The National Nanotechnology Initiative: Review and Outlook

Testimony of
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Introduction

Good morning, Chairman Inglis and Ranking Member Hooley. Greetings from South Carolina and Clemson University. Clemson University continues to climb in the national rankings which bodes well for the state of South Carolina and its drive toward a knowledge-based economy. On behalf of the Center for Advanced Engineering Fibers and Films (CAEFF), our university partners (the Massachusetts Institute of Technology and Clark Atlanta University), our 20 industry partners, and Clemson University, I would like to thank the committee for inviting me to represent CAEFF at this hearing. The National Nanotechnology Initiative provides a systemic program for helping the U.S. maintain is research and technology leadership in the increasingly competitive global environment. I am please to be here to provide CAEFF's support of the Initiative.

The Center for Advanced Engineering Fibers and Films (CAEFF) is one of only 22 Engineering Research Centers funded by the National Science Foundation. The CAEFF research team consists of faculty and students from nine academic departments at Clemson University (the lead institution), MIT (a core partner), Clark Atlanta University (a core partner), Lehigh University, McGill University, the University of Illinois, and 20 industry partners. CAEFF provides an integrated research and education environment for the systems-oriented study of fibers and films. CAEFF promotes the transformation from trial-and-error development to computer-based design of fibers and films. This new paradigm for materials design is revolutionizing fiber and film development.

The NSF began funding CAEFF in 1998 and funding will continue through 2008, with research expenditures approaching $10 million annually. About 150 graduate students, 75 undergraduates, 15 high school students, and 50 faculty members support CAEFF's research program. Coordinated with CAEFF's research is an education program that is offering innovative multi-disciplinary courses, seminars, short courses, and workshops. The education experience is further enhanced by activities that emphasize teamwork and communication skills. CAEF promotes diversity in its research team through scholarships, fellowships, and collaboration with universities that serve under-represented populations.

CAEFF is a cornerstone of Clemson University's research program. Several research niches, particularly nanomaterials, fall under CAEFF, and other developing research programs have been incubated in CAEFF. After 2008, CAEFF will be a self-sufficient research enterprise through additional government and foundation funding, industry sponsorship, and royalties from intellectual property.

Nanotechnology-Related Research

The CAEFF team is very active in nanotechnology research that can potentially advance technology and impact our citizens' health and well being. Our researchers are using carbon nanotubes (highly ordered carbon structures) for biosensors, filtration, biocompatible coatings, and infection prevention. We are also exploring nanotechnology as a means for improving healing from surgery and wounds. Controlling cell growth through optimally changing the

texture at the nano-level of sutures and meshes will strongly influence healing and repair of living tissue as in a hernia repair.

We have also discovered that activated carbon fibers (carbon fibers with nano-sized pores) can be used to achieve 30% of the Department of Energy hydrogen storage target at room temperature and moderate pressure.

Adding nanoparticles to fibers dramatically improves the cut resistance of the fibers. Consequently, we are presently working with a company to exploit this technology for protective clothing that would improve workers' safety. This technology could be useful for police officers, workers that process food or handling sharp materials such as glass or sheet metal, or our infantry.

These areas point to nanotechnology that is being or is close to being applied in a commercial venture. However, CAEFF is also conducting fundamental research that provides results in new knowledge that may have impact on the way we make fibers or assembly materials. One of our research groups is trying to mimic the way spiders make fibers because spiders have optimized the fiber spinning process. They make a fiber with excellent properties at about room temperature and atmospheric pressure. Also, spiders do not use oil as the feedstock which is used for over 99% of all man-made fibers. All of the man-made fibers require various combinations of high temperature, high pressure, and toxic solvents. If we could mimic the process that spiders use to make fibers, then we could potentially develop processes that are less energy intensive and environmentally friendly.

We have also learning how to assemble molecules. Once we know how to do this, we will be able to sense, capture, and destroy toxins. This technology could be applied to provide healthier hospitals and security against bio-terrorism.

Another research group has learned how to blend materials to produce nanolayers. This technology has been termed smart blending. The implications of this technology are tremendous, so much so, that patents have been issued, several companies have licensed the technology and many more are interested. With smart blending, plastic parts have improved strength, food packaging prevents spoilage better, and static build up in plastic parts is minimized. We are just beginning to tap the potential of this exciting technology.

