University Transportation Research Center - Region 2

Final Report

Developing Self-cleaning and Air Purifying Transportation Infrastructure Components to Minimize Environmental Impact of Transportation

Performing Organization: Stony Brook University, SUNY

October 2013

Sponsor:
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The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis.

The UTRC was established in order to support research, education and the transfer of technology in the field of transportation. The theme of the Center is "Planning and Managing Regional Transportation Systems in a Changing World." Presently, under the direction of Dr. Camille Kamga, the UTRC represents USDOT Region II, including New York, New Jersey, Puerto Rico and the U.S. Virgin Islands. Functioning as a consortium of twelve major Universities throughout the region, UTRC is located at the CUNY Institute for Transportation Systems at The City College of New York, the lead institution of the consortium. The Center, through its consortium, an Agency-Industry Council and its Director and Staff, supports research, education, and technology transfer under its theme. UTRC's three main goals are:

Research

The research program objectives are (1) to develop a theme based transportation research program that is responsive to the needs of regional transportation organizations and stakeholders, and (2) to conduct that program in cooperation with the partners. The program includes both studies that are identified with research partners of projects targeted to the theme, and targeted, short-term projects. The program develops competitive proposals, which are evaluated to insure the mostresponsive UTRC team conducts the work. The research program is responsive to the UTRC theme: "Planning and Managing Regional Transportation Systems in a Changing World." The complex transportation system of transit and infrastructure, and the rapidly changing environment impacts the nation's largest city and metropolitan area. The New York/New Jersey Metropolitan has over 19 million people, 600,000 businesses and 9 million workers. The Region's intermodal and multimodal systems must serve all customers and stakeholders within the region and globally.Under the current grant, the new research projects and the ongoing research projects concentrate the program efforts on the categories of Transportation Systems Performance and Information Infrastructure to provide needed services to the New Jersey Department of Transportation, New York City Department of Transportation, New York Metropolitan Transportation Council , New York State Department of Transportation, and the New York State Energy and Research Development Authorityand others, all while enhancing the center's theme.

Education and Workforce Development

The modern professional must combine the technical skills of engineering and planning with knowledge of economics, environmental science, management, finance, and law as well as negotiation skills, psychology and sociology. And, she/he must be computer literate, wired to the web, and knowledgeable about advances in information technology. UTRC's education and training efforts provide a multidisciplinary program of course work and experiential learning to train students and provide advanced training or retraining of practitioners to plan and manage regional transportation systems. UTRC must meet the need to educate the undergraduate and graduate student with a foundation of transportation fundamentals that allows for solving complex problems in a world much more dynamic than even a decade ago. Simultaneously, the demand for continuing education is growing – either because of professional license requirements or because the workplace demands it – and provides the opportunity to combine State of Practice education with tailored ways of delivering content.

Technology Transfer

UTRC's Technology Transfer Program goes beyond what might be considered "traditional" technology transfer activities. Its main objectives are (1) to increase the awareness and level of information concerning transportation issues facing Region 2; (2) to improve the knowledge base and approach to problem solving of the region's transportation workforce, from those operating the systems to those at the most senior level of managing the system; and by doing so, to improve the overall professional capability of the transportation workforce; (3) to stimulate discussion and debate concerning the integration of new technologies into our culture, our work and our transportation systems; (4) to provide the more traditional but extremely important job of disseminating research and project reports, studies, analysis and use of tools to the education, research and practicing community both nationally and internationally; and (5) to provide unbiased information and testimony to decision-makers concerning regional transportation issues consistent with the UTRC theme.

UTRC-RF Project No: 49997-10-24

Project Date: October 2013

Project Title: Developing self-cleaning and air purifying transportation infrastructure components to minimize environmental impact of transportation Approaches in the Context of NYC Conditions

Project's Website:
http://www.utrc2.org/research/projects/self-cleaning-and-air-purifying-transportation-infrastructure

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16. Abstract

Creating transportation infrastructure, which can clean up itself and contaminated air surrounding it, can be a groundbreaking approach in addressing environmental challenges of our time. This project has explored a possibility of depositing coatings on the existing materials to address a feasibility of this approach. More specifically, we have quantified the rates of removal of pollutants from the air by a new generation of coatings, which can be applied on any architectural elements and transportation infrastructure. We have also used indicators synthesized in our lab to demonstrate the self-cleaning properties of these now commercially available coatings. In addition, we have worked with the company pioneering this technology in the US and Europe to scope the new application of this technology. The survey of the existing and future commercial projects has indicated that this technology is already leading to very exciting applications in transportation sector, where concrete, asphalt, steel, glass and masonry surfaces will become green and sustainable interfaces mitigating the environmental and health impacts of transportation. The results obtained in this project have a significant relevance to the USDOT goals, such as development of livable communities by providing an access to environmentally sustainable travel options. Moreover, it has also relevance to another DOT goal focused on environmental sustainability, where self-cleaning properties of the coatings have a potential to improve both energy and water conservation.

