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

Project Title: **ENRTF ID: 161-E**

Cheap Efficient Air Filter to Remove Organic Compounds

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

Total Project Budget: $ 386,187

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

Summary:

This project is to develop a new air filter to remove airborne organic compounds, polycyclic aromatic hydrocarbons. The technology is very low-cost and highly efficient to improve Minnesota air quality.

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Sponsoring Organization: U of MN

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Web Address

Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Current Technology and Proposed New Technology

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

_____ Extent of Impact _____ Innovation _____ Scientific/Tech Basis _____ Urgency

_____ Capacity Readiness _____ Leverage _______ TOTAL ______%

PROJECT TITLE: Cheap Efficient Air Filter to Remove Organic Compounds

I. PROJECT STATEMENT

The objective of this project is to develop a cheap efficient air filter to remove airborne polycyclic aromatic hydrocarbons (PAHs). PAHs are a large group of organic compounds. They are highly lipid-soluble and can be absorbed at lung, gut and skin of mammals. Once absorbed, their mutagenic and carcinogenic activity through biotransformation can be fatal to one's health. Every year there are more and more PAHs released to dust from industrial chimneys and vehicles. However, there is no commercial air filters which can efficiently remove PAHs because PAHs are very small organic compounds. This proposed work is a new waste treatment technique which can decompose PAHs very efficiently from the sources. The proposed air filter is based on carbon nanotubes and titanium dioxide composite using advanced manufacturing, and to combine ultraviolet radiation to decompose PAHs, making the dust clean and innocent. Titanium dioxide is a semiconductor with photocatalytic property under UV irradiation. Carbon nanotubes is a material with very large surface area and active catalytic activity as a support of titanium dioxide. The composition of carbon nanotubes and titanium dioxide will provide the air filter with super large surface area to react with PAHs to its best. Currently, the research on PAHs remediation techniques is nearly blank due to their numerous structures and difficulty to decompose. The proposed air filter will fill the research gap, and pave a new way for the development of PAHs remediation instrument. The advanced manufacturing techniques at the University of Minnesota allow us to develop the instrument at very low cost, while ensuring the performance of PAHs remediation filter reliable and efficient. In addition, the air filters can be assembled with chimneys and vehicles to eliminate PAHs contamination in Minnesota from the sources. This project is intended to develop highly efficient PAHs filter, to prove its feasibility, and to provide foundational knowledge of the technique. In the next phase of the research, we will closely collaborate with state agencies, air pollutant researchers, and industry to develop an implementation plan for the air filters in heavy industrial regions and on vehicles in Minnesota.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Development of highly efficient air filters to remove organic compounds* **Budget: $250,907**

The objective of this activity is to develop highly efficient air filters using carbon nanotubes and titanium dioxide. They are very cheap, efficient, accurate, and reliable for PAHs decomposition. Air filters will be designed and fabricated to remove PAHs in airborne dust. The shell for the filters is transparent to allow the ultraviolet light radiation in. The air filter will reduce the concentration of PAHs down to 5% of the original value, while the cost is one tenth of automobile exhaust gas purifier or chimney filters.

Outcomes	**Completion Date**
1. Layer-by-layer self-assembled carbon nanotubes/titanium dioxide nanocomposite; filter hardware developed for continuous decomposition of PAHs in dust; Initial testing results of small size filters in response to PAHs in lab ***[$110,000]***	*6/30/2019*
2. Decomposition efficiency will be tested in comparison with conventional results in lab; Improved filters with optimized design, fabrication, and testing; Filters testing of PAHs decomposition of dust sampled from chimneys and vehicle tailpipes in Minnesota ***[$100,000]***	*6/30/2020*
3. Comprehensive assessment of the techniques will be completed ***[$40,907]***	*6/30/2020*

Activity 2: *Development of standard size filters and field testing on chimneys and vehicles* **Budget: $135,280**

Standard size air filters to be assembled with chimneys or vehicle tailpipes will be designed and constructed. A test site will be set up to demonstrate the feasibility of the filters. Field testing will include picking up an industrial chimney and vehicle tailpipes, testing the efficiency of the reactor in the field. Upon completion of the project, we will demonstrate the filters to the stakeholders and LCCMR committee members and officials.

