Fraunhofer IST

Test Report

Determination of the photocatalytic air-cleaning performance of SAULEDA fabrics towards nitric oxide in a stirred tank reactor

Quotation-No.: Ne20190607-01

Contractor:

NANOAIR SOLUTIONS S.L.
Dr. Joaquín Piserra
CEO
Ronda Sant Pere 40 principal 2ª
08010 Barcelona
SPAIN

Tel.: +34 93 348 64-76
jpiserra@pureti.es

Contract execution:

Fraunhofer Institute for Surface Engineering and Thin Films IST
Mr. Frank Neumann
Head of Photo- and Electrochemical Environmental Engineering
Bienroder Weg 54 E, D-38108 Braunschweig
GERMANY

Tel.: +49 531 2155-658
frank.neumann@ist.fraunhofer.de

Braunschweig, 12 August 2019

1 Principle and intention of the work

The aim of the project was to determine of the photocatalytic air-cleaning performance of SAULEDA fabrics following the setup of CEN/TS 16980-1 but with modified test parameters.

The European specification CEN/TS 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 stirred tank reactor (CSTR) in continuous operation is used, which applies a tangential flow to the sample and thus assesses the determination of the internal photocatalytic reduction rate of the materials on an absolute scale. The performance for the photocatalytic specimen under test is evaluated by measuring the degradation rate of nitric oxide (NO). For the measurements and calculations described in this standard the concentration of nitrogen oxides (NOx) is defined as the stoichiometric sum of nitric oxide (NO) and nitrogen dioxide (NO_2).

Moreover, the photocatalytic abatement rate can be calculated from the observed rate by eliminating the effects of mass transfer. By linear interpolation of the reciprocal intrinsic photocatalytic degradation rate and the reciprocal fan flow rate $1/r_{NO,i}^{photo}$ versus $1/F_{V,i}$, the upper intrinsic limit of the photocatalytic activity of the material can be calculated. The intrinsic photocatalytic abatement rate is an intrinsic property of the material tested and allows to distinguish the photocatalytic activities of various products with an absolute scale. However, the method is not suitable for pigments.

In order to comply with the customer´s requirements, the test conditions in comparison to CEN/TS 16980-1 were adapted as follows: The tests were performed at a constant fan speed of 70 m^3/h. 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. Measurements with optional determination of mass transfer with varying fan speed were not performed.

2 Overview of samples tested

On behalf of the customer the specimen were delivered by Nanoair Solutions S.L., Spain, and shipped to Fraunhofer IST in July 2019. All specimen were fabricated in form of spray coated fabrics. The samples were cut down to a regular size of 8 x 8 cm. In accordance with the customer all samples were pre-activated by UV irradiation of an intensity >1 mW/cm^2 according to ISO 22197-1:2016 clause 8.1.2 followed by a subsequent washing step in deionized water and 16 hours drying in an oven at 40 °C .

Set Nr.	Sample name
1	SAULEDA (coarse meshed)

The tests were performed in August 2019. All samples were consumed.

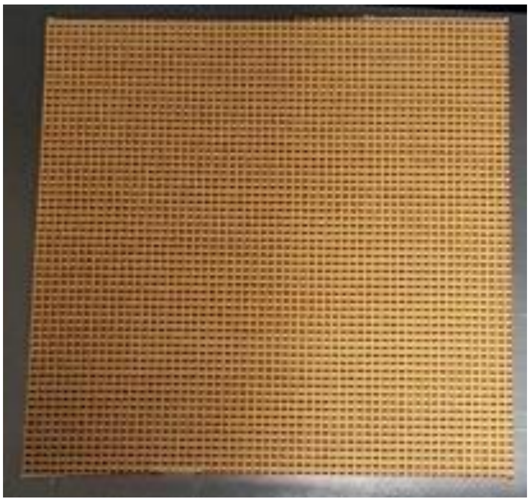
3 Removal of nitric oxide in a continuously stirred tank reactor (CSTR)

Table of test conditions:

Test method	Removal of nitric oxide in a continuously stirred tank reactor (CSTR) following the setup of CEN/TS 16980-1		
Executing laboratory	Fraunhofer Institute for Surface Engineering and Thin Films IST		
Test period	05.-07.08.2019		
Examiner	Hendrik Thiem		
Test gases	Nitric oxide (NO), 50 ppm_v in N_2, Linde AG, Art.-Nr.: 3800152; Synthetic air (SA), free of hydrocarbons, Linde AG, Art.-Nr.: 10207951		
UV-Lamp (pre-conditioning)	Philips Actinic BL TL-K 40W; peak @ 365±10 *nm*		
Pre-conditioning of samples	365 *nm* UV; 24 *h*; 2,1 mW/cm^2; according to ISO 22197-1:2016 clause 8.1.2 followed by a subsequent washing step in deionized water and 16 hours drying in an oven at 40 °C		
UV-Detector type	Ophir 3A-P-FS-Thermopile (Nova II), Ophir Spiricon Europe GmbH		
Measurement conditions			
Reactor net volume	3,2 *l*		
Nominal fan speed	70 m^3/h		
Sample no.	SAULEDA		
Temperature in reactor	21,9±0,4°C		
Relative humidity in reactor	40,2±0,8%		
Test gas feed	100 *ppbv* nitric oxide in technical air; 1,0 *l/min*		
UV-Lamp (measurement)	UV bench lamp; 15 watts, 352 nm, 230 VAC/50 Hz		
UV irradiance (sample surface)	1,48 mW/cm^2 @ 352 *nm*		
UV-Detector type	Ophir 3A-P-FS-Thermopile (Nova II), Ophir Spiricon Europe GmbH		
NO-Analyzer	AC32M Chemiluminescence Detector, Environnement S.A.		
Variations from standard	Test gas feed and concentration lowered (100 ppb, 1,0 l/min); UV intensity increased (1,5 mW/cm^2); omission of optional determination of mass transfer with varying fan speed;		

