International Association of Chinese Infrastructure Professionals

IACIP

CASE WESTERN RESERVE UNIVERSITY EST. 1826

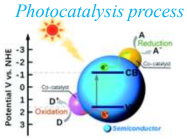
Analyses of the Performance of Novel Wide Band Photocatalyst for Improving Highway Environment

Ojo Samuel Tosin, Graduate Research Assistant, Case Western Reserve University, sto25@case.edu
Zhuoying, Jiang. Graduate Research Assistant, Case Western Reserve University.
Xiong (Bill) Yu, Professor, Case Western Reserve University.

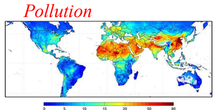
INTRODUCTION

- Modernization, lead to increase in vehicle emission of pollutant which have become global concern.
- Regional air quality and residents' health are been impaired by the exhaust gas released from motor vehicles.
- Exhaust gas include different air pollutant which are carbon monoxide, nitrogen oxides, sulfur dioxide, hydrocarbon and particulate matters.
- Aside the methods of reducing emissions through designing of new vehicles, self cleaning pavement is an alternative
- Mixing of Nano sized titanium dioxide have been adopted for the self cleaning of the pavement.
- However, titanium dioxide requires higher activation energy for it photodegradation process of reducing the pollutant.
- Solar light can used to generate clean and higher energy however it only have 6% of UV light and 52% of visible light, which is not useful for titanium dioxide.

Photocatalysis process



NASA Maps Global Air Pollution



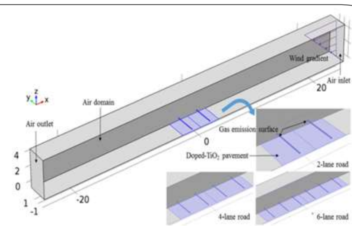
Polluted Human Environment

OBJECTIVES

- To analyze the kinetic of nitrogen dioxide removal by doped-TiO_2 with visible solar light driven photocatalytic pavement.
- To evaluate the performance of doped –TiO_2 with regular TiO_2 under the same condition.
- To evaluate the effect of the traffic flow on the performance of the photocatalyst.

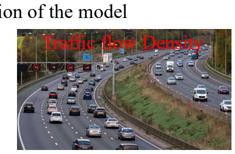
METHODOLOGY

Simulation Model



Numerical Simulation

The configuration of the model



- Traffic flow densities
  - ✓ Free: 5 numbers of cars per mile
  - ✓ Stable: 20 numbers of cars per mile
  - ✓ Optimum: 40 numbers of cars per mile
- Photocatalyst dosage
  - ✓ Case 1: TiO2 at 50 (g/m^2)
  - ✓ Case 2: Doped-TiO_2 at 1.0 (g/m^2)
  - ✓ Case 3: Doped-TiO_2 at 10 (g/m^2)
  - ✓ Case 4: Doped-TiO_2 at 25 (g/m^2)
  - ✓ Case 5: Doped-TiO_2 at 50 (g/m^2)
  - ✓ Case 6: Doped-TiO_2 at 100 (g/m^2)
- Wind Speed
  - ✓ Wind Velocity of 0.5 m/s
  - ✓ Wind Velocity of 2 m/s
  - ✓ Wind Velocity of 5 m/s
- Lane type
  - ✓ 2 lanes road
  - ✓ 4 lanes road
  - ✓ 6 lanes road

