Environment and Natural Resources Trust Fund
2018 Request for Proposals (RFP)

Project Title: **ENRTF ID: 160-E**

Cheap Solar Energy from Simple Roll-to-Roll Manufacturing

Category: E. Air Quality, Climate Change, and Renewable Energy

Total Project Budget: $ 388,852

Proposed Project Time Period for the Funding Requested: 3 years, July 2018 to June 2021

Summary:

This project is to develop cheap clean solar energy by simple roll-to-roll manufacturing. Perovskite is a new photovoltaic material, very economical while maintaining high power conversion efficiency.

Name: Tianhong Cui

Sponsoring Organization: The University of Minnesota

Address: 111 Church Street SE, Minneapolis, MN 55455

Minneapolis MN 55455

Telephone Number: (612) 626-1636

Email cuixx006@umn.edu

Web Address

Location

Region: Statewide

County Name: Statewide

City / Township: Minneapolis

Alternate Text for Visual:

Comparisonn of Old and New Technology

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT TITLE: Cheap Solar Energy from Simple Roll-to-Roll Manufacturing

I. PROJECT STATEMENT

The objective of this proposal is to develop cheap clean solar energy based on roll-to-roll manufacturing approach. Perovskite is a brand new materials for the next generation of solar cells under development with very high efficiency and super low cost. The proposed advanced manufacturing is a simple roll-to-roll process using low-temperature physical-chemical deposition of perovskite, which is highly energy-efficient and very inexpensive. Potentially perovskite solar cells are one of the most disruptive renewable energy sources, and the proposed new manufacturing is the key to make it happen eventually. The proposed roll-to-roll manufacturing approach will enable the development of high-performance solar cells with extremely low cost, compared to silicon solar cells. The success of this proposal will provide renewable green energy as centralized power plants to reduce the import of energy from foreign countries. In addition, as low-cost distributed energy sources, the perovskite solar cells can be easily adopted by families or individual electronics customers, which will significantly improve the energy efficiency of all economic sectors. Through the proposed roll-to-roll manufacturing, perovskite solar cells can become a truly clean, low-cost, renewable energy source in Minnesota.
This project is intended to provide foundational knowledge of the technique and prove its feasibility of cheap perovskite solar cells. In the next phase of research, we will closely collaborate with state manufacturers and energy providers in Minnesota to further develop an implementation and commercialization plan.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Development of low-cost roll-to-roll manufacturing for perovskite solar cells* **Budget: $259,281**

The objective of this activity is to develop cheap advanced manufacturing technique based on roll-to-roll, low-temperature processes and to build economical perovskite solar cells accordingly. New perovskite solar cells will be designed and fabricated for high-efficiency solar energy to electricity conversion. Through this new advanced manufacturing, the target is to develop perovskite solar cells with a power conversion efficiency of 15% ~ 25% comparable to silicon solar cells and fabrication cost of 1/10 ~ 1/100 of silicon-based solar cells, resulting in an overall installation cost of at least 5 times lower than existing silicon photovoltaics.

Outcome	Completion Date
1. Roll-to-roll manufacturing processes set-up, coupled with low-temperature chemical-physical vapor deposition	*6/30/2019*
2. Design and experiments of roll-to-roll manufacturing processes for perovskite solar cells	*6/30/2019*
3. Design, fabrication, and characterization of perovskite solar cells in lab using the developed roll-to-roll manufacturing processes	*6/30/2020*
4. Comprehensive assessment of the new perovskite techniques and silicon solar cells	*6/30/2020*

Activity 2: *Development of perovskite solar cells and field testing* **Budget: $129,571**

A prototype panel of perovskite solar cells will be designed and constructed to demonstrate the feasibility. Field testing protocol and hardware will be developed and tested. Field testing will include setting up a test site in Minnesota. Upon completion of the project, we will demonstrate the perovskite solar cells panel to the stakeholders and LCCMR committee members and officials.