Interaction with Industry

NSF Engineering Research Centers (ERC), like CAEFF, are required to have industrial partners on the research team. These partners help the ERC define the systems-level research program which is the key characteristic of an ERC. Systems-level research occurs on three planes – fundamental knowledge, enabling technology, and engineered system. Clearly, the industry partners provide practical perspective on what fundamental knowledge is needed, the technology that must be developed to make the research advancement a viable commercial product, and the experience to package the technology into a system for commercialization.

By focusing on fiber and film technology, CAEFF supports a critical component of the U.S. manufacturing base. The fiber and film industries provide the consumer with synthetic fibers, nonwoven fabrics, multi-layer films, flexible packaging, and state-of-the-art electronic components – just to name a few of its products. When CAEFF was selected as an NSF Engineering Research Center in 1998, economic projections indicated that the fiber and film industries could grow by 50% over the next ten years – if they responded to the needs of their customers by improving existing products, developing new products for future markets, and instituting more efficient, environmentally friendly processes. If it was apparent then that traditional research and development practices, basically a trial and error approach to product and process development, had not produced the breakthroughs necessary to revitalize these industries so crucial to our quality of life, today it is glaringly evident. A significant portion of the commodity fiber industry has relocated outside of the U.S. to take advantage of lower labor costs and to be close to the textile industry that they supply. Industry-wide restructuring has changed the operating philosophy of many major producers, who have increased profitability by reducing research and technical support. This point is driven home by the shift of polyester production from the US, Europe, and Japan to China, Japan and India and, closer to home, the regular announcements of textile plant closings in the southeast. However, the polymer industry is adjusting to globalization by focusing on value-added or "niche" products and on products that are not labor intensive such as carpet and consumables. Development of value-added products ties well to the push for an economy driven by innovation.

Since its inception, CAEFF's mission has been to arm industry with a unique modeling tool to design fiber and film processes and predict final properties of the fiber or film product. This modeling capability provides industry with the knowledge, in a user-friendly software package, to develop innovative fiber and film products. Some of our industry partners are using this capability in designing processes for new polymers. It is our belief that the fiber and film industries need to develop products and processes in advanced engineering environments that use computer modeling techniques and visualization to minimize experimentation, allow manipulation of both molecular and continuum information, and maximize engineers' understanding of and control over structure formation and resultant properties. The properties of films and fibers depend on their polymeric structure. In nearly all commercial fiber and film processes, this structure is created by the production process.

In response to these industry and societal needs, the Center has developed a materials design environment, featuring an integrated model that allows users to design an entire fiber or film system by inputting precursor specifications, processing parameters, and desired properties. This virtual testbed will bring design improvements to current manufacturing systems, and also significantly reduces, if not alleviates trial-and-error experiments needed for the design of next-generation fiber and film processes.

Given the evolution of our research and the emerging needs of industry, CAEFF revised its strategic research plan in the last year. The primary change to the strategic plan was to establish six systems-level product areas that complement the multi-length scale modeling effort that is the cornerstone of the vision and strategic plan of CAEFF. Each of the product areas supports an opportunity for the polymer industry to develop value-added products. CAEFF is uniquely position to conduct research in these product areas because each requires cross-disciplinary

teams to make substantive systems-level research advancements. The six product areas were selected because they focus the modeling efforts on specific commercial products that could help reshape the polymer industry as globalization drives production of conventional fibers and films offshore. The research will enable industry to shorten the cycle from concept to commercialization.

CAEFF presently has 20 industry partners that support our research with directed and undirected financial support and in-kind support. Our members represent a broad spectrum of companies from large to small and producer to user. The logos of our industry partners are shown on the chart below. Each member pays a membership fee that CAEFF management strategically directs to research, equipment and management. Some companies choose to provide additional funding for research specific to their needs. In this case, the company defines the research project. In many cases a confidentiality agreement is executed so that the company can exploit the results of the research that they sponsored.

