Messlabor für Photokatalyse

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D-TOX

Report following the order dated 27.04.2016 placed by Photocat A/S Roskilde

Photocatalytic activity test concerning the Degradation of NO

A photocatalytic bitumen sample has been tested concerning the photocatalytic degradation of NO in the gas phase. The sample has been pre-illuminated with 1 mW/cm^2 UV-A light for 5 days.

Degradation of NOx according to ISO 22197-1 Standard

The photocatalytic NO-Oxidation is measured with an apparatus in which synthetic air (relative humidity 50%) containing 1 ppm NO is flowing at a rate of 3 L/min across the surface of a sample with an illuminated surface area of 50 x 100 mm^2. The measurement is performed employing a NO/NO_2-Analyser equipped with a fluorescence detector that has a detection limit of 1 ppb NO. The illumination is performed with UV(A) light at an intensity of 1.0 mW/cm^2 measured at the surface of the samples.

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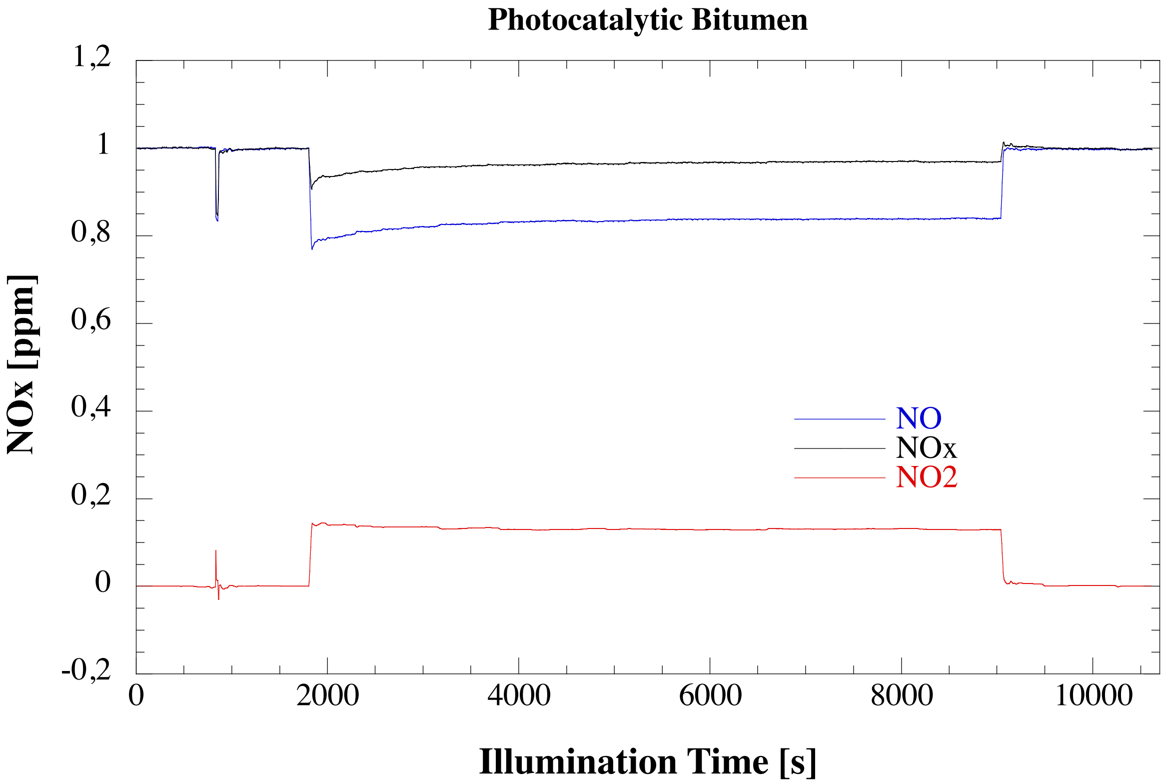
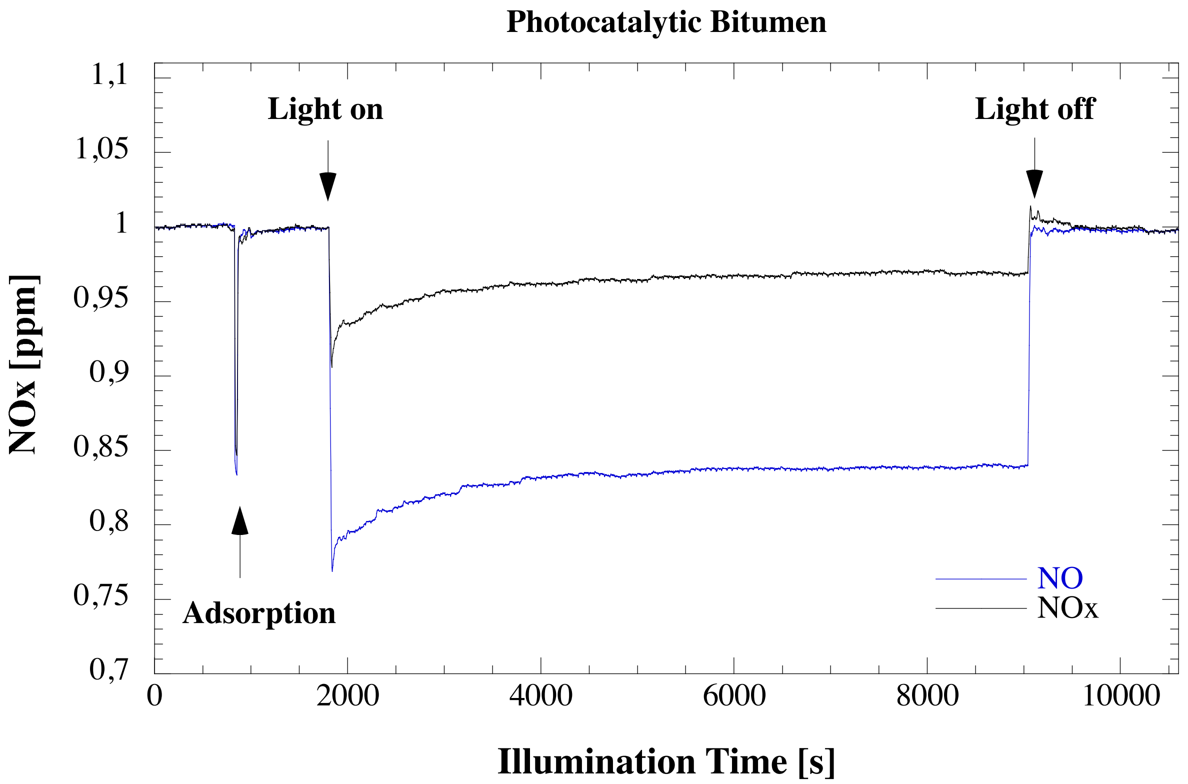
Result:


Photocatalytic Bitumen
1,2
1
0,8
0,6
0,4
0,2
0
-0,2
NOx [ppm]
NO
NOx
NO2
0
2000
4000
6000
8000
10000
Illumination Time [s]


Photocatalytic Bitumen
1,1
1,05
1
0,95
0,9
0,85
0,8
0,75
0,7
NOx [ppm]
Light on
Light off
Adsorption
NO
NOx
0
2000
4000
6000
8000
10000
Illumination Time [s]

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Data Analysis:

The employed UV(A) illumination intensity is 1 mW/cm^2, with an illuminated sample area of 50 cm^2 the total power is 50 mW. Taking an average illumination wavelength of 350 nm this can be converted to:

50 mW = 1.47×10^{-7} *molhν/ s*

The continuous test apparatus operates with a flow rate of 3 L/min. Assuming an ideal gas the following holds:

24 L Gas = 1 mol (at p = 1 bar and 25°)

i.e., it takes 8 min for 1 mol gas to pass the sample. The gas flow contains 1 ppm NO, hence 10^{-6} mol NO flow across the sample within 8 min. During the same time the sample is illuminated with

1.47×10^{-7} *molhν / s x 60 s/min x 8 min =* 70×10^{-6} *molhν .*

If total oxidation (loss) of the 1 ppm NO is observed, the Photonic Efficiency ζ will be:

$\zeta = 10^{-6}$ *mol NO /* 70×10^{-6} *molhν = 0.0143 = 1.43 %*

For a measured degraded amount of x ppm NO the Photonic Effiency can consequently be calculated with the following formula:

ζ_x = x (ppm) * 1.43 (% / ppm)

<u>Result:</u>

Photocatalytic Bitumen :

<u>NO-Degradation</u>: 0.230 ppm (initial)

Photonic Efficiency ζ = **0.33%**

<u>NO-Degradation</u>: 0.155 ppm (final)

Photonic Efficiency ζ = **0.22**%

<u>NOx-Degradation</u>: 0.0933 ppm (initial)

Photonic Efficiency ζ = 0.133%

<u>NOx-Degradation</u>: 0.0293 ppm (final)

Photonic Efficiency ζ = 0.042 %

<u>NO_2-Formation</u>: 0.137 ppm (initial)

Photonic Efficiency ζ = 0.196%

<u>NO_2-Formation</u>: 0.1257 ppm (final)

Photonic Efficiency ζ = 0.180%

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The test conditions employed here are identical to those suggested by the ISO 22197-1 standard, i.e., 1ppm NO, 3L/min air flow, 50% Relative Humidity (RH), 1 mW/cm^2 UV(A) illumination. According to the mathematical data treatment described in ISO 22197-1 the data obtained here can be used to calculate the amount of removed NO in μmol as follows:

$$n_{NO} = 3L\ min^{-1} / 22.4\ L\ mol^{-1}\ x\ (C_{NO,in} - C_{NO,out})\ x\ 300\ min$$

*For "**Photocatalytic Bitumen**"* $C_{NO,in} - C_{NO,out} = 0.155$ *ppm, i.e., 0.155 µL/L*
$n_{NO} = (3/22.4)\ x\ 0.155\ x\ 300\ \mu mol$
$n_{NO} = 6.23\ \mu mol$ *(in 5 hours illumination time)*

In analogy, the amount of NO_x degraded is calculated via
$n_{NOx} = 3L\ min^{-1} / 22.4\ L\ mol^{-1}\ x\ (C_{NOx,in} - C_{NOx,out})\ x\ 300\ min$
*For "**Photocatalytic Bitumen**"* $C_{NOx,in} - C_{NOx,out} = 0.0293$ *ppm, i.e., 0.0293 µL/L*
$n_{NOx} = (3/22.4)\ x\ 0.0293\ x\ 300\ \mu mol$
$n_{NOx} = 1.18\ \mu mol$ *(in 5 hours illumination time)*

Finally, the amount of formed NO_2 is calculated via
$n_{NO2} = 3L\ min^{-1} / 22.4\ L\ mol^{-1}\ x\ (C_{NO2,in} - C_{NO2,out})\ x\ 300\ min$
*For "**Photocatalytic Bitumen**"* $C_{NO2,in} - C_{NO2,out} = 0.1257$ *ppm, i.e., 0.1257 µL/L*
$n_{NO2} = (3/22.4)\ x\ 0.1257\ x\ 300\ \mu mol$
$n_{NO} = 5.05\ \mu mol$ *(in 5 hours illumination time)*

These results can be directly compared with the test data shown in Annex A of ISO 22197-1.
Alternatively, the following calculation is often used:
The molecular weight of NO is $30\ g\ mol^{-1}$, the illumination surface area is $0.005m^2$.
The degradation of 1μmol is equal to *30 µg* or $6\ mg/m^2$.
The sample "***Photocatalytic Bitumen***" degrades *6.23 µmol* in 5h, i.e., 1.25 μmol/h or ***7.5 mg NO/m²h***.

A value more than 5.0 mg NO/m^2h can be regarded as a very good degradation efficiency. The German Photocatalysis Association has recently defined a threshold value of 0.6 mg NO/m^2h to discriminate between photocatalytically inactive and active samples.

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Data Interpretation

With an efficiency of ζ = 0.22% (NO-Degradation, final value) the "Photocatalytic Bitumen" tested here exhibits a very good activity for the photocatalytic degradation of NO in the gas phase (Our Ranking Scale is as follows: sufficient: 0.01%< ζ < 0.05%, satisfying: 0.05%< ζ < 0.1%, good: 0.1%< ζ < 0.2%, very good: 0.2%< ζ < 0.5%, excellent: ζ > 0.5%). Hence, based upon its activity the "Photocatalytic Bitumen" belongs into the top group of products tested in this laboratory.

Hannover, 03.05.2016

Anja Hülsewig