North Carolina State University, a land-grant university and a constituent institution of The University of North Carolina

Office of the Chancellor
Box 7001 / A Holladay Hall
Raleigh, North Carolina 27695-7001

NC STATE UNIVERSITY

919.515.2191 (phone)
919.831.3545 (fax)

October 15, 2007

MEMORANDUM

TO: John G. Gilligan
Vice Chancellor for Research and Graduate Studies

FROM: James L. Oblinger
Chancellor

SUBJECT: Request for Authorization to Plan the NCSU Silicon Solar Research Center called SiSoC (Silicon Solar Consortium)

In response to your Memorandum dated October 12, 2007, authorization is hereby granted to plan the NCSU Silicon Solar Research Center called SiSoC (Silicon Solar Consortium) in accordance with NCSU Regulation 10.10.4 and Article II of NCSU Centers and Institutes Management Guide. As the planning progresses, please keep me informed.

Best wishes for continuing progress with the development of this Center.

JLO/mh

cc: George Rozgonyi, Director of Silicon Solar Research Center
John Strenkowski, COE Associate Dean - Research
Matt Ronning, Associate Vice Chancellor, Director of SPARCS
✓Larisa Oktyabrsky, Coordinator – Centers and Institutes

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Office of Research and Graduate Studies

NC STATE UNIVERSITY

Office of the Vice Chancellor
Campus Box 7003
103 Holladay Hall
Raleigh, NC 27695-7003

919.515.2117
919.515.7521 (fax)

October 12, 2007

MEMORANDUM

TO: James L. Oblinger
Chancellor

FROM: John G. Gilligan
Vice Chancellor for Research and Graduate Studies

SUBJECT: Request for Authorization to Plan the NCSU Silicon Solar Research Center called SiSoC (Silicon Solar Consortium)

On behalf of the College of Engineering, I request the authorization to plan the NCSU Center SiSoC in accordance with NCSU Regulation 10.10.4 and Article II of NCSU Centers and Institutes Management Guide.

A detailed proposal describing the proposed Center and a letter requesting permission to plan from Dr. John Strenkowski are included for your review. If additional information is required, please let me know.

Your consideration of our request to plan this Center is greatly appreciated. I look forward to your response.

JGG/mh

Enclosure

cc: George Rozgonyi, Director of Silicon Solar Research Center
John Strenkowski, COE Associate Dean - Research
Matt Ronning, Associate Vice Chancellor, Director of SPARCS
Larisa Oktyabrsky, Coordinator – Centers and Institutes

Request to Plan
A Silicon Solar Research Center

This is a proposal requesting permission to plan a new multi-university Center, called SiSoC (Silicon Solar Consortium) at NC State. This Center will be part of NSF's Industry/University Cooperative Research Center (I/UCRC) program.

Internationally recognized leaders in the research, fabrication, and development of advanced Photovoltaic (PV) materials and devices are located at North Carolina State University's (NCSU) Silicon Solar Materials Group and at the Georgia Institute of Technology's (GIT) DOE supported "University Center of Excellence in Photovoltaics Research and Education" (UCEP), as well as at the 11 industrial PV companies and the National Renewable Energy Laboratory (NREL) in Golden, CO who have provided letters of intent to join the SiSoC I/UCRC.

The proposed Center has already obtained a planning grant from I/UCRC.

Relationship of the proposed center to the mission of NC State University

Teaching and Research

The projects funded by the Center will provide new research opportunities for obtaining educational goals in Materials Science and Engineering. These opportunities will lead to additional funding and development of new research topics.
The mentorships provided by the Center's industrial members will assist in to improving cross communication between the industrial world and academia and in creating employment opportunities for graduate students.

Community Involvement and Extension

The SiSoC research activities will provide an opportunity for getting involved with one of the most important technical and scientific challenges of out time: freeing ourselves from the use of fossil energy, more specifically through the conversion of sunlight into electricity. These activities will involve NCSU students and researchers, but also enhance NCSU and the State of North Carolina's stature and level of visibility.
The research involved will also be a good enticement for the obtention of REU (Research Experience for Undergraduates) grants from NSF.