Our industrial collaboration, including transfer of intellectual property, is governed by a common CAEFF Membership Agreement that all companies must execute. The Membership Agreement provides each industry partner a seat on the Industrial Advisory Board (IAB). The IAB is the body that provides industry guidance on research direction and policy as discussed above. A primary function of the Membership Agreement is the transfer of intellectual property. The intellectual property policy in the Agreement is structured to favor licensing by industry partners. The following flow chart shows the licensing process that is called out in the Agreement. The key features of the intellectual policy are: an industry sponsoring research has first rights to a license resulting from their project; intellectual property resulting from research funded by NSF, the state, or other federal agencies will be offered to all of the industry partners; and CAEFF will

place industry-experienced personnel on the committee that determines which intellectual property will be patented by Clemson University.

The two greatest barriers to academic/industrial cooperation are the elimination or drastic reduction of central research and development staff in large companies and the existence of companies that have the vision to exploit new nanotechnology developed by CAEFF.

Support for CAEFF and Self Sufficiency

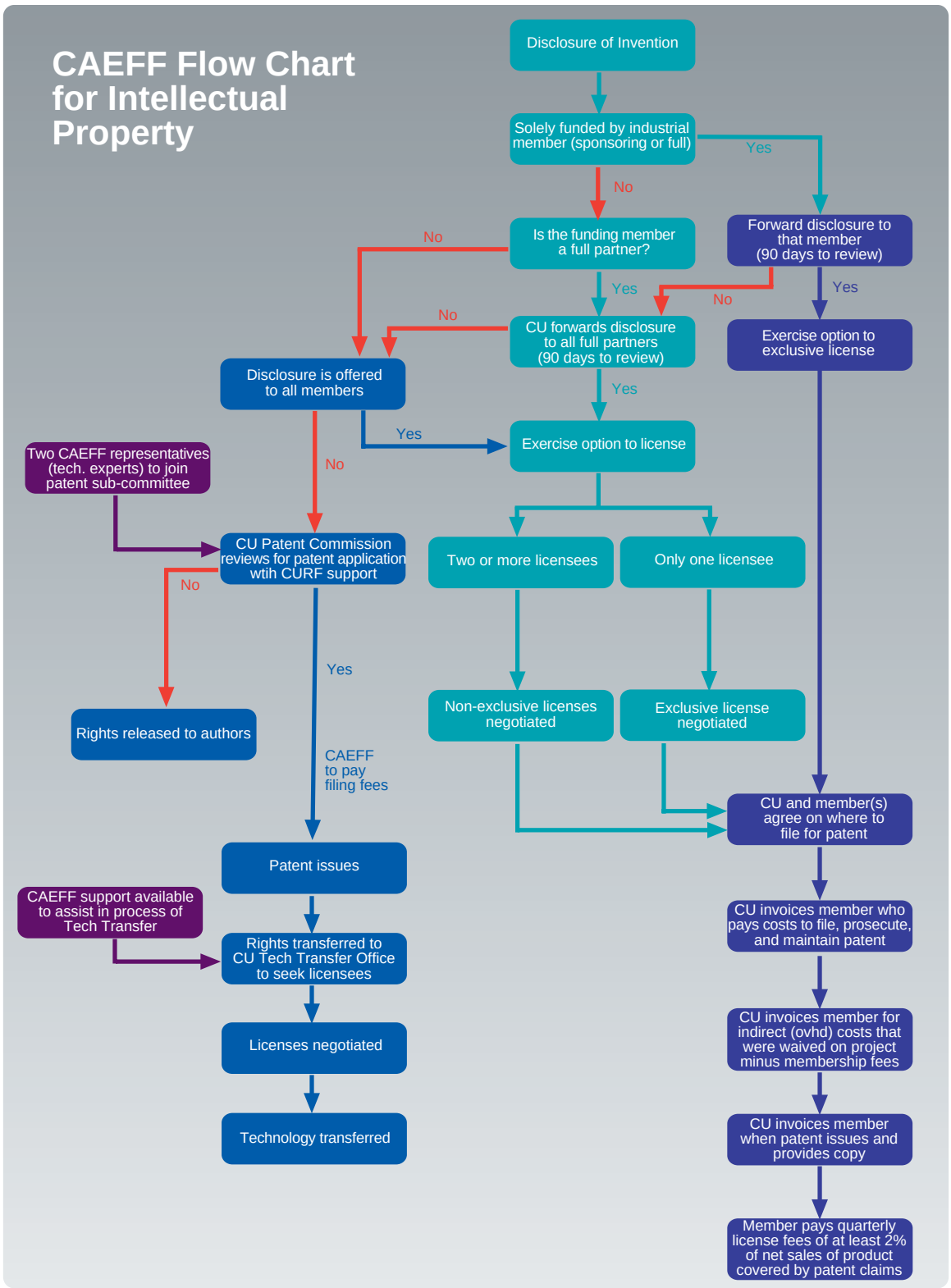
CAEFF derives its support from four sources: the base NSF ERC grant (currently about $3.8 million annually), the state of South Carolina ($1.0 million annually as cost share for the NSF ERC grant), industry membership fees (approximately $150,000 annually), industry supported research ($250,000 annually), and other federal support routed through CAEFF($3.6 million annually). When CAEFF was in the formative stages the state and Clemson University provided even more support for renovation of space and salary support for CAEFF leadership to develop the research and education program. Additionally, the state has provided funding for the design and development of a new academic building on the Clemson campus for CAEFF and the School of Materials Science and Engineering. Construction of the building will commence when the next bond bill is approved by the South Carolina legislature.