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Abstract

Creating transportation infrastructure, which can clean up itself and contaminated air surrounding it, can be a groundbreaking approach in addressing environmental challenges of our time. This project has explored a possibility of depositing coatings on the existing materials to address a feasibility of this approach. More specifically, we have quantified the rates of removal of pollutants from the air by a new generation of coatings, which can be applied on any architectural elements and transportation infrastructure. We have also used indicators synthesized in our lab to demonstrate the self-cleaning properties of these now commercially available coatings. In addition, we have worked with the company pioneering this technology in the US and Europe to scope the new application of this technology. The survey of the existing and future commercial projects has indicated that this technology is already leading to very exciting applications in transportation sector, where concrete, asphalt, steel, glass and masonry surfaces will become green and sustainable interfaces mitigating the environmental and health impacts of transportation. The results obtained in this project have a significant relevance to the USDOT goals, such as development of livable communities by providing an access to environmentally sustainable travel options. Moreover, it has also relevance to another DOT goal focused on environmental sustainability, where self-cleaning properties of the coatings have a potential to improve both energy and water conservation.

Introduction

Developing transportation infrastructure without compromising environmental quality is of paramount importance. This can also lead to improvement in the US economic competitiveness, which is intimately linked to modern transportation systems. However, developing such system in a sustainable way is not trivial. In this work we explore a topic of self-cleaning and air purifying structural components, which can save energy via reducing of surface contamination (e.g. soiling), improve environment via decomposition of pollutants emitted from the vehicles and protect human health by decreasing the ozone levels in urban environment. This project looks into inexpensive films, which are currently being studied in collaboration with a small NY based company called PURETi.

The idea of using solar light and special materials, called catalysts (or photocatalysts), is not new. There are already a number of studies, which looked into self-cleaning, air-purifying and antimicrobial properties of such common materials as TiO_2. When deposited on various substrates, TiO_2 can be activated by UV light to achieve the desired effects [1-7]. However, several problems have prevented the full deployment of this exciting idea in the US. One issue is the cost of such coatings. For example, it is possible to buy self-cleaning glass in Europe via company called Pilkington Glass. However, with a price tag of more than 15% higher than that of a regular glass, the growth in sales of this product is relatively modest [4]. Another approach is to mix TiO_2 into cement, an approach utilized by the European company Italcementi. However, given that most of the TiO_2 additives are not activated by light as they reside beneath the surface, such approach proved to be very costly. As a result, there are almost no large scale applications of photocatalysis on the US market.

Promisingly, this status quo is changing thanks to a very exciting work by the NY based company called PURETi. The idea is to use a very inexpensive coating, which can be deposited on almost any building material using spray coating. The active part of the coating is based on light activated nanoparticles, which are encapsulated into inorganic matrix. In order to prevent damage to substrate, given the oxidizing properties of nanoparticles, all the substrates are initially coated with protective inorganic coatings.

In this work we describe several important developments designed to evaluate the PURETi coatings and to assess current/potential large scale applications in the US and worldwide.

Methodology and Findings

We used a self-cleaning and air purifying coating which was developed by our industrial