Outcome	Completion Date
1. A prototype panel of perovskite solar energy will be developed, based on the fabricated solar cells using roll-to-roll manufacturing	*6/30/2021*
2. Field testing protocol and hardware will be developed	*6/30/2021*
3. The prototype unit will be set up on an outdoor site and real-time solar irradiation of perovskite solar cells will be tested.	*6/30/2021*

III. PROJECT STRATEGY

A. Project Team/Partners

Tianhong Cui, professor in the Department of Mechanical Engineering and affiliated graduate faculty in Department Electrical and Computer Engineering, will serve as PI and project manager. He will be responsible for overseeing the project, all reports, and deliverables. He will also design the roll-to-roll manufacturing processes and perovskite solar cells based on the advanced manufacturing technique. Under Professor Cui's supervision, the Post-Doc will be responsible for the manufacturing facility and the outdoor experimental test set-up, and the Ph.D. student will be in charge of design, fabrication, and characterization of perovskite solar cells.

B. Project Impact and Long-Term Strategy

Given the state's latitude, many people are surprised to learn that Minnesota has annual solar radiation similar to portions of Florida and Texas, with sunshine for about 5 hours per day on-average in Minneapolis. Solar energy production is a small but exponentially growing resource in Minnesota, where we now have more than 15 Megawatts (MW) of solar electric capacity. In May 2013, the Minnesota legislature adopted a mandate on investor-owned utilities in the state that requires them to produce 1.5% of their electricity from solar power by 2020. Statewide solar energy demand continues to grow as a result of advances in technology, declining costs, federal tax incentives, new utility incentives, increasing public awareness, and state support for the solar industry and its deployment. The Minnesota Legislature established a solar photovoltaic and solar thermal incentive program for consumers who install photovoltaic and solar thermal systems using solar modules and collectors certified as manufactured in Minnesota.

As a source of energy, nothing matches the sun. It out-powers anything that human technology could ever produce. Only a small fraction of the sun's power output strikes the Earth, but even that provides 10,000 times as much as all the commercial energy that humans use on the planet. However, today's commercial solar cells, most often made from silicon, typically convert sunlight into electricity with an efficiency of about 10 percent to 20 percent, although some test cells do slightly better. Given their manufacturing costs, modules of today's cells incorporated in the power grid would produce electricity at a cost roughly 3 to 6 times higher than current prices. To make solar economically competitive, engineers must find ways to lower their manufacturing costs and to improve the efficiency of the cells. This project will provide one solution for lowering the cost and improving solar efficiency by using new materials, including perovskite, together with low-cost roll-to-roll advanced manufacturing techniques.

Upon completion of the project, cheap and high-efficiency perovskite solar cells for outdoor solar to electricity conversion will be developed. The knowledge learned throughout the project will provide a solid foundation for further research and development efforts that would lead to implementation of the new solar cells for power plants or consumer electronics eventually enabling very cheap, clean, renewable, and high-efficiency solar energy sources in Minnesota. This will potentially provide a supplementary energy solution to current energy sources in Minnesota, ultimately help implement the renewable energy policy, and thus enhance the economic and ecological benefits of Minnesota.

C. Timeline Requirements

This project is planned for 3 years beginning on July 1, 2018 and ending on June 30, 2021. The first two years' activity will focus on the development of roll-to-roll manufacturing processes and single perovskite solar cell fabrication. Year 3 will be focused on development of a prototype solar cell unit and extensive field testing. The results of this study will be disseminated through oral and poster presentations by faculty and students involved in the project, briefings to the LCCMR as requested, and peer-reviewed publications. We also intend to present progress on this project periodically to relevant personnel who may be interested in photovoltaics in Minnesota.

