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Mock-up Test for NOx Reduction by Photocatalyst Paint for Indoor Use

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Abstract. In this study, the photocatalyst TiO_2 was mixed with a general paint and applied on indoor walls as part of a mock-up test to measure the reduction in the NOx concentration affected by the on or off state of a UV lamp. The findings may be summarized as follows; the NOx concentration was reduced by approximately 7% more (0.134 ppm) with the UV lamp on than when the lamp was off in the indoor space where the paint mixed with TiO_2 was applied.

1 Introduction

In recent years, particulate matter (PM10) have received much public attention due to their effects on health. Particularly, in Korea, the level of particulate matter is relatively higher than that in other major OECD countries. With many people currently spending more than 90% of their time indoors, particulate matter have ultimately become a health threat to indoor residents. To explore one of the methods of reducing particulate matter, a mock-up test was conducted in this study, to examine the performance of TiO_2-mixed paint for indoor use in reducing NOx, one of the main precursors to particulate matter. This study will prove its usefulness, as a basic study on the reduction of particulate matter, in the future.

2 Properties of Photocatalysts

2.1. Material Properties of Photocatalysts

A photocatalyst is a material that generates a certain reaction in response to light, enabling a chemical reaction induced only by light. In general, photocatalysts are used in semiconductors. Some of the most well-known photocatalysts include zinc oxide, cadmium oxide, tungsten oxide, and titanium oxide. The classification in accordance with the material properties of photocatalysts is shown in Table 1 below:

Table 1. Classification physical property of photocatalyst

Representative properties	Contents
Crystallization type	Rutile, Anatase, and Brookite exist, and Rutile is the most stable
Stability	Very stable material that does not dissolve in acid, alkali, water, and organic solvents under normal temperature and pressure conditions
Representative application	Generally used in toothpaste and cosmetics

2.2. Characteristics of TiO_2 as Photocatalyst

Of the four types, the photocatalyst that is used most widely is TiO_2, due to its air-purifying, antibacterial, deodorizing, and other such features. Specifically, the photocatalyst may be utilized as shown in Table 2:

Table 2. Characteristics of titanium dioxide photocatalyst

Characteristic	Contents	Representative utilization
Antifouling	Degradation and removal of pollutants by superhydrophilic action	Automotive coating
Air Cleaning	Removal of nitrogen oxides and sulfur oxides in air	Air-purification artificial plants, Building wall coating
Antibacterial	Oxidation of organics by OH radicals	Air-conditioner filter
Deodorization	Removal of VOCs and odors	Clothes-deodorizing device
Water Purification	Wastewater treatment	Factory wastewater and sewage treatment facility

Air purification of TiO2 photocatalysts is done through oxidation reactions, and oxidation reactions to NOx used in this experiment are shown in Table 3.

Table 3. Photocatalytic oxidation mechanism of nitrogen oxides

Activation	$TiO_2 + hv^* \rightarrow h^+ + e^-$
Absorption	$H_2O(g)+Site^{**} \rightarrow H_2O_{ads}$, $O_2(g) + Site^{**} \rightarrow O_{2ads}$ $NO(g)+Site^{**} \rightarrow NO_{ads}$, $NO_2(g)+Site^{**} \rightarrow NO_{2ads}$
Hole trapping	$H_2O + h^+ \rightarrow \cdot OH+H^+$
Electron trapping	$O_2+e^- \rightarrow O_2$-
Hydroxyl attack	$NO_{ads}+2 \cdot OH \rightarrow NO_{2ads}+H_2O$ $NO_{2ads}+ \cdot OH \rightarrow HNO_3$
Superoxide attack	$NO+O_2^- \rightarrow NO_3^-$

* hv : (UV), **Site : Surface of TiO_2

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3 Mock-Up Test

3.1. Introduction

For the purpose of the study, TiO_2 – known for its air-purifying property – was mixed with a general paint and applied on the walls inside a mock-up test room (2,675 × 2,750 × 2,860). To confirm the air-purifying effects of TiO_2, a UV lamp was used, since light energy is not as readily available in indoor spaces as in outdoor spaces. After the TiO_2-mixed paint was applied on the walls, NOx, one of the major precursors to particulate matter, was injected, in the form of a gas, into the room until a certain level of concentration (2 ppm) was attained. Thereafter, the changes in the concentration were measured with the UV lamp turned on and off. The indoor temperature was set at 25 °C. The details are shown in Fig. 1 and Table 3.