These funds can be divided into five broad categories: research, education, industry liaison, equipment, and management with the largest portion going to research, followed by education and equipment. Generally, the support for industry directed research his highly compatible with the research supported by NSF. We have used our modeling capability and experimental testbeds, developed with NSF support, on numerous industry sponsored projects.

The support for CAEFF from NSF and the state has been outstanding, enabling us to be positioned as a national leader in polymer research. Professor Mike Jaffe (New Jersey Institute of Technology and former employee of Hoechst Celanese Corporation,) has suggests that CAEFF provides "World leadership in modeling at Clemson CAEFF ERC." Without the NSF ERC and state support, the claim would not be possible. The NSF support for CAEFF will terminate in July 2008 as per ERC guidelines. CAEFF leadership is developing a strategic plan to assure that the NSF support will be replaced with funding from other resources.

Workforce Development for Nanotechnology

For the most part, the workforce and those entering the workforce in the nanotechnology area have received traditional engineering or science educations which do not provide a systems perspective related to nanotechnology. This perspective is crucial for companies because virtually all nano-based applications are multi-disciplinary, requiring the talents of scientists and engineers from several disciplines. Further, most engineering programs teach design at length scales that are much greater than the nanoscale.


CAEFF Flow Chart for Intellectual Property
Disclosure of Invention
Solely funded by industrial member (sponsoring or full)
Yes
No
Is the funding member a full partner?
No
Forward disclosure to that member (90 days to review)
Yes
No
Yes
No
CU forwards disclosure to all full partners (90 days to review)
Exercise option to exclusive license
Disclosure is offered to all members
Yes
Yes
Exercise option to license
Two CAEFF representatives (tech. experts) to join patent sub-committee
No
CU Patent Commission reviews for patent application wtih CURF support
Two or more licensees
Only one licensee
No
Yes
Rights released to authors
Non-exclusive licenses negotiated
Exclusive license negotiated
CAEFF to pay filing fees
CU and member(s) agree on where to file for patent
Patent issues
CAEFF support available to assist in process of Tech Transfer
CU invoices member who pays costs to file, prosecute, and maintain patent
Rights transferred to CU Tech Transfer Office to seek licensees
CU invoices member for indirect (ovhd) costs that were waived on project minus membership fees
Licenses negotiated
CU invoices member when patent issues and provides copy
Technology transferred
Member pays quarterly license fees of at least 2% of net sales of product covered by patent claims

The Center is graduating students with a broad, systems-oriented technical foundation; modeling, simulation, and visualization skills; the critical thinking skills necessary to both analyze and integrate information; an appreciation of the industry perspective; and the teamwork and communication skills necessary to function effectively in collaborative virtual design environments. CAEFF's integrated research and education programs have developed advanced materials design techniques that are communicated through courses, workshops and conferences, and outreach programs.