Need for the Proposed Center

The silicon photovoltaic industry has recently undergone a rapid growth created through many technical achievements and breakthroughs in photovoltaic science and technology. Some of these advances were developed independently by industry, while others were adopted from R&D performed at various academic institutions around the globe, often

stimulated by strong governmental support. In the US the PV industry is committed to advancing device and system performance, while improving reliability and developing products suitable for integration into residential and commercial building structures. The US technology development also includes building integrated photovoltaics, a rapidly growing solar application in which PV modules serve the dual purpose of replacing conventional building materials with products capable of generating electricity. Crystalline silicon accounts for 90% of photovoltaic production starting material worldwide and in order to achieve the PV industry roadmap goals for 2015 will require:

- Reduce solar electricity costs to less than $0.06/kWh (currently at $0.18/kWh)
- Increase PV module performance such that it reaches an average efficiency above 18%
- Reduce production and packaging costs drastically
- Decrease consumer PV installation prices, currently at $6.10/watt, by 40%
- Produce and supply, by the year 2025, half of all new electricity generated in the US
- Reestablish the United States as the global leader for PV systems, materials, equipment, and production processes as we serve the booming world market for PV.

Today the PV industry generates a total of 175 MW, but is expected to grow to 2500 MW by 2015, if we achieve an average module efficiency of 18% and solar electricity costs of $0.06/kWh. The industry grew by 50% in 2005 and now generates more than $6 billion in revenues annually. This growth is driven by innovative technology and manufacturing, which improve PV cost and performance, and by strong market development programs. However, the U.S. market share of this worldwide boom has dropped to less than 12%, the lowest level ever. The EU and Japan established almost 26% and 52%, respectively, of this PV market which was once dominated by the United States. The U.S. sales have grown, due to market incentives in individual states such as California, but overall fewer products were manufactured in the U.S. The bottom line is that we are importing a product invented in America, giving up domestic jobs and hurting our balance of trade.

What is needed and where SiSoC center will focus, is a strategic R&D investment for the United States to rebuild a strong market position in the PV industry, while creating tens of thousands of jobs by 2015. This will result in an industry whose products increase energy security, boost domestic economic development, lower peak energy costs, reduce pollution and cut greenhouse gas emissions. The SiSoC CENTER research, funded by the participating industry members, will focus on new areas of research that have recently emerged. The cutting edge of crystalline silicon science and engineering will be the primary focus, which will naturally lead to advances for the semiconductor and photovoltaic power industry.

During the 2006 DOE/NREL workshop on Crystalline Silicon, attended by the leading PV industry manufacturers, many industry attendees such as GE Energy, Evergreen Solar, BP Solar, Solar World, SunPower, Advent, and Applied Materials were very enthusiastic about the idea of establishing a Center as described above, and subsequently supplied letters of intent to support the Center as a participating member.

The proposed center will play an active role in reestablishing a global leadership role for the US Silicon PV industry. This will be enabled by having NSF and other government agencies, together with the solar-electric power industry jointly stimulating high quality university level research and education, while developing a skilled workforce, and at the same time creating new jobs in the U.S. PV industry. The SiSoC center will also play an important role in meeting the rapidly growing demand for electricity in the 21st century, while having the significant bonus of a minimal impact on the environment.

This I/UCRC CENTER, a partnership between PV industry, universities, national laboratories and the National Science Foundation, will be based on input from a partnership community focused on the following key research areas whose essential goal is to achieve advances in cost and performance of silicon PV material, PV cells and PV modules:

Several areas of research were identified by the leading PV manufacturers at the 2006 DOE/NREL workshop on Crystalline Silicon:

- Novel breakthrough designs and processes
- Improved impurity and defect engineering for higher performance at lower materials cost
- Methods to minimize power losses created by incorporating large-area cells into modules
- Products that last for 30 years and are simple to install and operate
- New hydrogen-passivation processes
- New silicon production processes
- Thinner materials and larger cells
- New processes and machine tools to create the generation manufacturing technology
- Innovations to reduce optical losses
- New or improved electrical contact systems

Goals and Objectives of the Proposed Center

Within the framework of SiSoC, Profs. George Rozgonyi and Gerd Duscher of NCSU, and Profs. Ajeet Rohatgi and Steven Danyluk of GIT will work together pooling their complementary PV device fabrication and materials diagnostic resources.