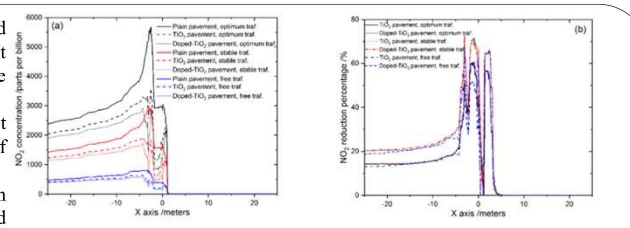
6 lanes road

2 lanes road

4 lanes road

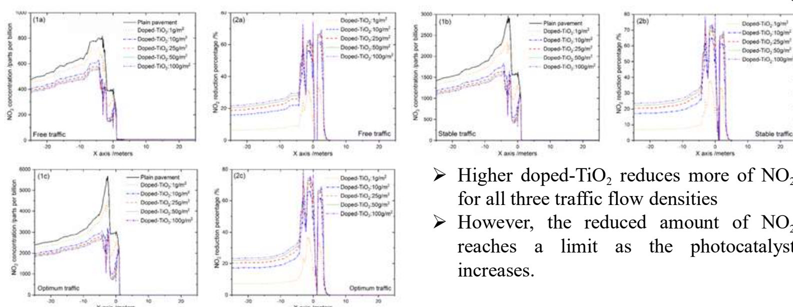
TRAFFIC FLOW RESULT AND ANALYSES

- Doped-TiO2 embedded photocatalytic pavement is efficient and effective to remove NO_2
- Traffic conditions do not affect the percentage of NO2 removal.
- About 70% of NO_2 can be reduced on the road and 20% near the road of distance 25m of can reduced



Reduction of NO_2 pollutant near 2-lane roads with different traffic flow densities. Pure TiO_2 or doped-TiO_2 coverage is 25 g/m2. Wind speed is calm. (a) NO_2 concentration, and (b) NO_2 reduced percentage

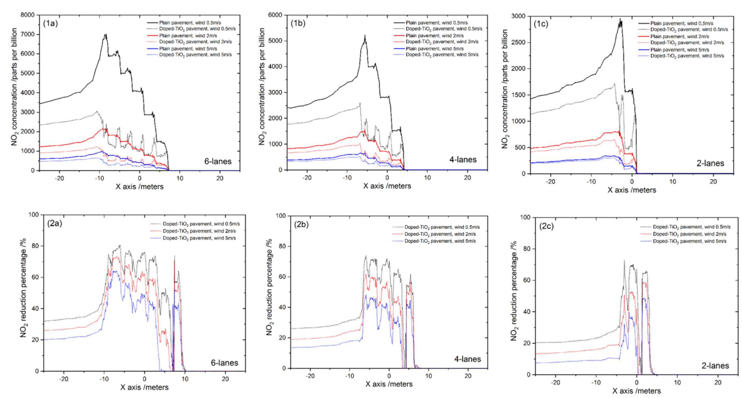
PHOTOCATALYST DOSAGE RESULT AND ANALYSES



- Higher doped-TiO_2 reduces more of NO_2 for all three traffic flow densities
- However, the reduced amount of NO_2 reaches a limit as the photocatalyst increases.

NO2 concentration change (1a, 1b, 1c) and NO2 reduced percentage (2a, 2b, 2c) near 2-lane roads with different doped-TiO2 coverages. The wind speed is calm. (1a) and (2a) for the free traffic flow condition, (1b) and (2b) for stable traffic flow condition, and (1c) and (2c) for the optimum traffic flow condition

LANE TYPE RESULT AND ANALYSES



NO2 concentration with increased lane and the percentage reduction efficiency of pure TiO2 and doped TiO2.

- The increase in the number of lane increased the concentration of NO2 quantities release (as much as 7ppm on the 6-lane road, which is about twice the quantities release NO2 in a 2-lane road).
- Photocatalytic pavement achieved higher percentage of NO_2 exhaustive gas reduction with increasing number of lanes.

CONCLUSIONS

- Novel wideband visible light driven photocatalysts is proposed to improve the photocatalytic efficiency for road applications.
- Results by holistic simulation model shows that the doped-TiO2 embedded pavement is efficient and effective to remove NO2 under different traffic densities.
- The visible light driven photocatalytic pavement successfully reduced the NO2 pollutant between 30% and 80% on the road and between 3% and 30% in the surrounding areas.
- The wind speed affects the efficiency of NO2 removal by photocatalysts.

Low Carbon Technologies and Resilience for Long-Lasting Infrastructure

The 13th Annual Workshop of the International Association of Chinese Infrastructure Professionals (IACIP)

January 2022