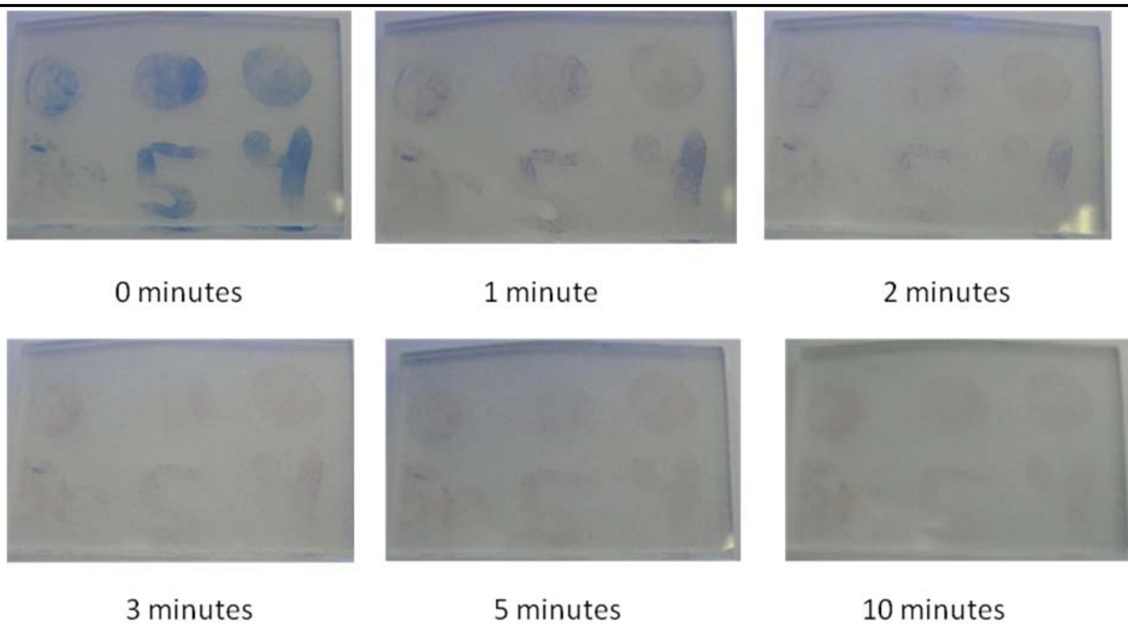

Figure 1. Different ink formulas absorbed into fillable markers which were used to apply the ink onto TiO_2 nanoparticle coated glass. The ink appears to mostly degrade after only two minutes and reach maximum degradation after 5 only minutes.

collaborators (PURETi) to evaluate the self-cleaning properties of this formulation. We used both company treated substrate as well as lab produced coatings. During the first stage of the project we evaluated the self-cleaning properties using an indicator ink. If the coating is active in decomposing contaminated adsorbed in the surface, it should also decompose the indicator ink and therefore give a visual confirmation of the catalytic activity. As mentioned in our proposal, we have also monitored self-cleaning properties using stearic acid; however, our previously employed method was more complicated as it required infrared spectrometer. Figure 1 shows the performance of self-cleaning coating deposited on glass. We found that under the UV light ink disappears within 10 minutes, which is very remarkable. This indicates a very significant promise of the coating for self-cleaning applications. In addition to glass, it can be further extended to concrete, asphalt and other building materials.