2016 Detailed Project Budget

Project Title: Cheap Solar Energy from Simple Roll-to-Roll Manufacturing

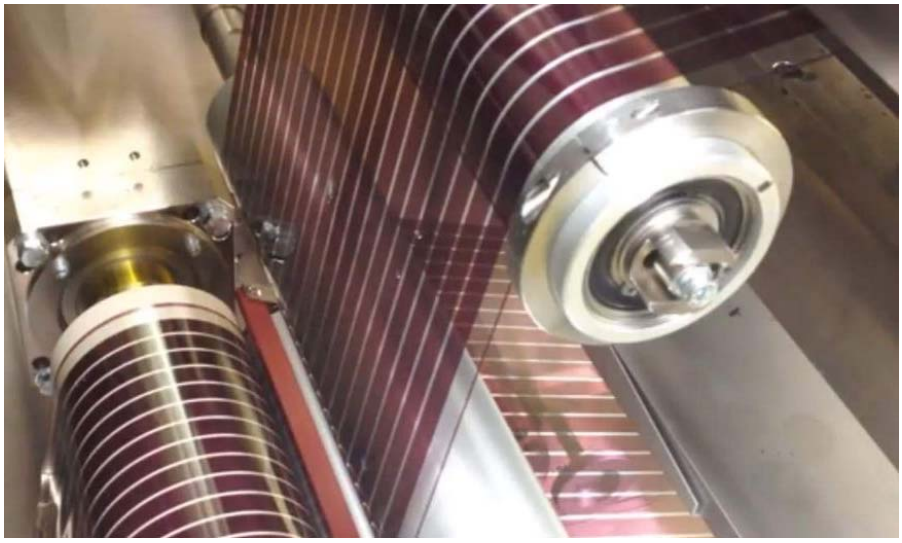
IV. TOTAL ENRTF REQUEST BUDGET: 3 Years

BUDGET ITEM	AMOUNT
Personnel:	
Dr. Tianhong Cui, PI, 1 month summer salary (11% FTE) & 33.5% fringe for 3 years	$ 70,903
Post-Doc, 6 months (50% FTE) plus 21.4% fringe for 3 years	$ 89,074
Graduate Research Assistant, 50% FTE (fall & spring semesters include 15% fringe plus $19.32/hour tuition, summer 15% fringe only) for 3 years	$ 144,562
Equipment/Tools/Supplies:	
Lab Materials & Supplies: fabrication materials & supplies including silicon wafers ($6,000), polymer substrates ($5,000), chemicals ($14,813), roll-to-roll manufacturing set-up items ($16,000), bottles, gloves, other electronics for testing, etc. ($6,000)	$ 47,813
Sceintific Services: User fees at Minnesota Nano Center and Characterization Facility at the University of Minnesota. The cost is about $475 per month for the Post-Doc, and $400 per month for the research assistant for 3 years.	$ 31,500
Travel:	
Travel- Cui Domestic travel year 2 & 3: Mileage, lodging, and meals for travel to and between the solar testing sites and the university based on the university compensation policy	$ 5,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 388,852

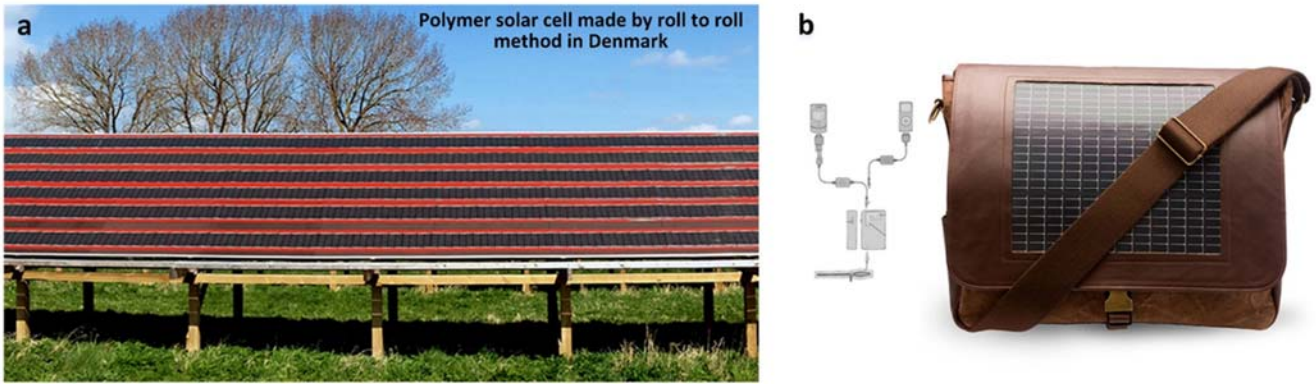
V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period: *N/A*		
Other State $ To Be Applied To Project During Project Period: *The University Overhead*	$ 171,955	*Secured*
In-kind Services To Be Applied To Project During Project Period: *N/A*		
Funding History: *N/A*		
Remaining $ From Current ENRTF Appropriation: *N/A*		

