**Project:** FV40209 "Use of optimized photocatalytic nanocomposites for removal of harmful substances from the air"

**Title:**

# Evaluation of effectivity of ozone degradation by FN2 and P25 coatings

## 1. Goals

The aim of this series of experiments was to find out whether photocatalytic degradation of ozone is possible. If it proves to be possible, the research shall focus on assessment of quantity dependence on individual parameters. The selected parameters are relative air humidity and UV radiation intensity.

## 2. Introduction

Ground-level ozone is an air pollutant. Because of its significant oxidizing property, ozone is considered being one of the most dangerous pollutant as it negatively affects all living organisms. Ozone is created by photolysis of nitrogen dioxide ($NO_2$) by solar UV radiation. Therefore, it is formed by default on warm sunny days when intensity of UV radiation is the highest.

However, UV radiation is also used to activate photocatalysis which is a process by which chemical decomposition of harmful substances occurs in the presence of photocatalyst. Therefore, it leads to air purification. This means the same radiation causing creation of ozone may as well help with its decomposition.

## 3. Methods

Functional coating suspension (FN2, resp. P25) was applicated on roughened glass slides 5 × 10 × 0.5 cm in size using an airbrush spray gun. The final sample weight was 50±1 mg. Slide with applied layer was dried by a stream of warm air and placed into a desiccator.

The experimental setup is shown in Fig. 1. ISO standard photoreactor was used. The dimensions of the reactor are 32 cm in length and 5 cm in width. The slit height was 0.5 cm which results in the reactor volume of 80 $cm^3$. The standard flow rate 3000 $cm^3$ $min^{-1}$ of the air stream corresponds to a linear velocity of 0.2 m $s^{-2}$. Before the measurement took place, the ozone was adsorbed under dark conditions to reach steady state and avoid ozone loss because of adsorption during the measurement itself.

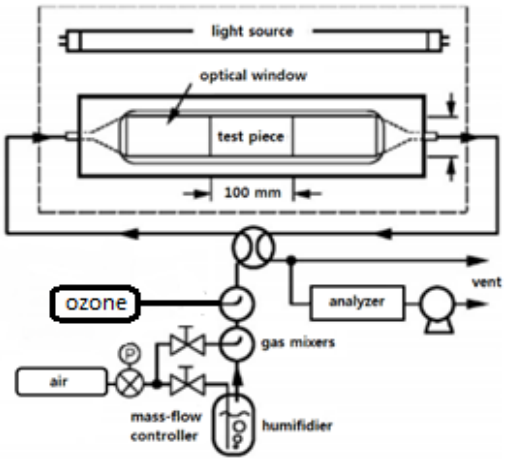



**Fig. 1** Experimental setup including photoreactor with laminar flow for photocatalytic oxidation of gaseous streams containing defined concentration of ozone at defined relative humidity

The ozone was generated by ozoniser SOG-1, P/N 97-0066-02, UVP, through which the air flowed. UV-C lamp with adequate shielding was used to reach required ozone concentrations.

The ozone concentrations were measured with an analyser HORIBA APOA-370.

As there is no ISO standard for measuring ozone, most of the measurement parameters were picked according to ISO 22197-1:2016 standard which determines the measurement parameters for nitric oxide. Besides the already mentioned photoreactor, it is UV-A radiation of the corresponding wavelength (365 nm) and intensity of 1 mW $cm^{-2}$ (when the UV intensity dependence was measured, the intensity varied between 0.05 and 5 mW $cm^{-2}$). The flow rate of 3000 $cm^3$ $min^{-1}$ corresponds with the ISO standard as well and so does the relative humidity of 50 % (when the relative humidity dependence was measured, the humidity varied between 0 and 100%). Ozone concentrations were chosen to be 10 ppb respectively 100 ppb which are the lowest and the highest ozone concentration in the Czech Republic (according to Czech Hydrometeorological Institute data for 2019). Each measurement lasted 1 hour.

