Fraunhofer IST

Test Report (2nd Ed.)

Determination of the photocatalytic air-cleaning performance of coated polycarbonate samples according to EN 16980-1 with modified tests conditions

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1 Principle and intention of the work

The aim of the project was to determine the photocatalytic air-cleaning performance of coated polycarbonate samples treated with Pureti Coat by a non-electrostatic spray system. The test has been performed following the setup of EN 16980-1 with modified test conditions. Tests with modified test conditions are mostly used in the development or pre-series production of products to document the progress of a development or to secure findings from it. Tests according to this pattern do not replace tests according to standard conditions and are therefore primarily intended for internal use.

The European standard EN 16980-1 describes a method for assessing the performance of photocatalytic inorganic materials as thin films or coatings on a variety of substrates for the photocatalytic abatement of nitric oxide in the gas phase. In contrast to ISO 22197-1, a continuously stirred tank reactor (CSTR) is used and a fan ensuring perfect mixing inside the reaction chamber. The photocatalytic abatement rate is calculated from the observed rate by eliminating the effects of mass transfer and thus makes it possible to distinguish the photocatalytic activities of various products with an absolute scale. However, the method is not suitable for pigments.

The performance of the photocatalytic specimen under test is evaluated by measuring the degradation rate of nitric oxide (NO) using the method specified above. For the measurements and calculations described in this standard the concentration of nitrogen oxides (NO_x) is defined as the stoichiometric sum of nitric oxide (NO) and nitrogen dioxide (NO_2).

In accordance with EN 16980-1 the resulting intrinsic photocatalytic abatement rate of NO $k_R = \frac{v_{NO}^{photo}}{c_{NO}^{IN}}$ is calculated by dividing the NO abatement rate $v_{NO,i}^{photo}$ at nominal fan flow of 70 m^3/h (i=0) by the concentration of NO c_{NO}^{IN} at reactor inlet.

In order to comply with the requirements of the customer the test was performed at nominal fan speed, while UV irradiation was realized by a 352 nm fluorescent lamp @1,5 mW/cm^2. NO feed concentration was lowered to 100 ppb and NO flux rate was adjusted to 1,0 l/min. The sample was pre-activated for 24 hours according to ISO 22197-1:2016 clause 8.1.2. Subsequently, a 2 hours washing step in deionized water and 24 hours drying in an oven at 40 °C was performed. Optional determination of mass transfer with varying fan speed according to optional clause 10 of the standard was not part of this work.

2 Overview of samples tested

On behalf of Dott.Gallina s.r.l., Italy, the samples were delivered by Nanoair Solutions S.L.U., Spain, and shipped to Fraunhofer IST in September 2023. The samples were fabricated in form of honeycomb structure like polycarbonate samples in size of 8 x 8 cm^2. According to the customer, the samples were coated Pureti Coat 4.0 by an electrostatic spray process and were pre-cured under UV-A light for more than 48 hours.

Sample No.	Sample name
1	Polycarbonate G1

The tests were performed in September 2023. All samples were consumed.

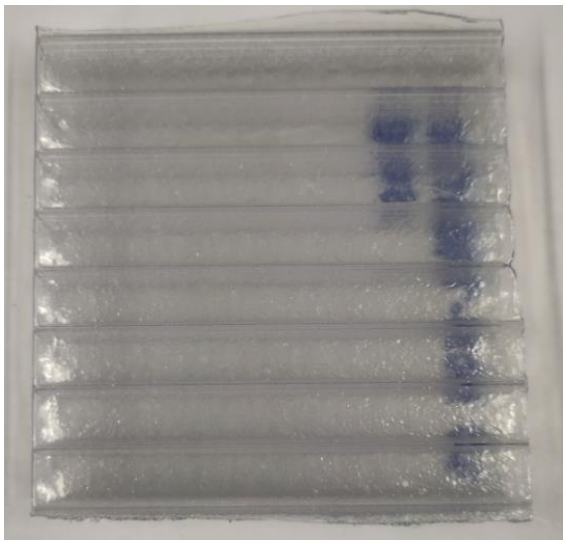
3 Removal of nitric oxide in a continuously stirred tank reactor (CSTR)

