Visible Light TiO_2 Photocatalysts Assessment for the Indoor Air Decontamination

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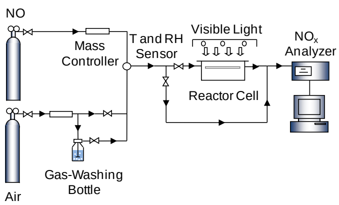

Different commercial, visible light response, TiO_2 powders are studied in order to assess their application in indoor air decontamination. To do that the TiO_2 powders were immobilized on borosilicate glass plates according to a dip coating method. Then, the photocatalytic performance of these plates under visible light was evaluated in a continuous gas flat plate photoreactor using nitrogen oxide gas (NO) as the pollutant. The photocatalytic NO_x degradation by immobilized TiO_2 powders was related with their optical properties, finding a clear correlation between them.
These results are useful to decide which TiO_2 will be more efficient in a full scale air decontamination process under indoor conditions.

Indoor air quality has received much attention because of the very important role indoor environment plays on human health. Nitrogen oxides (NO and NO_2), sulfur dioxide (SO_2) and volatile organic compounds (VOCs), as typical inorganic and organic indoor air pollutants, can be emitted from cooking, combustion, exhaust gases, tobacco smoke, furniture, building materials, and even traffic pollutants from outside of the building and can cause serious health problems like drowsiness, headache, sore throat, and mental fatigue. The US Environmental Protection Agency pointed out that indoor air pollution poses greater risk than outdoor air pollution due to the fact that people spend more time in indoor environments. So, it is of vital importance to remove these pollutants in order to improve the indoor air quality for people's health. In addition, some studies have shown that when certain contaminants were removed from a working places, the performance of some office tasks improved.

Heterogeneous photocatalysis represents an emerging environmental control option for the efficient removal of chemical pollutants and it can be applied to water and air purification. However, normal TiO_2 can only be activated by UV radiation (280-400 nm) that represents 4% of the total energy of the sun; meanwhile the visible light constitutes 45% of the solar radiation. On the other hand, the UV radiation amounts to only 0.001-0.05 W/m^2 in indoor lighting [1]. To extend the use of photocatalysis to visible light region, it is necessary to prolong TiO_2 radiation absorption to wavelengths corresponding to visible spectrum (400-700 nm). So far, several modification methods of photocatalyst to amplify its absorption spectrum to visible radiation have been investigated and therefore, the applicability of heterogeneous photocatalysis has been extended [2,3]. Even several commercial types of modified TiO_2 can be already found in the market for indoor visible light applications.

In the present work, different visible light TiO_2 commercially available, one doped with carbon and the other one doped with nitrogen, are studied. The main objective of this work is to determine which photocatalyst will present the best pollution abating ability in a full scale application under real indoor conditions.

The immobilization of the TiO_2 powders was carried out over borosilicate glass plates by a dip coating procedure employing a coating suspension of 75 g L^{-1} of TiO_2 powder in deionised water. Every coating cycle, the glass pieces were dried at 110ºC for 24 hours and calcined at 500ºC for 2 hours. This procedure was performed four times for each TiO_2 powder.

The experimental setup to assess the photocatalytic performance is described in the Graphical Illustration. This consists of a continuous flat photoreactor where the glass pieces with the immobilized TiO_2 are placed inside of it. The photoreactor is fed by NO gas stabilized in air and irradiated with fluorescence visible light lamps. The outlet contaminant concentration from the reactor is analyzed with a chemiluminesence NO_x analyzer. Table 1 shows the main characteristics, dimensions and operating conditions of the employed test setup to execute the NO_x degradation experiments.

