and demonstrate the feasibility of applying this technology to several specific applications, such as reflective and anti-reflective coatings on weapon sensor windows.

Lockheed Martin has a multi-year "Shared Vision" program that is dedicated to collaborative engagements with Sandia. The program provides the environment to discover high-impact opportunities such as this self-assembling technology, a mechanism to get promising projects started quickly, as well as business and technical oversight to ensure appropriate technical progress and business relevance.

6. Lockheed Martin funding supported this CRADA for three years. The commercialization of this technology will occur soon and will take the form of licensing the basic technologies to small companies who will then develop product lines to make these coating technologies available for both government and commercial applications.

The primary transfer challenges were associated with adapting this technology to meet the unique and practical property and performance requirements of high-performance optical and electrical coatings. These challenges were overcome through the Lockheed Martin/Sandia collaboration by systematically developing a "tool box" of modeling and layer-by-layer assembling techniques that were adapted to meet a wide range of optical and electrical performance requirements.

7. Patent: Self-Assembly of Water-Soluble Nanocrystals. U.S. Patent application number 10,683,810.

Publications: An article on this technology was published in *Science* and has been featured on the covers of prestigious peer-reviewed journals including *Advanced Functional Materials*, *Chemistry of Materials*, and *Chemical Communications*.

1. Fan H.Y. *et al*., *Science*, **v304** 567-571, 2004.
2. Wright, A. *et al*. *Chemistry of Materials*, **18** (13), 3034-3038, 2006.
3. Fan H.Y., *et al*., *Advanced Functional Materials*, **16**, 891-895, 2006.
4. Fan H.Y. *et al*., *Chemical Communications*, **22**, 2323-2325, 2006.

PART B – Results

Address each of the following items on pages 2-3 and 2-4. See the award criteria for details on each item. If a criterion is not applicable, indicate why not and evaluators will make adjustments accordingly. **Criteria that are not addressed will not receive points.**

1. **New Relationships (5 points)**
2. **Follow-up Activities (10 points)**
3. **Outcome of Technology Transfer Effort (45 points)**

1. Although the initial technology transfer development was with Lockheed Martin Aeronautics, Sandia is developing new relationships to expand the transfer of this technology. For example, Sandia is currently working with Lockheed Martin Missiles and Fire Control Company on a Defense Advanced Research Projects Agency (DARPA) proposal to adapt this self-assembling coating technology to chemical and sensor platforms to detect highly toxic gases, TNT, and biological toxins. Sandia is also working on an additional CRADA with Lockheed Martin Aeronautics Company to expand the current project to include additional nanofunctional coatings with tailored properties, such as anti-reflective coatings on thermally sensitive lenses. Other new interactions include the discussions with LaSys, Inc. for sensor platforms and Intel Corp. for the next generation of high-capacity flash memory.

2. New follow-up activities from the initial transfer are identified almost daily. The technology and the nanomaterials resulting from this collaboration are attracting increasing attention from industries, especially from multiple Lockheed Martin programs and business units including Aeronautics, Missiles and Fire Control, Maritime Systems and Surveillance, and Space Systems. Discussions are underway between Lockheed Martin and Sandia to evaluate how to apply this technology to specific applications in the Lockheed Martin Corporation product lines, including:

- Anti-reflective coatings for sensor windows
- Thermal management on aerostats
- Shock-resistant coatings on space-based mirrors and sensors

Various companies and industries, including business units within Lockheed Martin, have notified Sandia that they are evaluating how to adapt this technology to meet their current and future needs. These discussions cover a diverse range of applications, including thermal control films for architectural windows, chemical and biological sensors, information storage, and lead solder replacement.

3. The outcome of this technology has received publicity. As previously mentioned, in 2007 the technology was honored with an *R&D 100 Award* and an LDRD Award.

The outcome of the transfer of this self-assembling coating technology to industry has effected a paradigm change in the areas of systems design, manufacturing, and field-supportability planning. Lockheed Martin is including this nanotechnology-based coating technology in its product line planning in the following areas:

1. Reduction of costs through direct replacement. That is, replace a coating currently producible only by an expensive conventional process such as sputtering with this low-cost process.
2. Introduction of field supportability of coatings. Currently a damaged coating requires that the component be returned to the factory for refurbishment or be scrapped altogether. Lockheed Martin is now considering how to reduce both the cost of repair and the number of spare parts required by using this new technology.
3. Enabling technology for new applications. A number of new systems designs are being evaluated that would use the tailored properties possible with this technology to produce integrated systems that would not be possible using off-the-shelf materials and manufacturing approaches.

Lockheed Martin has briefed members of its customer community on the technical nature and value of these technologies and these customers have expressed great interest in the opportunity to transfer these coating technologies to their programs and applications. These technologies are becoming an important component of the Business Case for a number of Lockheed Martin Corporation programs, as well as for other companies.

Because many large U.S. companies, such as Lockheed Martin, have evolved into systems integration companies rather than materials producers, it is anticipated that the commercialization of this technology will take the form of licensing the basic technologies to small companies that will then develop product lines to make these coating technologies available to both government and commercial applications.

Key benefits of this transfer of technology are in three primary areas. One benefit is cost. For example, Lockheed Martin has already identified an application for which the cost savings to the company (and ultimately the U.S.

Government) is over $150 million when compared to the costs of using conventional manufacturing approaches. The second benefit is the opportunity to produce coatings that are not practical by conventional manufacturing techniques, which will have a significant impact on the company's ability to introduce these products into U.S. Government systems. The third benefit is product supportability. This self-assembling technology offers a promise of being able to repair various coatings, especially optical coatings, on site that would otherwise require the damaged equipment to be replaced, shipped back to the factory, or scrapped altogether.