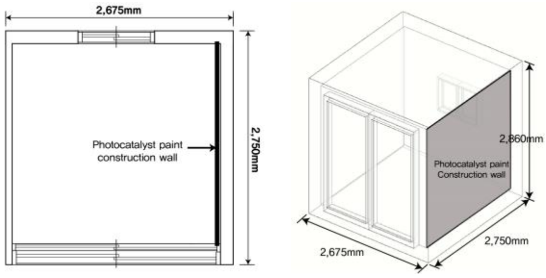

Fig. 1. Mock-Up Test Plan & 3D Picture

Table 3. Mock-Up Test Summary

Classification	Contents
Test Gas	NO gas
UV Lamp	UV-A BLB lamp, 0.505 mW/cm^2
Number of Experiments	UV ON-OFF 3 times, total 6 times
Measurement Interval	1 min
Measurement Instrument	Chemiluminescence instrument
Measurement Time	3 hours after attaining 2 ppm concentration in test room

3.2. Mock-Up Test Result

Considering the margin of error, three tests were conducted to use the average value. Fig. 2 shows the NOx concentration rising to 2 ppm after the precursor was introduced into the closed mock-up test room painted with TiO_2-mixed paint.

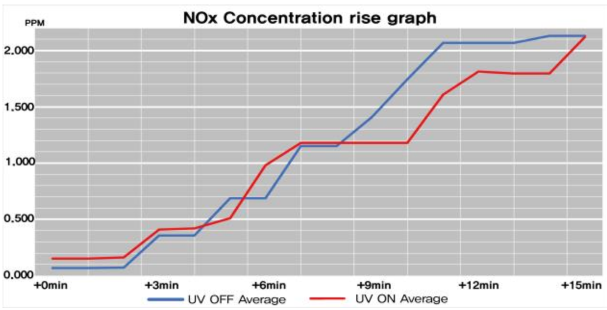

Fig. 2. NOx Concentration Rise Graph

When the NOx concentration reached 2 ppm in the closed room painted with TiO_2-mixed paint, the introduction of NOx was stopped. Fig. 3 and Table 4 show the reduction in the NOx concentration three hours after turning the UV lamp on/off. The values indicated on the graph are the averages taken from three tests, each conducted with the UV lamp on/off.

Table 4. Mock-Up Test Result

Classification	UV OFF	UV ON	Concentration difference
Start Concentration	2.028 ppm	2.038 ppm	+0.01 ppm
End Concentration	0.959 ppm	0.825 ppm	-0.134 ppm

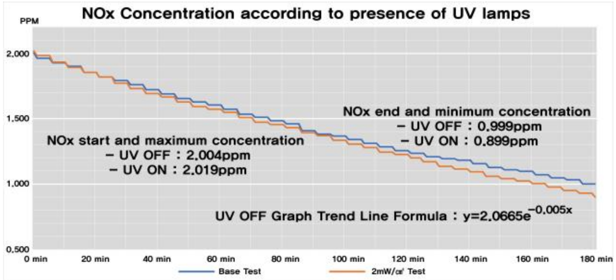

Fig. 3. NOx Concentration According to Status of UV Lamp

It was found that in the closed room where TiO_2-mixed paint was applied on the walls, the NOx concentration was approximately 7% (0.134 ppm) lower with the UV lamp on than with the lamp off.

4 Conclusions

The findings of this study can be summarized as follows; In the mock-up test on an internal space where TiO_2 with air-purifying property was mixed with a general paint and painted on the wall, the reduction in the NOx concentration was measured to compare the on and off states of a UV lamp. It was found that in the indoor space where TiO_2-mixed paint was used, the NOx concentration was approximately 7% (0.134 ppm) lower with the UV lamp on than with the lamp off.

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