Outcomes	Completion Date
1. Standard size air filters will be designed and developed ***[$40,000]***	*6/30/2021*
2. Test sites with chimneys and automobile tailpipes will be set up ***[$40,000]***	*6/30/2021*
3. Field testing will be performed with an industrial chimney and decomposition efficiency will be tested ***[$55,280]***	*6/30/2021*

III. PROJECT STRATEGY

A. Project Team/Partners: Tianhong Cui, Distinguished McKnight University Professor in Mechanical Engineering at the University of Minnesota, will serve as PI and project manager. He will be responsible for overseeing the project, all reports, and deliverables. Ms. Li Wang, Professor Cui's research assistant, will work on the design, fabrication, and testing of the air filter. Professor Cui and Ms. Wang will conduct in-lab tests, PAHs concentration analysis and field tests of the proposed filters with chimneys and vehicle tailpipes.

B. Project Impact and Long-Term Strategy

Every year there are 3,200 tons of PAHs generated in USA, and there is a big share in Minnesota, where populated by heavy industries in the Minnesota state. PAHs are well known as carcinogens, mutagens, and teratogens. Minnesota Pollution Control Agency (MPCA) works together with other agencies and advocacy groups in developing strategy to prevent, reduce, or mitigate airborne PAHs contaminants, reducing their impacts on human health and the environment. The most efficient and economic strategy is remove PAHs contamination from the source. However, currently, few PAHs remediation instruments are commercial available as PAHs have numerous structures, and they are very small and difficult to collect. In Year 2013, MPCA has funded a 2-year PAH monitoring study. However, little research about PAHs decomposition instruments has been done. Minnesota State currently provides strong support for air quality improvement. There are increased resources for air borne contaminations. As there is no PAHs decomposition instrument for industrialization yet, the proposed air filter becomes especially important. This proposal will provide low-cost, but high-performance techniques, i.e. unique photocatalytic air filter, for treatment of Minnesota's exhaust air pollutants from industrial chimneys and vehicles. Upon completion, this project will realize economical and high-performance airborne pollutants treatment techniques for continuous decomposition of exhaust gas. The knowledge learned throughout the project will provide a solid foundation for further research and development efforts that would lead to eventual implementation of the novel technique practically enabling broader treatment of Minnesota's air. This will provide a solution to current ineffective PAHs mitigation plight, ultimately help implement the MPCA's clear air strategy, and thus ensure people's safety in Minnesota.

In addition, we will plan to file patents on the proposed air filters for commercialization in the future. We can also use the air filters for PAHs decomposition of pollutants from chimneys, vehicle tailpipes, etc. As a result, the innovative technology can benefit the local residents by purifying the air in 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 will be focused on the air filter development, and Year 3 will be focused on development of standard size air filters and field tests. The results of this study will be disseminated through oral and poster presentations by faculty and research assistant 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 have been aware of this project and may be interested in the results, specifically at the Minnesota Pollution Control Agency and environment protection advocacy groups.

2018 Detailed Project Budget

Project Title: Cheap Efficient Air Filter to Remove Organic Compounds

IV. TOTAL ENRTF REQUEST BUDGET: 3 Years

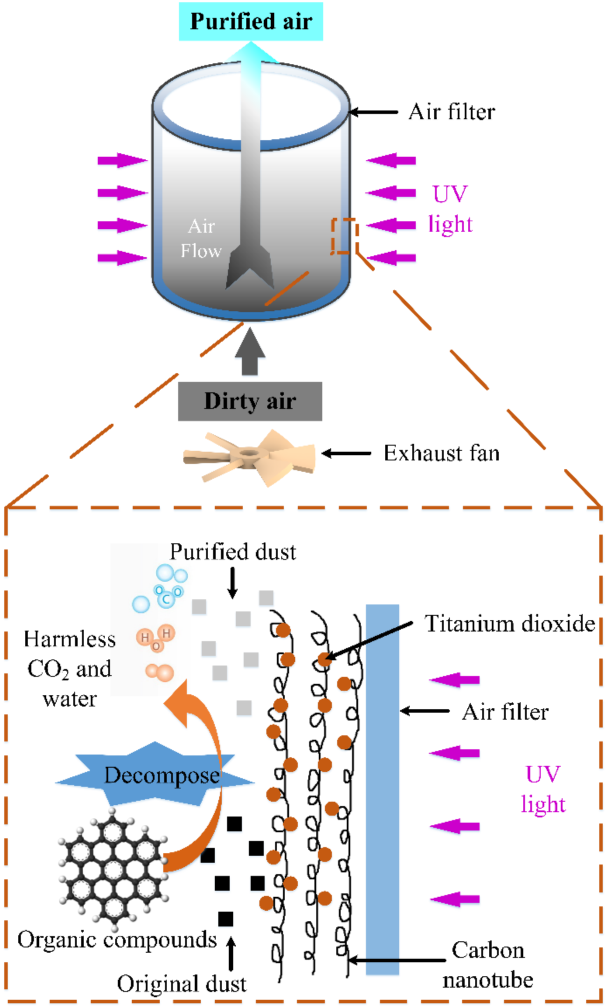
BUDGET ITEM	AMOUNT
Personnel:	
Dr. Tianhong Cui, PI, 2 months summer salary (22% FTE) & 33.5% fringe for 3 years	$ 139,025
One graduate Research Assistants, 50% FTE (fall & spring semesters include 15% fringe plus $19.32/hour tuition, summer 16.6% fringe only) for 3 years	$ 144,562
Equipment/Tools/Supplies:	
Lab Materials & Supplies: fabrication materials & supplies including silicon wafers ($6,000), polymer substrates ($5,000), chemicals ($6,000), manufacturing set-up items ($9,000), bottles, gloves, other electronics for testing, etc. ($7,000)	$ 33,000
Sceintific Services: User fees at Minnesota Nano Center and Characterization Facility at the University of Minnesota. The cost is about $1,750 per month for one research assistants for 3 years.	$ 63,000
Travel:	
Travel- Cui Domestic travels: Mileage, lodging, and meals for travel to and between the water treatment sites and the university based on the university compensation policy	$ 6,600
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 386,187