The optical properties of the immobilized TiO_2

in the glass plates were determined as a function of wavelength between 300 and 600 nm in an Optronic OL Series 750 spectroradiometer equipped with an OL 740-70 integrating sphere reflectance attachment. To evaluate the fraction of energy absorbed (A) by the coated glass with TiO_2, the spectral diffusive reflectance (R) and the spectral diffusive transmittance (T) were experimentally determined. The mathematical expression between the absorbed fraction, transmittance and reflectance is given by [4]:

$$1 = A + T + R$$

Table 1. Experimental setup characteristics and operating conditions.

Reactor	Length	2 dm
	Width	1 dm
	Height	0.03 dm
	Volume	0.06 dm^3
Photocat. Samples	Length	2 dm
	Width	1 dm
Visible Lamps: Philips Master TLD 865 x 3	Input Power	18 W
	Emission Wavelength	380-720 nm
Flow Rate		3 L min^{-1}
Relative Humidity		50%
Irradiance Flux		10 W m^{-2}
NO Inlet Concentration		1 ppm
NO_2 Inlet Concentration		0 ppm

Figure 1 shows the conversion results of total NO_x by the carbon and nitrogen doped TiO_2. Clearly, the carbon doped TiO_2 has shown a better photocatatlytic performance for the NO_x degradation than the nitrogen doped TiO_2 powder. Meanwhile the total NO_x conversion by the TiO_2 - C is about 18%, the TiO_2 - N presents only 6% of NO_x degradation.

Figure 2 shows the spectral fraction of energy absorbed by both immobilized TiO_2 powders calculated from the experimentally determined diffuse reflectance and transmittance of the coated glass plates. In addition, the spectral emission distribution (E_λ/E_{total}) of the employed lamps in the reacting experimental setup is shown in this figure. Despite that these lamps do not emit radiation in the UV region, where the TiO_2 presents a significant light absorption, the energy emitted in the visible light range is enough to activate this kind of modified photocatalysts.

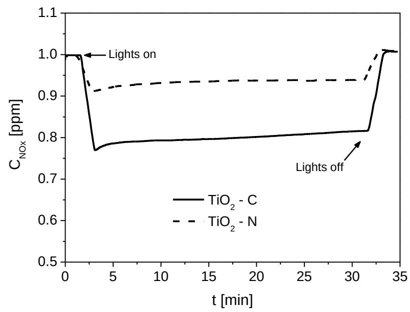

Figure 1. NO_x outlet concentration evolution for the carbon and nitrogen doped TiO_2.

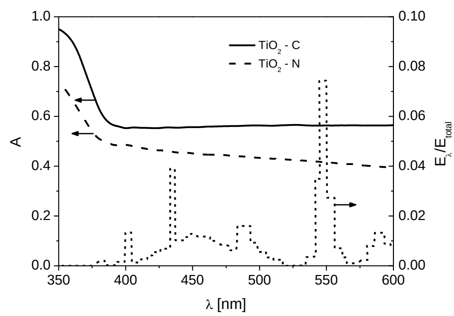

Figure 2. Spectral fraction of energy absorbed by the immobilized carbon and nitrogen doped TiO_2; and the spectral emission distribution of the visible light lamps employed in the photoreactor.

A correlation between the obtained results for the photocatalytic performance and the fraction of energy absorbed by the immobilized TiO_2 powders can be observed. At the same time that the TiO_2 - C absorbs about 20% more energy than TiO_2 - N, it can convert 66% more NO_x. However, it is worth to mention that other photocatalyst characteristics can influence in its performance, for instance the specific surface.

Indeed, the carbon modified photocatalyst promises a better performance for a real application of indoor purification.

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References

[1] C.S.Kuo, Y.H. Tseng, C. Huang, Y. Li, *J. Mol. Catal. A: Chem,.* 270 (2007) 93.
[2] H. Kisch, W. Macyk, *Chemphyschem*, 3 (2002) 399.
[3] D. Chatterjee, S. Dasgupta, *J. Photochem. Photobiol. C: Photochem. Rev.*, 6 (2005) 186.
[4] *Thermal Radiation Heat Transfer.* R. Siegel, J. Howell, New York, Taylor and Francis, 2002.