The initial transfer of this technology to industry will be in optical coatings, because these coating designs are currently the most mature. The ability to tailor the optical properties of these coatings means that a common approach can be applied to a wide range of windows, from visual through the infrared. Products using this technology will have enhanced optical performance, producibility, durability, and supportability. One example of optical applications under consideration is as an anti-reflective coating on transparencies and sensor windows for high-performance military aircraft. In both training and war fighting operations, these windows are subject to damage from a wide range of environmental factors, especially rain erosion and sand. Window coating repair is expensive and generally requires that the entire unit be removed from the aircraft and shipped to the manufacturer. We expect that this technology will allow coatings to be repaired in the field by flight line mechanics, which will significantly reduce both the cost and logistics trail of replacement parts. Lockheed Martin is studying the potential that the sensor system repair kit of the future will include applicator bottles of the coating, much like the touchup paint used to fix a scratch in car paint. In addition to terrestrial-based applications for optical coatings, there are also space-based applications for this new coating technology. Future extraterrestrial telescopes and earth-sensing satellites will benefit from the flexibility and shock-resistant (both thermal and mechanical) nature of these self-assembled coatings applied to mirrors and optical lenses.

Another optical application of this technology is for the thermal management of aerostats and high-altitude airships to improve the stability of the gas inflation pressure across day/night cycles. This new application method, along with the optical and mechanical properties of this self-assembled thin film coating, is ideally suited to the treatment of the thousands of square feet of flexible fabric required for these large gas-filled structures.

Small, thermal-processing-sensitive MEMS devices for both terrestrial- and space-based devices, including sensors, will also benefit from the ability of this new coating technology to perform at ambient temperatures. Several device-specific components, such as adaptive micromirrors, which are extremely difficult to coat using conventional thin film coating techniques, have already been identified as excellent candidates for this new coating technology.

The technology transfer effort has expanded into discussions with additional companies, identifying a diverse set of new applications based on the core of this nanotechnology. Some examples of these applications include:
1) High-density storage for high-density flash memory: The ability to manufacture a film with isolated metallic nanoparticles in a dielectric backbone architecture is a building block for high-density memory.
2) High-density 3D interconnects for next-generation electronics: Placing metallic nanoparticles in a low-viscosity solvent enables filling, and subsequent interconnection, of complex 3D wiring networks, where conduction paths exist without line-of-sight access to the surface.
3) Electrical interconnects for frequency-dependent conductivity: By optimizing material choice and film structure, we can affect the electron hopping and hence radio-frequency (RF) conductivity.
4) Magnetic coatings for information storage: This technology allows deposition of metallic nanoparticles into high-density, patterned features to generate the starting material for high-density information storage.
5) Sensor coatings for chemical and biological sensor platforms: Metal nanoparticles are key components to surface-enhanced Raman-scattering-based detection methods for chemical and biological sensors. This technology increases both the reliability and sensitivity of such sensors.
6) Emissivity-tailored windows: Controlling the amount of radiant energy reflected/transmitted by windows can help reduce structural heating and cooling loads.
7) Thermal shielding: Materials with high reflectivity in the infrared are important for suppressing the thermal spread within a structure.

2008 FLC Award for Excellence in Technology Transfer
Section 3 – Submission Verification Checklist

(This page will only be accepted via fax at 856-667-8009)

Laboratory Name: Sandia National Laboratories
Title of Nominated Technology Transfer: Self-Assembling Process for Fabricating Tailored Thin Films

Please review each item below and determine whether your nomination meets the stated requirements. For the last two items, you must simply agree to comply with these requirements in the event that the nomination is chosen as a winner.

- ☑ The FLC Laboratory Representative and the representative's immediate supervisor are not nominated.
- ☑ The majority of the nominee(s) are employees of the FLC member laboratory listed above. In the case of a group nomination, more than 50% of the staffing or funds provided came from this laboratory.
- ☑ The technology is not solely funded by a Small Business Innovation Research (SBIR) contract or is a 100% grant funded commercial project.
- ☑ The nominee(s) has been nominated no more than three times in any year as an individual or as part of a group.
- ☑ The technology transfer achievement took place in the last five years.
- ☑ There is no proprietary information contained within this nomination.
- ☑ The technology involved is clearly described in layman's language.
- ☑ The Submission Cover Sheet (Section 1) is completed per instructions and comprises the first four pages of the nomination package.
- ☑ The nomination was reviewed and approved by all the nominators listed on the Submission Cover Sheet (Section 1).
- ☑ The Submission Narrative (Section 2) uses the page format established by the FLC, is typed in 10 point type or larger, addresses all items listed in the award criteria, and comprises pages 2-1 through 2-4 of the nomination.
- ☑ Section 1 and Section 2 of the nomination package are being submitted electronically to the FLC Management Support Office via mchambers@utrs.com by **Friday, October 19, 2007.**
- ☑ No supporting documentation is attached.
- ☑ The FLC may use this entire submission as a resource document and for media purposes.
- ☑ In the event of being chosen as a winner, at least one nominee will participate in the award ceremony at the 2008 FLC National Meeting in Portland, Oregon.
- ☑ The nominee(s) will provide a poster display for an exhibit at the 2008 FLC National Meeting in Portland, Oregon.

As the nominating official and FLC Representative from this laboratory, I understand that entries not conforming to this checklist will be returned without consideration.

____________________	____________________	____________________
Signature	Phone	Date