CAEFF is working with a team of universities to develop an undergraduate macromolecular engineering curriculum that addresses design at the molecular level. This exciting concept will essentially bring together features of a materials science curriculum and those of engineering disciplines such as chemical and mechanical so that graduates will have background to consider molecular or nano issues in the design of systems. Adding molecular level considerations to the design process will expand the design envelop, leading to new value-added products in transportation, medicine, defense, and national security.

Thirty-three percent of South Carolina's population is minority, principally African-American, the opportunity exists to greatly increase the diversity in both the student body and the faculty. For the population of South Carolina's Land Grant University to reflect the demographics of the state, a long-term, well funded educational program must be implemented at all societal and educational levels in South Carolina so that all students realize the importance of higher education and have prerequisite academic credentials and/or enter into bridge programs that give them the opportunity to succeed in the rigorous academic environment of engineering and science disciplines. Consequently, the goal of CAEFF became to develop a diverse community of scholars trained in polymeric materials design. The various populations (pre-college, undergraduate, graduate and faculty) of this community of scholars will mirror the demographics of the State of South Carolina. Meeting this overall metric was very aggressive and will substantially exceed national engineering-wide averages for the involvement of women, underrepresented racial minorities, and Hispanic-Americans. We are approaching our goals for underrepresented racial minorities in our undergraduate and masters student populations. Outlined below are the components of CAEFF's diversity program.

The Center has formed a partnership with Clark Atlanta University (CAU) to increase the participation of African-American faculty and students in the research and education programs of CAEFF. A research contract was awarded to CAU for the remainder of CAEFF's NSF lifetime. Faculty members and students from CAU are being integrated into CAEFF's research topics as core members of the research teams. CAU is being targeted to provide undergraduate and graduate students to CAEFF's programs at Clemson University. Our intent is to develop a dual degree program with CAU.

Diversity in the Center has been fostered by outreach through Women in Science and Engineering, the Girl Scouts of the USA, and the Research Experiences for Undergraduates program. The Center has also secured supplemental funding to support diversity initiatives. Department-of-Education-funded Graduate Assistantships in Areas of National Need provide attractive financial incentive packages to minority and female students of superior academic ability from across the nation. The Hearst Scholarship endowment targets a diverse,

academically qualified and economically disadvantaged student population. The newly-funded Southeast Alliance for Graduate Education and the Professoriate will provide a mechanism for recruiting students from the University of Florida, the University of South Carolina, and the University of the U.S. Virgin Islands. This grant will also provide international opportunities for students through collaboration with the Latin American and Caribbean Consortium of Engineering Institutions.

Our graduates are entering the workforce as engineers and scientists in the polymer industry. Many on them have taken jobs with our industry partners. Several have chosen to enter academe.

The Federal/State/Industry/Academe Nanotechnology Partnership

The National Nanotechnology Initiative provides significant support for infrastructure, faculty, and students. As various components of the research mature, the challenge will be to transfer the technology in to profitable business ventures. It is likely that an entirely new industry will be spawned from the nanotechnology initiative. This new industry will probably be comprised of small businesses that fit a niche or are exploiting research advancements. For these small companies to survive, they may well need bridge funding which can be made available through the Small Business Innovative Research and Small Business Technology Transfer Programs, available from all federal agencies, and also the Advanced Technology Program which is run through the National Institute of Standards and Technology.

To accelerate the application of nanotechnology and to identify unforeseen issues surrounding nanotechnology systems, agencies that have a major stake in applied research and development such as NASA, the Department of Defense, and the Department of Transportation can bring nanotechnology into practice through demonstration programs. This paradigm was used successfully by NASA and the Department of Defense to accelerate the application of advanced composite materials in the 1970's and 1980's. These programs were partnerships between government and industry that drove industry to educate its personnel and develop infrastructure. It also provided validation of the advantages afforded by composites. Finally, after 20-25 years, advanced composites are being extensively used on commercial aircraft for major structural components. This large time lag was predicable because industry needed time to train a workforce, establish design methods, and build a database, all of which are required for confident application of composites in complex systems and structures.

Closure

Thank you for inviting me to testify before your subcommittee today. I am fully supportive of the National Nanotechnology Initiative. It is a critical initiative with huge potential to impact the citizens of the U. S. I would be pleased to answer your questions.