Table of test conditions:

Test method	Removal of nitric oxide in a continuously stirred tank reactor (CSTR) following the setup of EN 16980-1 with modified test conditions			
Executing laboratory	Fraunhofer Institute for Surface Engineering and Thin Films IST			
Test period	27 September, 2023			
Examiner	Hendrik Thiem			
Test gases	Nitric oxide (NO), 50 *ppmv* in N_2, Linde AG Synthetic air (SA), free of hydrocarbons			
UV-Lamp (pre-conditioning)	Philips Actinic BL TL-K 40W; peak @ 365±10 *nm*			
Pre-conditioning of samples	365 nm UV; 25,5 h; 1,67 mW/cm²; according to ISO 22197-1:2016 clause 8.1.2; followed by a subsequent washing step in deionized water (2 h) and drying in an oven at 40 °C for a period of 22 hours.			
UV-Detector type	Ophir 3A-P-FS-Thermopile (Nova II), Ophir Spiricon Europe GmbH			
Measurement conditions				
Reactor type	Continuously stirred tank reactor (CSTR)			
Reactor net volume	3,2 *l*			
Nominal fan speed	70 m^3/h			
Sample No.	1			
Temperature in reactor	26,7±0,3 °C			
Relative humidity in reactor	41,2±0,8 %			
Test gas feed	100 *ppbv* nitric oxide in technical air; 1,0 *l/min*			
UV-Lamp (measurement)	UV-A bench lamp; 15 *W*, 352 *nm*, 230 VAC/50 *Hz*			
UV irradiance (sample surface)	1,49 mW/cm^2 @ 352 *nm*			
UV-Detector type	Ophir 3A-P-FS-Thermopile (Nova II), Ophir Spiricon Europe GmbH			
NO-Analyzer	AC32M Chemilumineszenz-Detektor, Environnement S.A.			
Variations from standard	Test gas feed and concentration lowered at the same time (1,0 l/min,100 ppb); UV intensity increased to 1,5 mW/cm²; omission of optional determination of mass transfer with varying fan speed;			

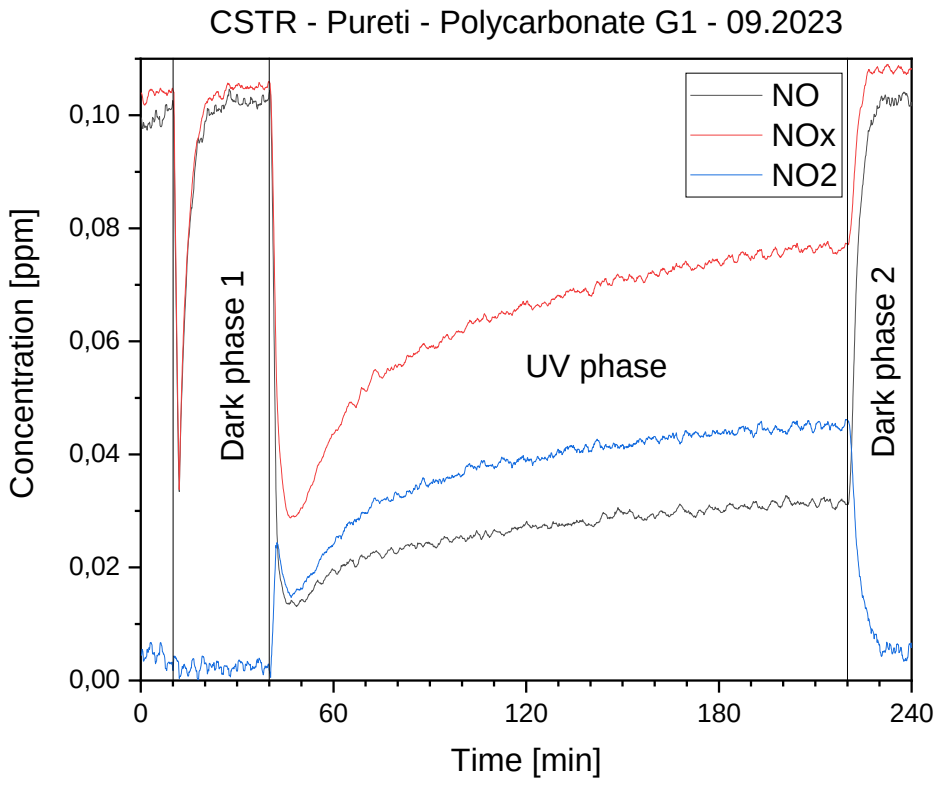
4 Specific test results

Exemplary image of the test specimen:



Sample No 1: Polycarbonate G1, effective irradiated area 8 x 8 cm²;

Specific test results:



The NO abatement rate $r_{NO,i}^{photo}$ at nominal fan speed (i = 0) and the NO_2 photocatalytic production rate $r_{NO_2,i}^{photo}$ are expressed as mass (micrograms) of NO consumed or mass of NO_2 produced by the sample per unit of time and unit of exposed surface area. These rates are calculated as the difference between the abatement/production rates and the rates observed in the dark according to:

$$r_{\mathrm{NO,i}}^{\mathrm{photo}} = \frac{122F^{*}}{S}\left(\frac{\eta_{\mathrm{NO,i}}^{\mathrm{total}}}{(1-\eta_{\mathrm{NO,i}}^{\mathrm{total}})} - \frac{\eta_{\mathrm{NO}}^{\mathrm{dark}}}{(1-\eta_{\mathrm{NO}}^{\mathrm{dark}})}\right)$$ NO abatement rate in µg/(m²*h);

$$r_{\mathrm{NO_2,i}}^{\mathrm{photo}} = \frac{188F^{*}}{S}\left(\frac{\eta_{\mathrm{NO_2,i}}^{\mathrm{total}}}{(1-\eta_{\mathrm{NO,i}}^{\mathrm{total}})} - \frac{\eta_{\mathrm{NO_2}}^{\mathrm{dark}}}{(1-\eta_{\mathrm{NO}}^{\mathrm{dark}})}\right)$$ NO_2 production rate in µg/(m²*h);

$$r_{\mathrm{NO_x,i}}^{\mathrm{photo}} = 1{,}53\ r_{\mathrm{NO,i}}^{\mathrm{photo}} - r_{\mathrm{NO_2,i}}^{\mathrm{photo}}$$ NO_x abatement rate in µg/(m²*h)

with:

F	actual flow of reactant gas entering the reactor expressed in m^3*h^{-1}
S	sample irradiated surface area in m^2
$\eta_{NO,i}^{total}$	overall conversion of NO (NO_2) measured at nominal fan speed (70 m^3/h)
η_{NO}^{dark}	conversion of NO (NO_2) in the dark

(*) According to the lowered gas concentration and flow rate the factors for modified test conditions of $r_{NO,i}^{photo}$ and $r_{NO_2,i}^{photo}$ were adapted to 122*F* and 188*F*, respectively.

The resulting intrinsic NO photocatalytic abatement rate $k_R = r_{NO}^{photo}/c_{NO}^{IN}$ is calculated by dividing the NO abatement rate $r_{NO,i}^{photo}$ with i = 0 by the concentration of NO at reactor inlet. The intrinsic NO photocatalytic abatement rate can also be expressed as photocatalytic deposition velocity.

Table of test results:

Sample No.	NO inlet concen-tration [ppmv] c_{NO}^{IN}	NO abatement rate [µg/(m²*h)] $r_{NO,i}^{photo}$	NO_2 production rate [µg/(m²*h)] $r_{NO_2,i}^{photo}$	NO_x abatement rate [µg/(m²*h)] $r_{NO_x,i}^{photo}$	Overall conversion of NO [%] $\eta_{NO,i}^{total}$	NO photo-catalytic abatement rate [m/h] $k_R = \frac{r_{NO}^{photo}}{c_{NO}^{IN}}$
1	0,099	2488,12	2262,49	1544,34	68,51	19,83

According to the test results above the tested sample **"Polycarbonate G1"** exhibits an intrinsic NO photocatalytic abatement rate of

$$k_R = 19{,}83 \text{ m/h}.$$

All test results in this report relate exclusively to the samples tested in this report.

5 Final remarks

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