Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2018 ENRTF Work Plan (Main Document)

Today's Date: February

Date of Next Status Update Report: Jan. 1, 2019

Date of Work Plan Approval:

Project Completion Date: June 30, 2021

Does this submission include an amendment request? __

PROJECT TITLE: Develop Solar Window Concentrators for Electricity

Project Manager: Uwe Kortshagen

Organization: University of Minnesota

College/Department/Division: College of Science and Engineering / Mechanical Engineering

Mailing Address: 111 Church Street SE

City/State/Zip Code: Minneapolis, MN 55455

Telephone Number: 612 625 4028

Email Address: kortshagen@umn.edu

Web Address: http://www.me.umn.edu/labs/ukgroup/

Location: statewide

Total Project Budget: $350,000

Amount Spent: $0

Balance: $350,000

Legal Citation: M.L. 2018, Chp. xx, Sec. xx, Subd. xx

Appropriation Language:

I. PROJECT STATEMENT:

The objective of this project is to inexpensive "solar windows". Solar windows are based on solar concentrators using highly luminescent nanometer-sized silicon crystals, a technology developed at the University of Minnesota. The silicon crystals, embedded in or coated onto the window pane, absorb harmful-to-humans ultraviolet and blue light and turn it into red light, which is guided by internal reflection to the edge of the window pane, where it is concentrated onto a small area solar cell. See Figure 1 in section IX.B for an illustration. The concentrator sheet can be made largely transparent such that it can serve as a window. As light is collected by the large area of the window but only a small and thus cheap solar cell is required, the cost of solar electricity is reduced. Moreover, these luminescent solar concentrators collect light from any direction and virtually invisibly integrate with buildings, thus eliminating aesthetic objections and the *cost of land* for solar installations. This cheap renewable energy technology may widely expand the adoption of clean solar electricity, reduce air pollution, and ameliorate climate change.
The progress of luminescent concentrators has long been hampered by the lack of suitable luminescent species. Recently, University of Minnesota investigators demonstrated that luminescent silicon crystals have virtually ideal properties for this application. First silicon-based window concentrators have shown promising efficiencies. The project will focus on solving the remaining bottleneck science and engineering problems on the way to producing large-area solar windows.

II. OVERALL PROJECT STATUS UPDATES:

First Update January 31, 2019

Second Update June 30, 2019

Third Update January 31, 2020

Fourth Update June 30, 2020

Fifth Update January 31, 2021

Final Update June 30, 2021

III. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Demonstrate Efficient Silicon-Based Window Luminescent Concentrators
Description: Largely transparent window solar concentrators will be produced by coating thin films of luminescent silicon crystals dispersed in common plastics onto inexpensive sheets of glass. Luminescent silicon crystals are ideal for this application, as they strongly absorb invisible ultraviolet light with limited loss of visible light. They are also compatible with common, sturdy plastics like poly(methyl methacrylate), also known as Plexiglas®. By carefully selecting the silicon crystal concentration in the plastic coating, the optical properties of the luminescent concentrators can be tuned to produce transparent to semi-transparent devices, ideal for window applications.

ENRTF BUDGET: $119,241

Outcome	Completion Date
1. Produce silicon-based test concentrator windows of least 100 cm^2 in area	Jan 31, 2019

2. Characterize device efficiency as function of concentration & film roughness	June 30, 2019
3. Evaluate visible transparency for suitability for window applications	June 30, 2019

First Update January 31, 2019

Second Update June 30, 2019

Third Update January 31, 2020 **N/A**

Fourth Update June 30, 2020 **N/A**

Fifth Update January 31, 2021 **N/A**

Final Update June 30, 2021 **N/A**

ACTIVITY 2: Explore Maximum Silicon-Based Concentrator Efficiency

Description: While transparent concentrators have great potential for window applications, the efficiency may be improved by absorbing and concentrating more solar light with semi-transparent to opaque devices. Such designs may find applications as colored architectural façades, siding panels, or stand-alone solar concentrators. The interplay between silicon crystal properties, concentration, and concentrator size will be examined in order to determine the upper efficiency limit of these devices. Additionally, the concentrator efficiency may change for curved devices, which will be studied.