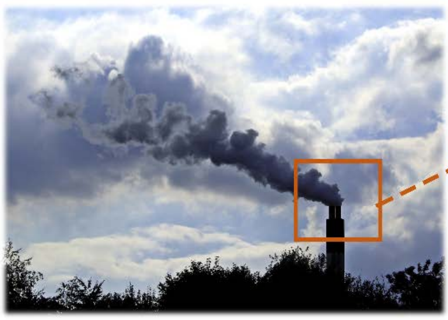
V. OTHER FUNDS

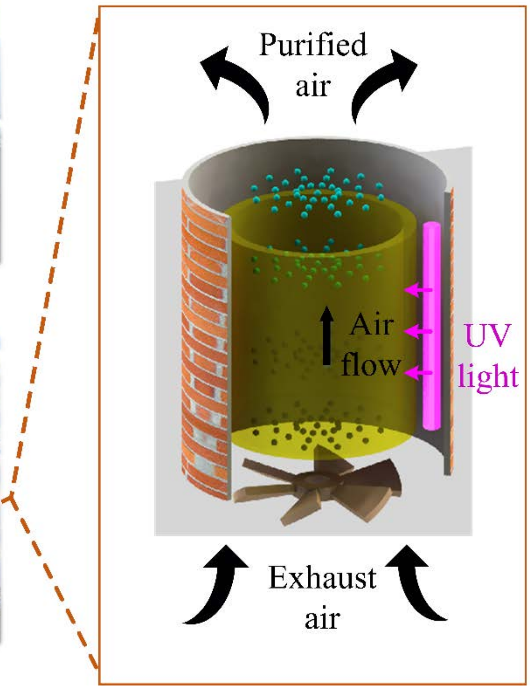
SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period: *N/A*		
Other State $ To Be Applied To Project During Project Period: *The University Overhead*	$ 130,478	*Secured*
In-kind Services To Be Applied To Project During Project Period: *N/A*		
Funding History: *N/A*		
Remaining $ From Current ENRTF Appropriation: *N/A*		

Current Technology

New Technology Proposed







Future applications to airborne organic compounds (*e.g.* PAHs) decomposition in Minnesota

Project Manager Qualifications

Tianhong Cui is currently the Distinguished McKnight University Professor at the University of Minnesota. He is a Professor of Mechanical Engineering and an Affiliate Senior Member of the graduate faculty in Department of Electrical and Computer Engineering. He joined the faculty of the University of Minnesota in 2003. He was also a visiting professor at University of Freiburg in Germany and University of Paris East. He is an international leading expert on micro devices and advanced manufacturing. He has more than 285 publications and 7 US patents. His research has been sponsored for more than 6 million dollars in the last few years by NSF, DARPA, NASA, DOE, and companies. As an editor-in-chief, he is also responsible for a 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 full-time Ph.D. student to work on design, fabrication, and characterization of air filters for polycyclic aromatic hydrocarbons decomposition. Professor Cui will hold weekly meetings with his advisee to ensure good progress of this proposed work, in addition to some daily technical discussion with his graduate research assistant.

Photocatalytic air filter including 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 Ph.D. students 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.