The research efforts at the NCSU center will emphasize materials characterization leading to a fundamental understanding of the impact of defects/impurities/mechanical behavior on silicon solar yield and performance including:

- Developing advanced characterization tools to accommodate the various needs of single- and multicrystalline Si wafers, thin films, and nanoscale PV science and technology.
- Understanding, as well as managing, performance limiting defects.

- Developing innovative strategies for processing advanced silicon PV structures and devices.
- Providing training, outreach, and enriching the educational experience of students.

GIT is well known for the modeling and fabrication of high efficiency silicon solar cells, novel materials for enhancing high performance PV and power devices, as well as with tandem solar cells using heterojunctions. The GIT team led by Profs. Ajeet Rohatgi and Steven Danyluk will focus its research on the challenging goals of the PV industry roadmap for 2015 and beyond, including:

- Improving the science and technology of advanced PV devices.
- Reducing the cost of PV generated electricity.
- Designing and fabricating record high efficiency solar cells.
- Developing low-cost materials and rapid thermal processes for next generation silicon solar cells.

The SiSoC Center will engage graduate students and post doc scholars in advanced PV research.

Organization of the Proposed Center

The Silicon Solar Consortium (SiSoC), an Industry University Cooperative Research Center (I/UCRC) brings together the North Carolina State University (NCSU) and the University Center of Excellence for Photovoltaics Research and Education (UCEP) at the Georgia Institute of Technology (GIT). The GIT and the NCSU are the major players in the proposed SiSoC and both will recruit enough members to satisfy the Full Partner Center requirements of the NSF I/UCRC program. Both universities have extensive experience hosting I/UCRCs and two team members have directed I/UCRCs.

NC State University will be the Lead Institution of the new Center. SiSoC will have two locations, one within the Department of Materials Science, College of Engineering, NCSU, Raleigh, NC, and another at the School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA.

George Rozgonyi and Steven Danyluk have previously directed NSF I/UCRCs and have the necessary experience for directing a new center. The SiSoC Center will continue and extend its ongoing collaboration with DOE/NREL, as well as with other universities experienced in the PV area, e.g. UC-Berkeley, MIT, U. of So. FL (please avoid abbreviations), Texas Technological University, and Lehigh University, bringing together the leading academic institutions with the primary PV industrial community.

The proposed Director of the multi-university SiSoC center is Prof. Rozgonyi, while Prof. Rohatgi will be Co-director and lead the efforts of the SiSoC research site at GIT.

Research Personnel at NC State University

Prof. George Rozgonyi (MSE Department) leads a research team which has a longstanding record of fundamental and industrial silicon research. Their research activities have made many contributions to the silicon industry. This has been achieved by maintaining a close relationship with Solar (BP Solar, GE Energy) and NREL by catering to the basic research demands of PV manufacturing and PV roadmap goals, and by providing an in-depth evaluation of material characteristics and fabrication processes.
The Rozgonyi group has an extensive suite of in-house characterization tools, including a high resolution microwave photoconductive decay (μ-PCD) system, a Near-Field Scanning Optical Microscope (NSOM), developed with support of NREL, as well as various other electrical (DLTS, EBIC), optical (defect etching), and mechanical characterization systems. They also have access to the electron microscopy lab of Prof. Gerd Duscher, with TEM attachments such as Z-contrast, STEM, and EELS, the extensive resources of the Analytical Instruments Facility on campus, as well as several processing labs.
While the UCEP Center of Georgia Tech is mainly focused on device processing technology, the NC State efforts emphasize materials characterization leading to a fundamental understanding of defect science. Both centers will bring their complementary skills and experience via a collaborative effort with the PV companies to address the challenging goals of the US Photovoltaics Industry Roadmap.