ENRTF BUDGET: $113,976

Outcome	Completion Date
1. Explore optimum efficiency on devices of at least 100 cm^2	*Jan 31, 2020*
2. Evaluate transparency / color for applications as windows or opaque building panels	*Jun 30, 2020*

First Update January 31, 2019 **N/A**

Second Update June 30, 2019 **N/A**

Third Update January 31, 2020

Fourth Update June 30, 2020

Fifth Update January 31, 2021 **N/A**

Final Update June 30, 2021 **N/A**

ACTIVITY 3: Characterize Efficiency of a Large Concentrator Window

Description: Published research on luminescent concentrators is largely limited to devices on the scale of 100 cm^2 or less, primarily due to optical losses encountered by the luminescent materials studied thus far. The team will develop large area devices to prove the silicon-based concentrator technology on a realistic scale and encourage commercialization. They will demonstrate a concentrator as large as standard size windows to enable study of the device in its real-world environment, provide an educational tool for visitors to the University, and

break records on luminescent concentrator size. Prolonged assessment of the device performance will establish expected lifetime estimates.

ENRTF BUDGET: $116,783

Outcome	Completion Date
1. Develop large-area thin film coating technology	Jan 31, 2021
2. Scale luminescent concentrator devices up to at least 2,000 cm^2	Jun 30, 2021
3. Evaluate performance & stability over time	Jun 30, 2021

First Update January 31, 2019 **N/A**

Second Update June 30, 2019 **N/A**

Third Update January 31, 2020 **N/A**

Fourth Update June 30, 2020 **N/A**

Fifth Update January 31, 2021

Final Update June 30, 2021

IV. DISSEMINATION:

Description:

Professors Kortshagen, Francis, and Ferry are active members of their scientific communities. As such, they routinely disseminate results of their research through the publication of peer-reviewed research papers in scientific journals, conference papers and presentations, and seminar presentations at other universities and companies.

The characterization techniques previously discussed will provide a wealth of data in many custom formats for each application. In general, computer data will be stored both in custom format as well as in a universal form that does not require specific software for access. Methods and conditions used for synthesizing and characterizing the samples will be recorded by the student researchers in the form of handwritten or electronic laboratory notebook entries. Access to the data will be provided, upon request to the project director, within a reasonable period of time after collection. Data and laboratory notebooks will be maintained and stored for at least 3 years beyond the project end date, or 3 years following publication, whichever date is later.

The proposed project does not involve intellectual property rights at the moment. However, if an invention or proprietary discovery arises from the project and involves the stored data, the data will be made accessible to interested parties only after the intellectual property has been legally protected and conditions of the property rights are satisfied. The data collected and managed for this project is also subject to the data management and intellectual property policies established by the University of Minnesota.

First Update January 31, 2019

Second Update June 30, 2019

Third Update January 31, 2020

Fourth Update June 30, 2020

Fifth Update January 31, 2021

Final Update June 30, 2021

V. PROJECT BUDGET SUMMARY:

A. Preliminary ENRTF Budget Overview: See attached budget spreadsheet

Explanation of Capital Expenditures Greater Than $5,000:
Coating experiments will be performed in the Coating Process and Visualization Laboratory in the department of Chemical Engineering and Materials Science at the University of Minneosta. Experiments will utilize an existing batch coating apparatus. The request for $8,000 to purchase a custom coating die and wider base plate for this equipment to be able to coat large area samples. The equipment will be available for use by other researchers at no cost for the remainder of its useful life.

Explanation of Use of Classified Staff: N/A

Total Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation:

Enter Total Estimated Personnel Hours: 1,760	Divide by 2,080 = TOTAL FTE: 0.85

Total Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation:

Enter Total Estimated Personnel Hours:	Divide by 2,080 = TOTAL FTE:

B. Other Funds:

SOURCE OF AND USE OF OTHER FUNDS	**Amount Proposed**	**Amount Spent**	**Status and Timeframe**
Other Non-State $ To Be Applied To Project During Project Period:			
	$	$	
Other State $ To Be Applied To Project During Project Period:			
	$	$	
Past and Current ENRTF Appropriation:			
	$	$	
Other Funding History:			
past federal funding (National Science Foundation, Department of Energy, Army Office of Research) to Professors Kortshagen for developing luminescent	~$ 9M	~$ 9M	This is an estimate of past funding.

silicon technology and Prof. Francis for developing coating technologies. (estimate)			