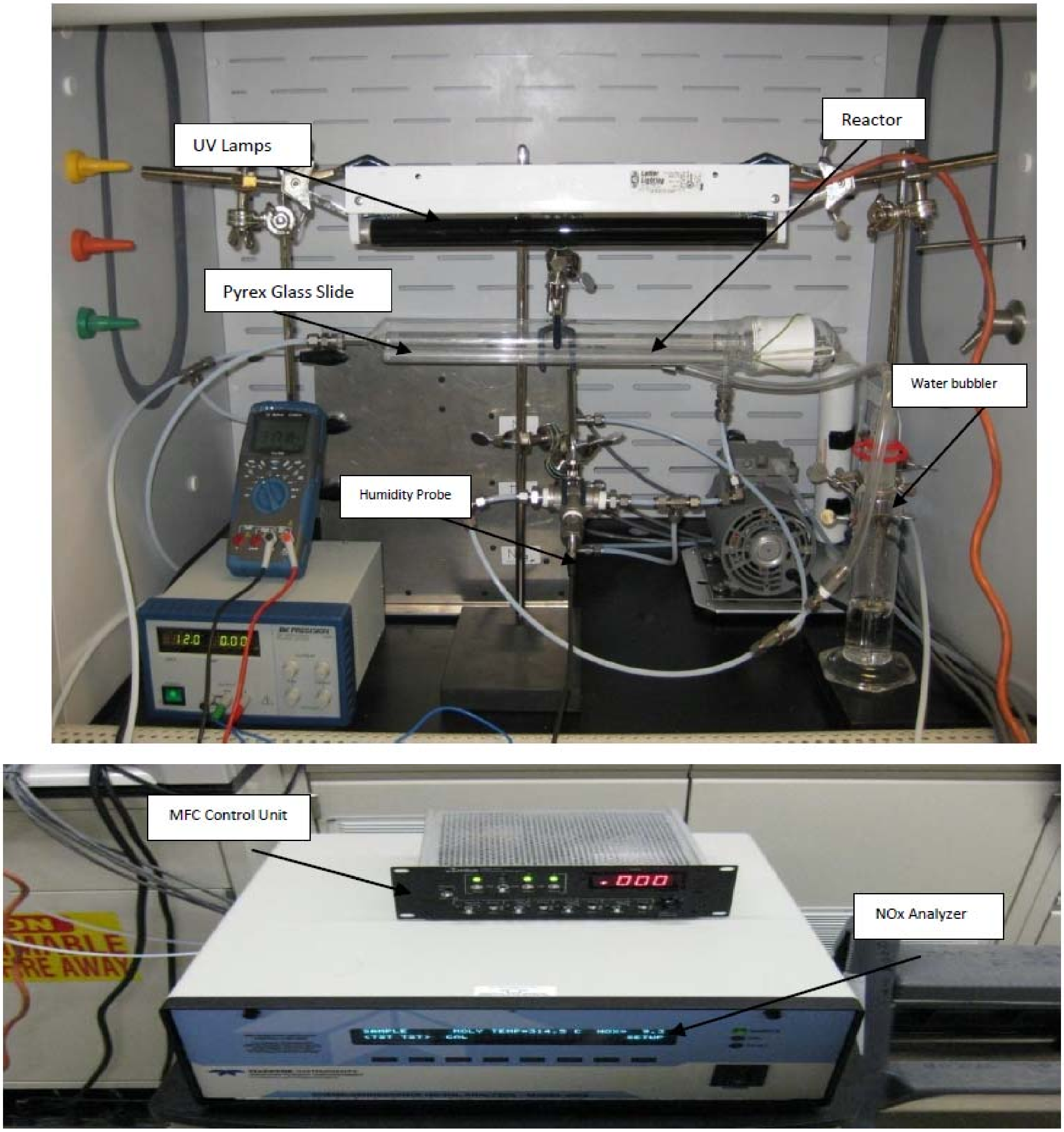

Figure 2. Experimental setup developed in our lab to evaluate the efficiency of coatings for removal of NO2, a priority air pollutant.

In addition we have also evaluated the performance of the coatings for removal of NO_2, a priority pollutant which is present in the environment due to emissions from mobile sources. One of the most prevalent problems with NO_2 emissions is the formation of ground level ozone, which is produced by NOx ($NO+NO_2$) reacting with volatile organic compounds (VOCs) in the presence of sunlight. Vehicle emissions can significantly contribute to both NOx and VOCs concentrations, leading to substantial increase in ozone concentration in the vicinity of transportation hubs. The experimental setup employed for experimental evaluations of the coatings is shown in Figure 2. It consisted of UV lamps, reactor where we place a sample, combination of several mass flow controllers and humidity probe to adjust humidity in the reactor. NO_2 (5 ppm concentration) was delivered from the cylinder and diluted to desired concentration via mass flow controllers. The final concentration (after the reactor) was determined by a photoluminescent analyzer. We allowed the flow of NO_2 to stabilize for 6 hours, with initial concentration reaching approximately 350 ppb, and then we turned on the UV light.