Current Silicon Solar Cell Production Line from CETC (Very Complex and Expensive)



Proposed Roll-to-Roll Processing of Perovskite Solar Cells (Very Simple and Cheap)



Future Applications of Proposed Cheap Solar Cells (Cheap, Clean, and Renewable)
(a) Solar Power Plant, (b) Soar Powered Consumer Electronics

Project Manager Qualifications

Tianhong Cui is currently a Professor of Mechanical Engineering and an Affiliate Senior Member of the graduate faculty in Department of Electrical and Computer Engineering at the University of Minnesota. He joined the faculty of the University of Minnesota in 2003. He was also a visiting professor at University of Freiburg in Germany in 2006. He is an international leading expert on micro devices and advanced manufacturing. He has more than 260 publications and 5 US patents. His research has been sponsored for more than 5 million dollars in the last few years by NSF, DARPA, NASA, DOE, and companies. As an editor-in-chief, he is also responsible for another Nature Journal, Light: Science & Applications, and recently he founded the first engineering journal of Nature Publishing Group titled *Microsystems & Nanoengineering*. He is also serving as an associate editor for *Journal of Nanoscience and Nanotechnology* and *Journal of Nano Research*, and he was a past editor for *IEEE Sensors Journal*.

Organization Description

Professor Tianhong Cui in Mechanical Engineering will serve as PI and project manager. He will be responsible for overseeing the project, all reports, and deliverables. He will supervise one post-doc and one Ph.D. student to work on design, fabrication, and characterization of cheap perovskite solar cells. Professor Cui will hold weekly meetings with his advisees to ensure good progress of this proposed work, in addition to some daily technical discussion with his post-doc and graduate research assistant.

Cheap solar cells including roll-to-roll manufacturing and characterization will be performed at the University of Minnesota in the Technology Integration & Advanced Nano/Microsystems Laboratory (TIAN Lab), located in room ME4128 of the Mechanical Engineering Building, on the Minneapolis campus of the University of Minnesota. Professor Cui is the director of TIAN Lab equipped with the state-of-the-art instrument and facilities to conduct the proposed research, with a variety of fabrication and characterization equipment and tools, sufficient for Professor Cui, his post-doc, and Ph.D. student to design, fabricate, characterize and analyze the proposed solar cells.

The proposed other part of fabrication work will be partially done in Minnesota Nano Center (www.nfc.umn.edu) at the University of Minnesota in a 7000 square foot facility, including 3000 square feet of class 10 clean room. The Lab contains all of the major pieces of processing equipment. Minnesota Nano Center well maintains these systems, keeps safe operating procedures, and trains students. State support, support from NSF through NNIN, and industry usage allows Minnesota Nano Center to offer academic rates that are normally less than half of the actual cost of operation. In 2014, NFC took possession of a second clean room as part of a new Physics and Nanotechnology Building. The new building is across the street from the ECE Building which houses the existing clean room. At 5000 square feet under filter and almost 10,000 square feet gross, it is more than double the existing space. In addition to expanding the suite of clean room tools available, the lab will also operate two new non-clean core labs that support research in nanomaterials and nanotechnology.