VI. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role

B. Partners NOT receiving ENRTF funding

Name	Title	Affiliation	Role

VII. LONG-TERM- IMPLEMENTATION AND FUNDING:

The project team has a strong track record in technology transfer from academic labs to industry. The nanocrystal plasma synthesis process developed in Kortshagen's lab has been patented and was exclusively licensed to Innovalight, Inc. (acquired by DuPont) and Dow Corning. Professor Lorraine Francis, is an expert in the area of coating microstructures and processing and has strong industrial cooperations through the Coating Process Fundamentals Program of the Industrial Partnership for Research in Interfacial & Materials Engineering (IPRIME). The project team is interested in continuing this proactive interaction with industry in order to translate any outcomes of the proposed research quickly into industry and interact with local Minnesota window manufacturers.

VIII. REPORTING REQUIREMENTS:

- **The project is for 3 years, will begin on July/1/2018, and end on June/30/2021.**
- **Periodic project status update reports will be submitted Jan./31 and June/30 of each year.**
- **A final report and associated products will be submitted between June 30 and August 15, 2021.**

IX. SEE ADDITIONAL WORK PLAN COMPONENTS:

A. Budget Spreadsheet
B. Visual Component or Map

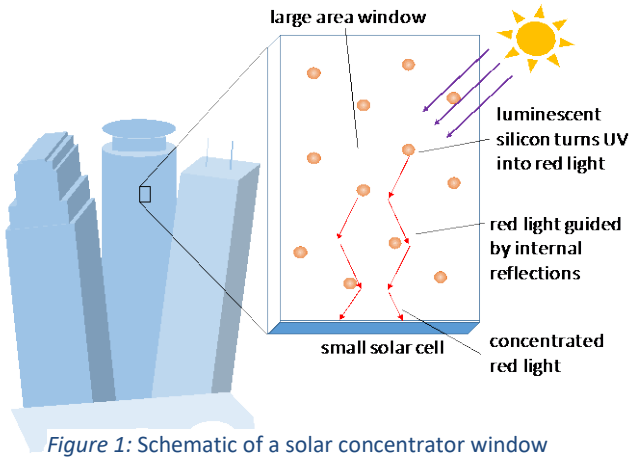

Figure 1: Schematic of a solar concentrator window

C. Parcel List Spreadsheet
D. Acquisition, Easements, and Restoration Requirements
E. Research Addendum

Attachment A:
Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet

Project Title: Develop Solar Window Concentrators for Electricity
Legal Citation:
Project Manager: Uwe Kortshagen
Organization: University of Minnesota
College/Department/Division: College of Science and Engineering / Mechanical Engineering
M.L. 2018 ENRTF Appropriation:
Project Length and Completion Date: 36 months, June 30, 2021
Date of Report: February 22, 2018

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$309,036	$0	$309,036
Uwe Kortshagen, PI: $13,673 (75% salary, 25% benefits); 4% FTE each year for 3 years, 3% increase years 2-3			
Lorraine Francis, Co-PI: $8,204 (75% salary, 25% benefits); 3% FTE each year for 3 years, 3% increase years 2-3			
Vivian Ferry, Co-PI: $4,764 (75% salary, 25% benefits); 3% FTE each year for 3 years, 3% increase years 2-3			
2 RAs at 37.5%: $73,821 (60% salary, 40% benefits); 37.5% FTE each year for 3 years, 3% increase years 2-3			
Equipment/Tools/Supplies	$19,142	$0	$19,142
Based on historical data, cost for purchasing supplies for coating operation ($1,056/yr) for yrs 1-2 and $1,358/yr for year 3			
Based on historical data, cost for purchasing precursor gases ($756/yr), sample substrates ($756/yr), and chemicals ($1356/yr) for nanoparticle synthesis, and chemicals for nanoparticle functionalization ($2356/yr)			
Capital Expenditures Over $5,000	$8,000	$0	$8,000
Custom coating die and wider base plate for this batch coater to be able to coat large area samples			
Other	$13,822	$0	$13,822
User fees for usage of facilities at the campus CharFac center for nanoparticle structural/property characterization (X-ray diffraction, secondary electron microscopy, Raman spectroscopy, electron microscopy, and electron energy loss spectroscopy)			
COLUMN TOTAL	$350,000	$0	$350,000