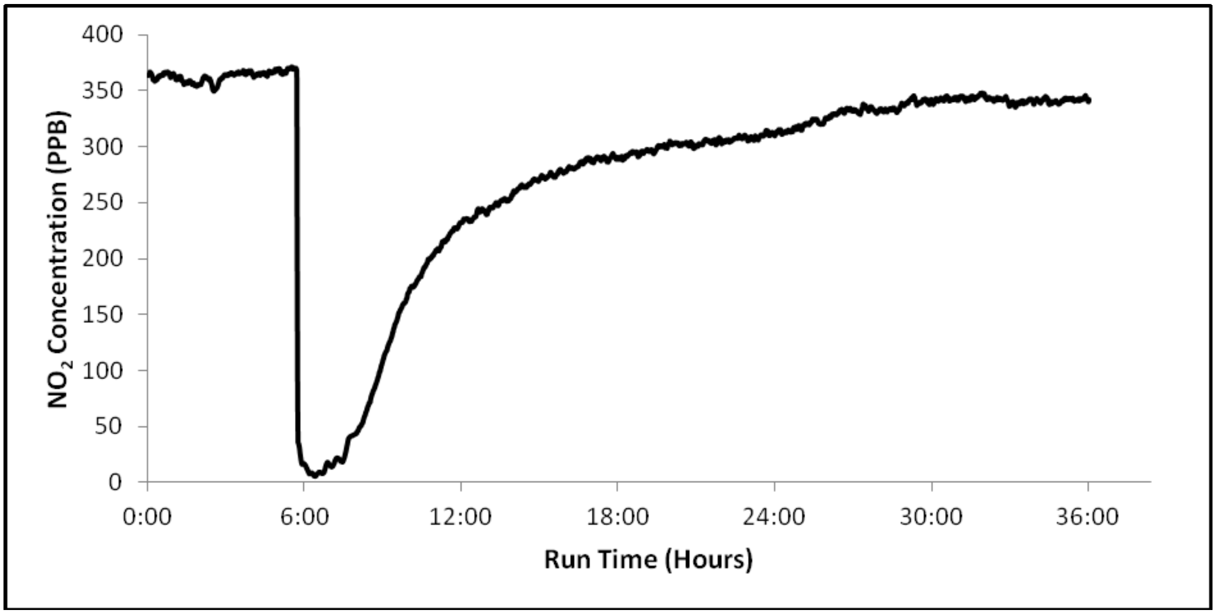

Figure 3. Shows an immediate drop in NO_2 concentration after turning on the UV light, resulting in almost 100% of NO_2 removal.

After activation of coating with light we found a complete elimination of NO_2, reaching almost 100% removal efficiency at the beginning of the experiment (Figure 3). Over time the efficiency of the coating went down, which might be attributed to formation of the intermediate products blocking active site on the surface. However, even after almost 36 hours of operation there was about 10% removal of NO2 as compared to control run. This demonstrates a very significant promise of the coating for air purification applications.

In addition to experimental studies we have also conducted an extensive review of large scale application of photocatalysis. Our survey of the recently completed and future commercial projects (by PURETi) has indicated a very substantial potential of this technology to purify air and clean up urban surfaces. Table 1 shows an impressive range of applications in commercial real estate, hospitality, education and public venue projects in the US and Europe. The largest project was coating of 1 million ft^2 of building exteriors in LA area. Several other projects include coating of 200,000 ft^2 street exteriors in Madrid as well as several other venues. It is also promising to see few NY based projects, which are either already completed or about to be completed or started. Although a long term performance of this coating still needs to be assessed, these current developments need to be noted by the policy makers in the US in terms of future urban planning and construction efforts.

Table 1. Survey of commercial projects for self-cleaning exteriors and interiors

Commercial RE		
Hines - Milano, NYC	2013/4	Building Exterior, IAQ
Johnson Controls, WI, Shanghai	2013/4	Building Exterior, IAQ
Vodafone, Milano	2013	Building Curtain Wall
EJM Proper6es, 835 7th Ave, NYC	2013	Concrete Façade
SL Green, Westchester, NY	2013	Building Façade and Windows
Crown Estate, London	2013	Building Interior, IAQ
Goshow Architects, NYC	2008	Building Interior, IAQ
Education		
SUNY Westchester CC	2013	66,000sf brick facade
UC Merced Science Building	2011	86,000sf façade and windows
Los Angeles Community College	2007/9	1 million sf building exteriors
Hospitality		
Baha Mar, Bahamas	2013	Building Exterior, Guest Room IAQ
Armani Hotel, Milano	2013	Guest Room IAQ
Hilton Hotel, Barcelona	2013	Guest Room IAQ
W Hotel, Barcelona	2013	Building Curtain Wall
Ritz Carlton Hotel, Buckhead, GA	2012	Guest Room IAQ
Resorts Casino Hotel, NJ	2011	Guest Room IAQ
Public Venues		
Campo Nou Stadium, Barcelona	2013	Locker Rooms and Public Facilities, IAQ
San Siro Stadium, Italy	2013	Building Exterior, IAQ
Sun Life Stadium, Miami	2013	Exterior Concrete
British Museum, London	2013	Glass Dome
Streets of Madrid, Spain	2013	200,000sf pollution reversal study

Summary and Conclusions

Experimental studies of a new generation of self-cleaning air purifying coatings have shown a potentially transformative nature of this approach. This study has confirmed that these coatings have indeed exhibited very substantial self-cleaning and air purifying properties. In addition, there is very impressive increase in commercial applications of this approach in both the US (including NY) and Europe. We believe that there is an incredible potential to apply this technology in the US to transform the environment affected by pollution originated from mobile sources.

Future Research, Next Steps

Given our very promising results and based on discussion with the company provided us with the coating materials several avenues of the research need to be pursued. Firstly, we found that performance of the coating goes down with time and this needs to be studied in details. Secondly, the long term stability of the material need to be investigated, including the effects of environmental conditions and mechanical stress on coating integrity. Finally, atmospheric modeling of urban air quality improvements due to application of this method need to be conducted to fully assess environmental impact of this approach.

This report will be shared with the company which was providing us with the samples of their coating and updating us on current developments in this area. We are also exploring the opportunities to apply for a follow-up funding from UTRC to conduct a more comprehensive work in this area.

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