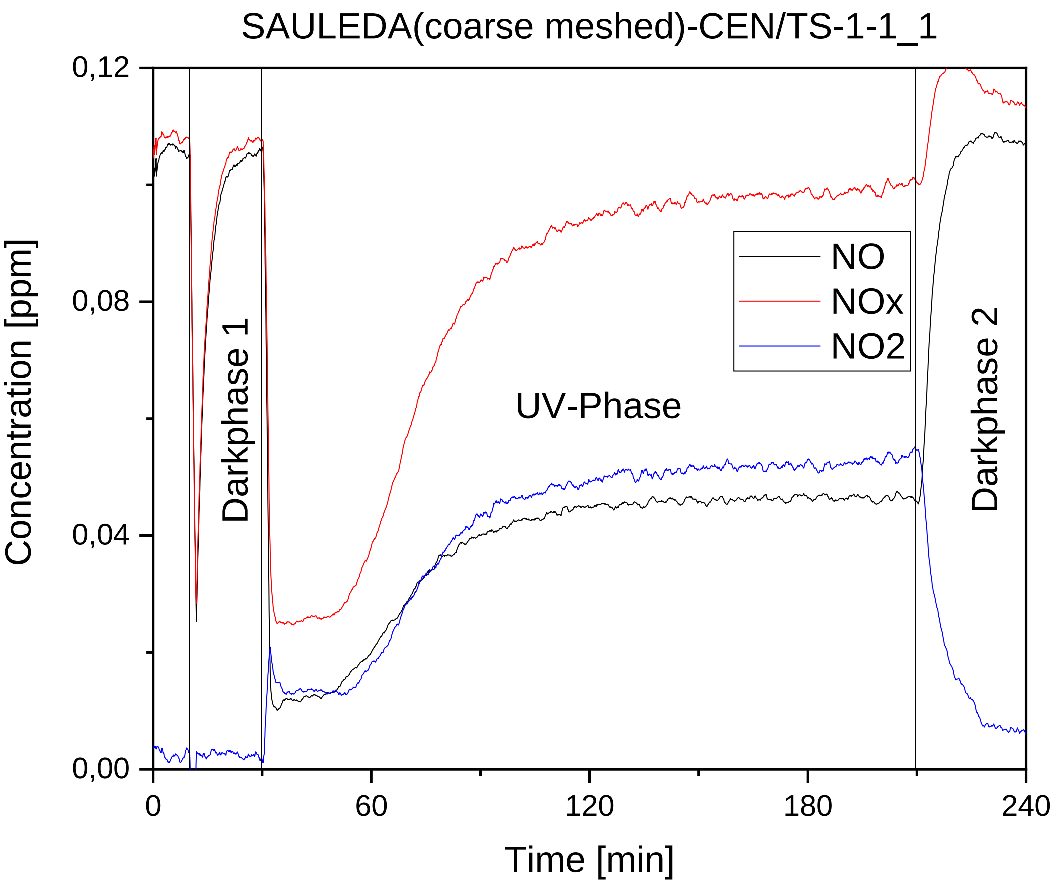
4 Specific test results

Exemplary image of the test specimen:



SAULEDA coarse meshed

Specific test results:



The NO abatement rate $r^{photo}_{NO,i}$ at nominal fan speed (i = 0) and the NO_2 $r^{photo}_{NO_2,i}$ photocatalytic production rate 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:

$$r^{\text{photo}}_{\text{NO,i}} = \frac{\overset{*122,3}{\cancel{613}}F}{S}\left(\frac{\eta^{\text{total}}_{\text{NO,i}}}{(1-\eta^{\text{total}}_{\text{NO,i}})} - \frac{\eta^{\text{dark}}_{\text{NO}}}{(1-\eta^{\text{dark}}_{\text{NO}})}\right)$$

; NO abatement rate in µg/(m^2*h); *factor changed according to modified test conditions;

$$r^{\text{photo}}_{\text{NO}_2\text{,i}} = \frac{\overset{*187,9}{\cancel{940}}F}{S}\left(\frac{\eta^{\text{total}}_{\text{NO}_2\text{,i}}}{(1-\eta^{\text{total}}_{\text{NO,i}})} - \frac{\eta^{\text{dark}}_{\text{NO}_2}}{(1-\eta^{\text{dark}}_{\text{NO}})}\right)$$

; NO_2 production rate in µg/(m^2*h); *factor changed according to modified test conditions;

$$r^{\text{photo}}_{\text{NO}_x\text{,i}} = 1{,}53\ r^{\text{photo}}_{\text{NO,i}} - r^{\text{photo}}_{\text{NO}_2\text{,i}}$$

; NO_x abatement rate in µg/(m^2*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

$\eta^{total}_{NO,i}$ overall conversion of NO (NO_2) measured at nominal fan speed (70 m^3/h)

η^{dark}_{NO} conversion of NO (NO_2) in the dark

The resulting intrinsic NO photocatalytic abatement rate $k_R = \frac{r^{photo}_{NO}}{c^{IN}_{NO}}$ is calculated by dividing the NO abatement rate $r^{photo}_{NO,i}$ 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 in accordance with ISO 31-0:

Sample	NO inlet concen-tration [ppmv] c^{IN}_{NO}	NO abatement rate [µg/(m^2*h)] $r^{photo}_{NO,i}$	NO_2 production rate [µg/(m^2*h)] $r^{photo}_{NO_2,i}$	NO_x abatement rate [µg/(m^2*h)] $r^{photo}_{NO_x,i}$	Overall conversion of NO [%] $\eta^{total}_{NO,i}$	NO photo-catalytic abatement rate [m/h] $k_R = \frac{r^{photo}_{NO}}{c^{IN}_{NO}}$
SAULEDA	1,0543	1384,53	1856,56	261,77	55,88	10,84

According to the test results above the tested sample

SAULEDA (coarse meshed)

exhibits an intrinsic NO photocatalytic abatement rate k_R of 10,84 m/h with a total NO conversion of 55,88%.

5 Final remarks

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Braunschweig, 12 August 2019