Gerd Duscher, Assistant Professor at NC State researches the possibility to use high efficiency Poly-Crystalline Silicon for manufacturing of PV cells. Polycrystalline silicon is cheaper and more widely available than single crystalline silicon and therefore an obvious choice for the solar industry. However, the efficiency of solar cells made from Poly-Si is still below the level to make them cost-effective. The reason for the lower efficiency is not the grain boundaries themselves, but the impurity precipitations at these grain boundaries. Cheap processing of Poly-Si will always produce material with a high impurity content especially transition metals and oxygen. Therefore, the electricity activity of the transition metal silicides and silicon dioxide precipitates at the grain boundaries cannot be avoided in cheap material.
Their research focus on two obvious routs to improve the efficiency of polycrystalline silicon materials with impurities:

1) Passivation of the interfaces of the precipitates
   The interfaces of the transition metal silicide precipitates are the electrically active component. Segregation of other elements to these interfaces can be achieved because grain boundaries constitute a fast diffusion path. The selection of an effective element is the goal of this task.
2) Using precipitates to increase efficiency: Instead of passivating the interfaces, we can attempt to make the precipitates in the notoriously electrically active triple pockets of the polycrystalline silicon, the active part of the solar cell.

Jinggang Lu, Research Associate, and Magnus Wagener, Senior Researcher, both with MSE department, have valuable knowledge and experience in the field of fundamental and industrial silicon research.

Research Personnel at Georgia Institute of Technology

Professor Ajeet Rohatgi (GIT PI) created the solar energy program at Georgia Tech and is the director and founder of the University Center of Excellence for Photovoltaics Research and Education (UCEP). The mission of UCEP is to improve the fundamental understanding of the science and technology of advanced PV devices, reduce the cost of PV generated electricity, fabricate record high efficiency solar cells, develop low-cost materials and rapid thermal fabrication processes, provide training and enrich the educational experience of students in this field, and give the U.S. a competitive edge by providing guidelines to industry and DOE for achieving cost-effective and high-efficiency PV devices. UCP available technologies include: furnace diffusion, RTP diffusion, and screen-printing and annealing equipment. In addition device and material characterization tools and equipment such as automated dark & light I-V, DLTS, EBIC, FTIR, and Corescan, PCD lifetime, IQE are available at UCEP. UCEP has extensive experience in gettering and passivation of defects and impurities in multi-crystalline silicon. UCEP has also recently developed and modeled improved fabrication processes for high efficiency textured solar cells with screen-printed contacts through an understanding of the contact formation mechanism.

Professor Steven Danyluk, Director of the Manufacturing Research Center and Professor in the School of Mechanical Engineering at Georgia Tech, conducts research on the mechanical properties of semiconductors and the development of methods to measure the damage in these materials when they are processed. Dr. Danyluk's research group works in close cooperation with the PV industry to develop the automation, handling, inspection and factory information systems for the use of large thin silicon wafers. Recently, Dr. Danyluk's group developed a Bernoulli gripper to improve the handling of thin wafers, and the CAMX Information software for control of PV manufacturing equipment. Recent work has focused on correlation of residual stresses in low-cost Si wafers, measured and mapped with a full field near-IR polariscope, to the dislocation density.

The organizational structure of SiSoC will use the successful model of the SiWEDS I/UCRC center, founded by Prof. Rozgonyi in 1997 and currently directed by Prof. Duscher. The organizational chart attached shows the different entities involved in the SiSoC activities as well as how they relate to one another.

Units Similar to the Proposed Center

The proposed Center does not duplicate any existing academic programs or other established centers in the UNC System.

The existing Solar Center at NCSU does not conduct any of the research that will be performed in the context of SiSoC. In fact, the Solar Center does not focus on silicon. It mostly addresses applications, instead of the materials and devices that convert solar energy into electricity. The information found on the Solar Center web site (http://www.ncsc.ncsu.edu/) clearly indicates that all its PV projects pertain to the installation of devices, not the creation, or the improvement neither of devices, nor of the silicon-based components used in the fabrication of these devices.

