

# Development of a wall covering for indoor air purification: Design, characterization and photocatalytic efficiency assessment

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## Introduction

Air quality topic has been discussed for many years, focusing in most cases on the outdoor air, which is constantly deteriorated by many reasons for example car exhaust gases, factories and many more. A topic which is not that much discussed, but has the same or even deeper direct influence on our lives, is indoor air quality (IAQ). One of the reasons why the IAQ has such an influence is simply because people spend most of the time in indoor environment, e.g. home, car, public transport, office, hospital or public places such as library or museum. Most of things that people collect indoors can emit harmful substances into the environment and affect the comfort, health and productivity of human beings. Moreover, there are many other sources such as smoking, combustion, cleaning agents and outdoor sources /1; 2/.

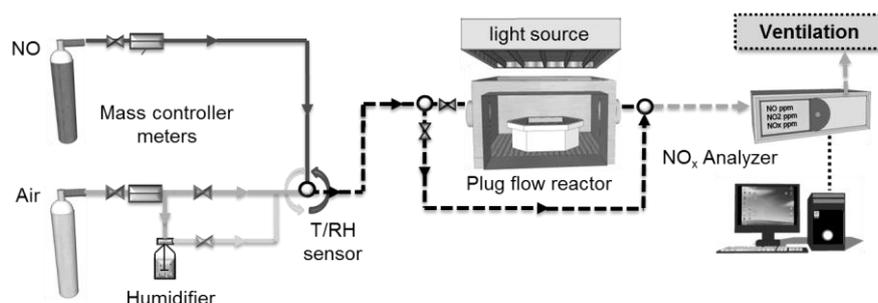
The current research is focused on the improvement of the IAQ by utilizing photocatalytic oxidation applying a wall covering material. The aim is to incorporate a nano-sized carbon-doped titanium dioxide (C-TiO<sub>2</sub>), visible light responsive photocatalyst, into a commercially used waterborne protective top-coating, designed for a wall covering.

## Materials & Methods

The photocatalysts were C-TiO<sub>2</sub> in the powder and waterbased slurry (40% of C-TiO<sub>2</sub>) form (Kronos International). The protective top-coating was a waterborne acrylic type (BN International). The carrier was a wall covering substrate, consisting of a paper coated with PVC. The glass substrate was used only in case of the C-TiO<sub>2</sub> slurry and only for a pre-conditioning investigation.

The C-TiO<sub>2</sub> powder was firstly pre-dispersed in water by a high-energy mixer and then mixed-in with the top-coating. The C-TiO<sub>2</sub> slurry was mixed in with the top-coating as received. The coatings were then

applied on a wall covering carrier with the size of 100 mm x 200 mm (width x length) by using a drawdown technique. A coating rod with a steel wire producing coatings with a wet thickness of 8  $\mu\text{m}$  was used. The drying under ambient conditions or curing under infrared irradiation was performed. The morphology of the coatings was investigated with the scanning electron microscope. The photocatalytic efficiency was evaluated via a plug-flow experimental set-up (see **Fig. 1**). Nitric oxide was used as a model pollutant. The experimental conditions were fully controlled and in agreement with ISO 22197-1:2007 with the exception of applied visible light source /3/.



**Fig. 1:** Experimental set-up scheme

### WP coating design

Several coating designs were made with a C-TiO<sub>2</sub> powder and waterborne top-coating (designated **WPXX**). The dosage of the photocatalyst varied from 5 to 20% by weight of the top-coating. Reference samples were made on a wall covering with waterborne acrylic top-coating (designated **WPRX**).

### KC coating design

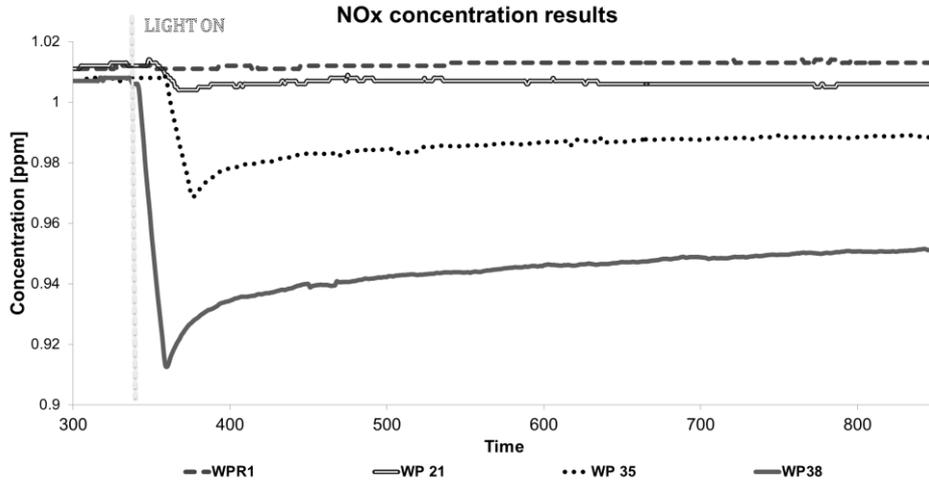
The pre-conditioning of the C-TiO<sub>2</sub> slurry was investigated on a glass carrier. Two sets of coatings were made then using the C-TiO<sub>2</sub> slurry on the wall covering (designated **KCX**). The pure C-TiO<sub>2</sub> slurry and a mixture of C-TiO<sub>2</sub> slurry with the waterborne top-coat were prepared. All designs were made in duplicate in order to evaluate the drying (laboratory) and curing (infrared) effect.

