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Degradation of NO using photocatalytic coatings applied to different substrates

Thomas Martinez [a,b], Alexandra Bertron [a,*], Erick Ringot [a,b], Gilles Escadeillas [a]

[a] Université de Toulouse, UPS, INSA, LMDC (Laboratoire Matériaux et Durabilité des Constructions) 135, avenue de Rangueil, F-31 077 Toulouse Cedex 04, France
[b] LRVision SARL, Zi de Vic, 13 rue du Développement, 31320 Castanet-Tolosan, France

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ABSTRACT

This article deals with the degradation of NO present in the air by means of a photocatalytic oxidation process based on TiO_2 nanoparticles incorporated in a polymer-matrix-based coating. The experimental set-up consisted of a flow type reactor adapted from the ISO 22197-1 standard. NO_2 in the gas phase, and nitrate ions adsorbed on the photocatalytic surface were detected as finals products. Various parameters influencing the NO degradation efficiency were studied: the coating composition, the substrate nature, the initial concentration of NO, the polluted air flow rate and the humidity. Compared to glass, the use of mortar as the substrate enhanced the photocatalytic performance of coatings by reducing the generation of gaseous NO_2 as a by-product.

1. Introduction

In an urban environment, air is strongly polluted by nitrogenous oxides NO_x (NO_x = NO + NO_2) produced by intensive human activity, notably transport. In living areas, NO_x are produced by domestic combustion devices such as gas burners for cooking and by the infiltration of outdoor pollution. Actually, in urban areas, pollution concentration levels are very similar inside and outside and can reach up to one ppm [1,2].

The aim of this paper was to investigate a promising way of limiting the NO_x levels in air. The main idea was to exploit the photocatalytic properties of titanium dioxide (in the form of anatase) under simulated solar illumination. Photocatalysis is activated by irradiation of semiconductor materials, here TiO_2 particles, with high energy photons ($h\nu$) that raise electrons e^- from the valence band (vb) to the conduction band (cb), thus leaving electron holes h^+ (reaction (1)). The pairs of mobile charges produced can reach the surface of the semiconductor particle and initiate a reduction–oxidation process. Moreover, through reactions with the adsorbed oxygen and water coming from the surrounding air, reactive oxygen species such as $HO^\bullet$ and $O_2^{\bullet -}$ are created (reactions (2) and (3)) and act as strong oxidants with the potential to decompose or mineralize a wide range of compounds [3,4].

$$TiO_2 \xrightarrow{h\nu} TiO_2 + h^+_{vb} + e^-_{cb} \quad (1)$$

$$H_2O_{ads} + h^+ \rightarrow H^+ + HO^\bullet \quad (2)$$

$$(O_2)_{ads} + e^- \rightarrow O_2^{\bullet -} \quad (3)$$

The reactivity of the oxygen species generated leads to the oxidation of NO to NO_2 which, in turn, produces nitrite and nitrate ions NO_2^-/NO_3^- [5–7]. Basically, the degradation of nitrogen oxides by photocatalysis can be described as follows:

$$NO \rightarrow HNO_2 \rightarrow NO_2 \rightarrow HNO_3 \quad (4)$$

As the band gap energy of unmodified TiO_2 is around 3.2 eV, the photocatalysis activation requires UV light ($\lambda < 388$ nm), which is, unfortunately, scarce in indoor environments. For indoor air purification, two methods are employed to make the photocatalyst active under visible light. One involves chemical modifications of the UV active photocatalyst in order to enlarge the photoadsorption to the visible region of the spectrum and to make it efficient in indoor environments. Other studies focus on the development of photocatalysts active under visible light. For example, carbon-doped TiO_2, BiOBr or $PbWO_4$ have shown NO_x purification abilities under visible light [8–10]. In this paper, commercially available TiO_2 active under UV light is used to study the NO_x purification under outdoor conditions.

Different processes can be used to bind the photocatalyst to the surface. Today, most photocatalysis applications for building materials involve the mixing of TiO_2 inside concrete or mortars. Because photocatalysis is a surface phenomenon, solutions such as coatings are also interesting because they can be applied to existing

* Corresponding author. Tel.: +33 5 61 55 99 31; fax: +33 5 61 55 99 49.
E-mail address: bertron@insa-toulouse.fr (A. Bertron).

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