The SiWEDS Center, which also involves silicon research, caters to a totally different industry than PV, and addresses very different issues. The research performed by SiWEDS is related to nano-electronic devices, whereas SiSoC will be involved with the conversion of sun power into electricity. It just so happens that silicon is used by both industries.

Financial Support

The Silicon Solar Consortium (SiSoC) will be a unique source for Solar Cell technology research and development of innovative PV material processing strategies. Worldwide the Solar Cell industry generates more than $6 billion in revenues annually, with a recent demonstrated growth potential of more than 30% per year. The potential US market share in annual revenue in the coming years could easily reach $ 8 billion by 2010 (this data is provided as an indication of the amount of research money that will be spent by the Solar Industry.). This does not include any estimates regarding the impact on the environment. Industrial partnership will be solicited from the Solar Cell sector in the areas of technology, PV manufacturers and PV processing equipment manufacturers.

Membership will be open to all corporations, institutes, government agencies and/or entities who: (1) are involved with R&D on PV or PV manufacturing, (2) directly contribute to PV research by making their facilities more efficient and competitive, and (3) are active in commercialization of clean solar energy technologies.
The membership fees will be $50,000 for a Full membership and $25,000 for an Associate membership. The Associate membership will be limited to small PV companies with less than 500 employees.

During the planning phase, SiSoC intends to secure membership from at least 12 organizations with total funding reaching at least $500,000. It is expected that the number of members will increase over time. Recruiting of new members will be done by the SiSoC Directors at PV conferences, DOE/NREL organized workshops, and potential member company sites through presentations of the mission, organization, research projects, and unique advantages of the SiSoC membership. New universities will be encouraged to join the SiSoC center only after recruiting new industry members with at least a total of $150,000 in annual membership fees.

Increase of dollar support will not only be through the addition of new members but also by obtaining support from other sources, particularly by taking advantage of the recently announced DOE Solar America Initiative(SAI) RFP for universities. It is not possible to put a dollar amount on this expected extra support, but many programs are already in place at the collaborative institutions. NCSU is currently partnering with GE Energy and BP Solar as part of the SAI industry-based Technology Partnership Program (TPP). UCEP at Georgia Tech has working relations with Schott Solar, Evergreen Solar and Ferro Inc. The organizations listed in the attached organization chart are potential participants in the I/UCRC SiSoC Consortium. Letters of support from several potential industrial members are also attached..

Many regional and local industries can benefit from continued advancements of the PV technology. As the I/UCRC matures, the companies from those benefiting industries could become interested in joining Center's membership.

Funding and expenditures
The table below was made on the estimate of initially recruiting 12 industrial members (8 Full Members and 4 Associate Members) and shows the capability of supporting 9 projects per year as, on average, the projects will have budgets of approximately $60,000 each. We expect that the number of members will grow over time.

	Funding			Expenditures		
	I/UCRC Grant	Member Fees	Total Funding	NCSU Overhead 9.5%	Admin. Support	Projects Funds
Planning Year	$10,000		$10,000		$10,000	
FY 1	$70,000	$500,000	$570,000	$47,500	$70,000	$543,000
FY 2	$70,000	$500,000	$570,000	$47,500	$70,000	$543,000
FY 3	$70,000	$500,000	$570,000	$47,500	$70,000	$543,000
FY 4	$70,000	$500,000	$570,000	$47,500	$70,000	$543,000
FY 5	$70,000	$500,000	$570,000	$47,500	$70,000	$543,000
Total for 5 years	$360,000	$2,500,000	$2,860,000	$237,500	$360,000	$2,715,000

No matching or cost sharing funds are requested.

Space and Capital Equipment for the Center

SiSoC does not need any additional space, but some adjustments in office location of Center personnel at NCSU might be needed to allow for easier communication between students and researchers.

No capital equipment is required for the support of the Center.

Support and Mentoring Plan

It is expected that the SiSoC research activities will provide research associates and researchers with valuable experience that will help them in obtaining permanent positions at NCSU, over time.

It is also expected that some of the findings obtained through the research will make their way into the MS&E curriculum.