## Results

### WP coating design

The results showed that the addition of the C-TiO<sub>2</sub> powder into the waterborne coating changes the transparency significantly, due to the micron-sized agglomerates of the photocatalyst. **Fig. 2** shows some selected results of the de-NO<sub>x</sub> efficiency (WPR1-reference; WP21-5% C-TiO<sub>2</sub>; WP35-10% C-TiO<sub>2</sub>; WP38-20% C-TiO<sub>2</sub>). As can be seen, relatively low PCO efficiencies were observed. A dosage of 20% of C-

TiO<sub>2</sub> leads to the NO<sub>x</sub> reduction of only 6%. The photocatalyst was after incorporation rather easily removed from the coating by rubbing.



**Fig. 2:** WPC de-NO<sub>x</sub> results

**KC coating design**

The experiments of the NO<sub>x</sub> degradation of the pure C-TiO<sub>2</sub> slurry applied on a glass carrier revealed a necessity for a pre-conditioning phase in order to promote the PCO efficiency of the coating. The pre-conditioning was performed by an ultraviolet irradiation for a period of time.

The de-NO<sub>x</sub> experiments performed on a wall covering coated with the pure C-TiO<sub>2</sub> slurry and with the C-TiO<sub>2</sub> slurry mixed with a waterborne top-coating showed positive results.

A NO<sub>x</sub> degradation efficiency of 12 and 16% was observed for samples coated by C-TiO<sub>2</sub> slurry and dried under laboratory conditions (lab) or cured by infrared irradiation (IR), respectively.

**Table 1:** KC de-NO<sub>x</sub> results

	C	NO	NO <sub>2</sub>	NO <sub>x</sub>		C	NO	NO <sub>2</sub>	NO <sub>x</sub>
<b>KC1</b> (lab)	C initial [ppm]	1.01	0.01	1.01	<b>KC2</b> (IR)	C initial [ppm]	1.01	0.00	1.01
	C final [ppm]	0.73	0.16	0.89		C final [ppm]	0.68	0.16	0.85
	%degradation	27.72	-	<b>11.88</b>		%degradation	32.67	-	<b>15.84</b>
<b>KC3</b> (lab)	C initial [ppm]	1.01	0.00	1.01	<b>KC4</b> (IR)	C initial [ppm]	1.01	0.00	1.01
	C final [ppm]	0.99	0.01	1.01		C final [ppm]	0.82	0.06	0.88
	%degradation	1.98	-	-		%degradation	18.81	-	<b>12.87</b>

A NO<sub>x</sub> degradation efficiency of 0 or 13% was observed for samples coated by mixture of C-TiO<sub>2</sub> slurry and waterborne top-coating and dried under laboratory conditions (lab) or cured by infrared irradiation (IR), respectively. The irradiation treatment had more profound effect on the PCO efficiency of the coating than in the case of applied pure C-TiO<sub>2</sub> slurry.

The as-prepared coatings were transparent (due to the nano-scale of the particles) with a pale brownish colour. The morphology analysis revealed a formation of micro-cracks, possibly due to the heat treatment or an uneven thickness of the coating which was observed in case of applied pure C-TiO<sub>2</sub> slurry. This will be a subject for the further investigation. In the terms of durability, the coating seems to be enhanced comparing to the ones prepared with C-TiO<sub>2</sub> powder.

## Conclusion

This article presents the preparation, treatment, morphology and assessment of a photocatalytic coating.

The experimental results showed that the addition of the powder C-TiO<sub>2</sub> strongly affects the transparency of the coating. On the other hand, the PCO efficiency and durability is low, considering the photocatalyst dosage. This could be avoided by breaking-up the agglomerates into nano-scale fractions prior to the application.

The application of C-TiO<sub>2</sub> slurry proved to be efficient only after a pre-conditioning phase which is necessary for exposing the photocatalyst to the environment. The infrared curing treatment of the samples prepared with a mixture of C-TiO<sub>2</sub> slurry and waterborne top-coating seems to be beneficial for the promotion of the PCO activity.

## Bibliographical references

- /1/ O. Geiss, G. Giannopoulos, S. Tirendi, J. Barrero-Moreno, B.R. Larsen, D. Kotzias: "The AIRMEX study - VOC measurements in public buildings and schools/kindergartens in eleven European cities: Statistical analysis of the data" Atmospheric Environment vol. 45, 3676-3684
- /2/ Ch.J. Weschler: "Changes in indoor pollutants since the 1950s" Atmospheric Environment vol. 43, 153-169
- /3/ Q.L. Yu, H.J.H. Brouwers "Indoor air purification using heterogeneous photocatalytic oxidation. Part I.: Experimental study" Applied Catalysis B: Environmental 92, 454-461