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Commercial photocatalytic coatings – Air purification technology
Comparative study.

Introduction

Dangerous nitrogen oxides (NOx) are among the most closely studied gaseous pollutants because of their toxicity to human health. The major source of NOx is road transport, producing around 40% of the total emissions, comprising a mixture of nitric oxide (NO) and nitrogen dioxide (NO_2). Of the NOx emitted from vehicles, around 80% comes from diesel-powered vehicles. Decrease in NO concentrations can be achieved on photocatalytic surface coated with photocatalytic coating.

What is photocatalytic coating?

Photocatalytic coating contains semiconductor photocatalyst titanium dioxide (TiO_2) that acts as a catalyst when exposed to ultraviolet (UV) light. The photocatalytic oxidation effect leads to the removal of atmospheric pollutants, such as nitrogen oxide (NOx) and volatile organic compounds (VOC). **Variety of photocatalytic coating are available from several commercial companies; however, it is not straightforward to predict the impact or performance of a particular TiO_2-based product from their name or marketing information. This is why we tested each product and characterised them individually for the photocatalytic efficiency using standard methods (ISO tests).**

Photocatalytic coating as a pollution abatement technology

The use of photocatalytic surfaces for pollution abatement is an attractive proposition in many respects. First, passive abatement technologies only need sunlight to function. However, field trials have also been undertaken where artificial UV light sources have been used to illuminate surfaces. Second, **the photocatalytic coatings can be easily applied to a wide range of surfaces and are relatively cheap. Photocatalytic surfaces fundamentally differ from most air pollution abatement technologies in that they do not aim to reduce emissions at source but aim to reduce concentrations once released to atmosphere**. Moreover, surfaces treated with TiO_2 usually stay clean due to the oxidation effect, regardless whether the material is glass or some other coated building material**. Building cleaning (glass and building fabric) does have a real cost and the use of TiO_2 surfaces may help reduce the costs associated with building cleaning due to the air pollution pollutions (atmospheric dirt)**.

ISO test for the photocatalytic determination of NOx reduction

The decomposition of NO in the air was based on **ISO 22197-1:2007**. The test concerns the removal of nitric oxide and specifies the air-purification performance of materials that contain a photocatalyst usually made from semiconducting metal oxides, such as titanium dioxide. In this report, we compared the photocatalytic performance of several commercial TiO_2-based products. **All manufacturers mentioned below declare that their product exhibit a photocatalytic properties**.

- Protectam FN®1 (Advanced Materials-JTJ, Czech Republic)
- Protectam FN®2 (Advanced Materials-JTJ, Czech Republic)
- Protectam FN®3 (Advanced Materials-JTJ, Czech Republic)
- Detoxy Color Interier (Rokospol, Czech Republic)
- Detoxy Color ALG (Rokospol, Czech Republic)
- Activa Healthy Environment (Activa Colors, Spain)
- CapaSan (Caparol, Germany)
- Aeroxide®TiO_2 P 25 (Evonik Industries, Germany)

All the coatings were applied to concrete blocks (5×10 cm) according to the manufacturer's instructions and assessed for their ability to reduce NOx concentration in the air. The photocatalytic reduction of NO concentration of ppmv (corresponding to 1227 μg/m^3) was carried out in laminar flow reactor (Fig. 1).

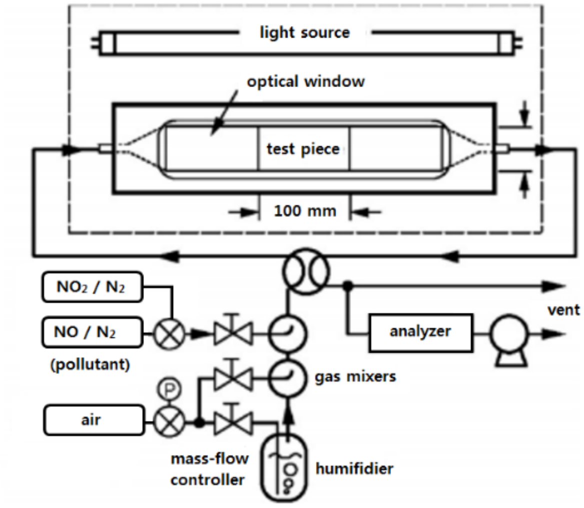

Fig. 1: Experimental set-ups comprising laminar flow reactor for the photocatalytic oxidation of gas streams containing low concentrations of nitric oxide at a specified humidity.

Results and Discussion

The comparison of the photocatalytic performance of commercial TiO_2-based products provided an interesting outcome. It is evident that photocatalytic activity for NOx oxides abatement differs significantly for each commercial TiO_2-based product (Table 1, Fig. 2). The use of products of CapaSan, Germany; Activa Healthy Environment, Spain; and both Detoxy Color, Czech Republic coatings, led to insignificant removal (i.e. less than 10% of deNOx removal). **This slight reduction in the NOx concentration is not sufficient for the use of these products as an air purification technology**. **On the other hand, all Protectam FN® and Aeroxide®TiO_2 P 25 coatings were very efficient in NOx abatement reaching 20–50% per single pass (laminar flow)**. **The highest deNOx decrease reached Protectam FN®3 for the inlet NO concentration corresponding to a highly polluted air, the decrease was almost 50% (from 1227 to 562 μg.m^{-3})**. While the photocatalytic activity with the lowest deNOx was observed for both Detoxy Color ALG and Interior, Czech Republic, just only 2%. The product Activa Healthy Environment, Spain exhibited deNOx removal in the absence of UV light, thus, it was not due to the photocatalysis, but due to a different process. Actually, the photocatalytic efficacy of FN®3 coating was higher than that of P 25, which is widely used nano-TiO_2 standard because of its high photocatalytic level in NOx abatement., it is not easy to find a photocatalyst showing activity higher than that of P25.

Nevertheless, in comparison with Aeroxide®TiO_2 P 25 (pure nano-TiO_2 powder containing no binder), Protectam FN® coatings have substantial advantages, especially the stable binder, which ensures very good cohesion of the layer and its strong adhesion to the construction material itself. Without any binder (case of Aeroxide®TiO_2 P 25) the nanoparticles tend to stick to the surface electrostatically, which is not sufficient to achieve satisfactory strength and durability.

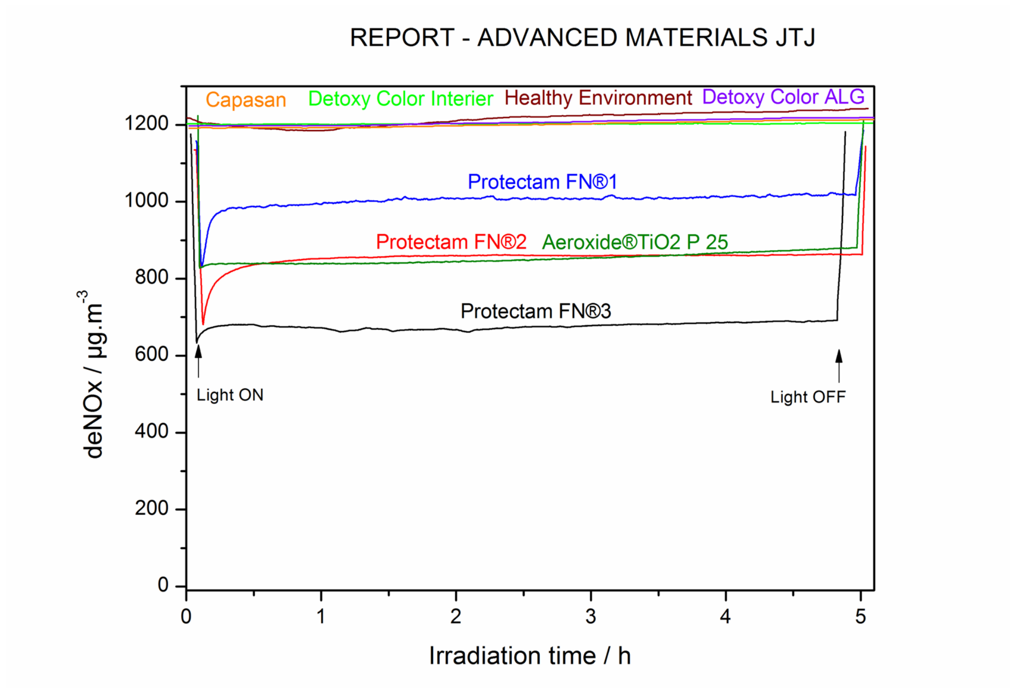

Fig. 2: DeNOx removal owing to the photocatalytic oxidation on commercial TiO_2-based products for the inlet NO concentration of 1 ppmv (corresponding to 1227µg.m^{-3}) at RH of 50%.

Table 1: Decrease in the NO concentration owing to the photocatalytic oxidation on commercial TiO_2-based products for the inlet NO concentration of 1 ppmv (corresponding to 1227 µg.m^{-3}) at RH of 50%.

Photocatalytic coating	deNOx [µg m^{-3}]	deNOx [%]	r(deNOx) [µg m^{-2} h^{-1}]
Protectam FN®3	562	46	112 400
Aeroxide®TiO_2 P 25	379	31	75 800
Protectam FN®2	365	30	73 000
Protectam FN®1	217	18	43 400
Activa Healthy Environment	31	3	6 200
CapaSan	23	2	4 600
Detoxy Color ALG	23	2	4 600
Detoxy Color Interier	21	2	4 200

deNOx [µg. m^{-3}], corresponding to real decrease of total concentration of NO_X ($NO+NO_2$) on the photocatalyst ´surface of an area of 50 cm^2. *deNOx coefficient* [%], NOx removal compared to the original value of 1227 µg. m^{-3}. *r(deNOx)* [µg m^{-2} h^{-1}], related to reaction rate of NOx removal from the gas stream related to the photocatalyst ´surface area of 1 m^2 within 1 hour.

Conclusion

The comparative study of photocatalytic activity of various TiO_2-based commercial products has generally shown that the concentration of NOx can be significantly reduced using photocatalytic Protectam FN® coatings. Aeroxide®TiO_2 P 25 also exhibited a high photocatalytic efficiency; however, is in the form of powder without any binder, which prevents its anchoring to the surface. The photocatalytic performance of other tested coatings is insufficient to be used as an air purification technology of highly polluted areas due to their low deNOx coefficient. The other tested photocatalytic coatings were insufficient during the photocatalytic testing and cannot be used as an air purification technology.

Prague, the 1st May 2017
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