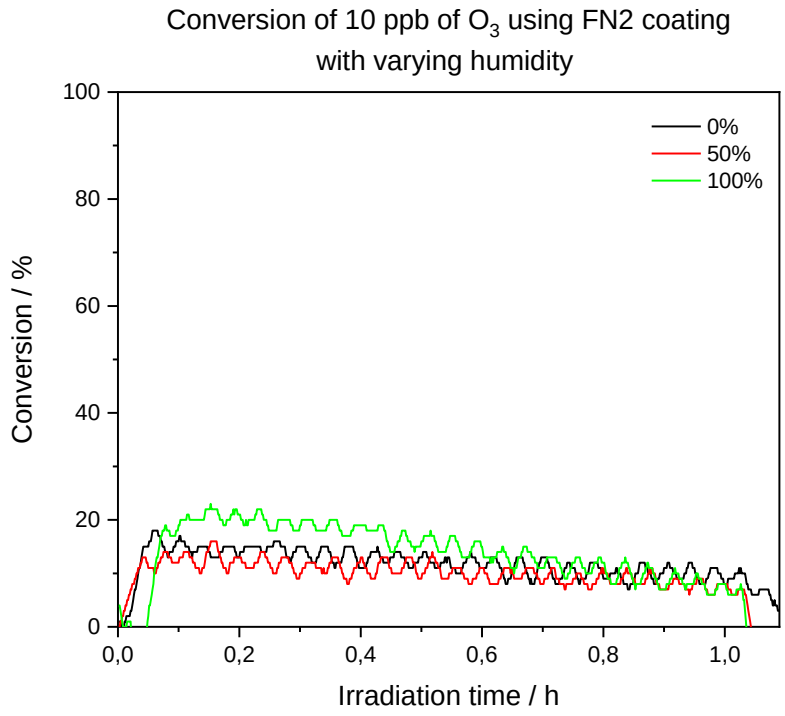
## 4. Results and discussion

### 4.1 Relative humidity

In Fig. 2a and Fig. 3a is shown ozone conversion in dependence on the time of measurement for each of humidities while using FN2 coating. It is evident that with increasing humidity the conversion rate decreases, especially at the higher ozone concentration (Fig. 3a). This trend is noticeable especially at the highest humidity level (100 %) where the difference from 50% humidity is much higher than at the lowest humidity level (0 %).

On the other side, the decrease of the conversion rate with increasing humidity is noticeable even at the lower ozone concentration while using P25 coating (Fig. 2b). This trend is even more noticeable at the higher concentration (Fig. 3b). At the 0% humidity, the conversion is comparable while using either of the photocatalysts, however with each humidity increase there is a significant decline when the P25 is used compared to the FN2.

a)




b)

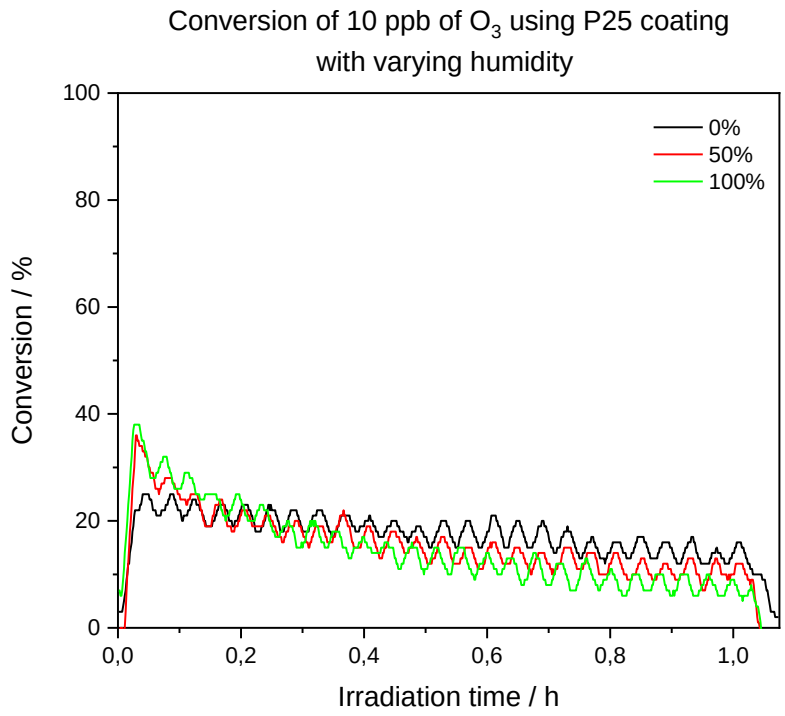
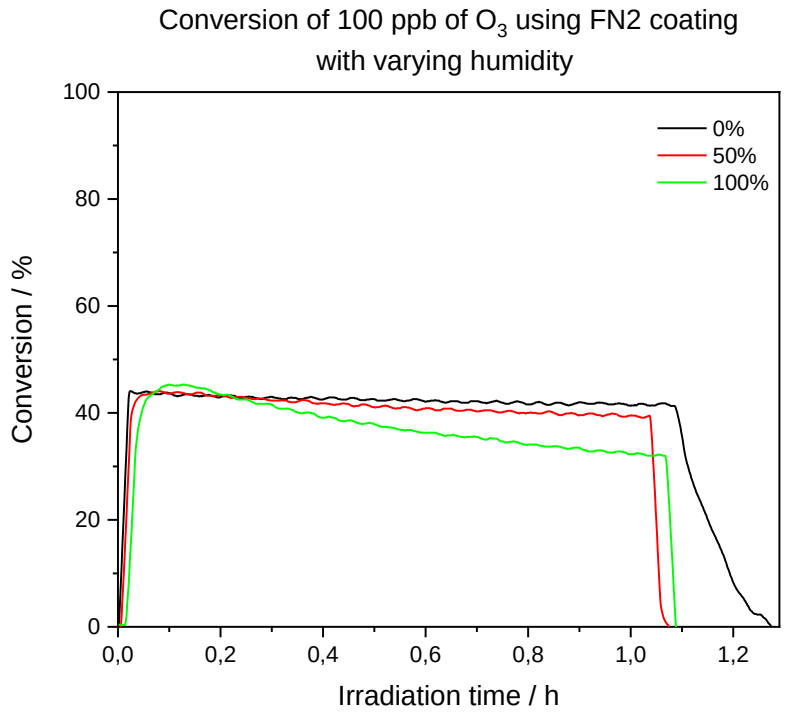



**Fig. 2** Dependence of $O_3$ conversion with inlet concentration of 10 ppb on the irradiation time at each humidity for functional coating: a) FN2; b) P25

a)




b)

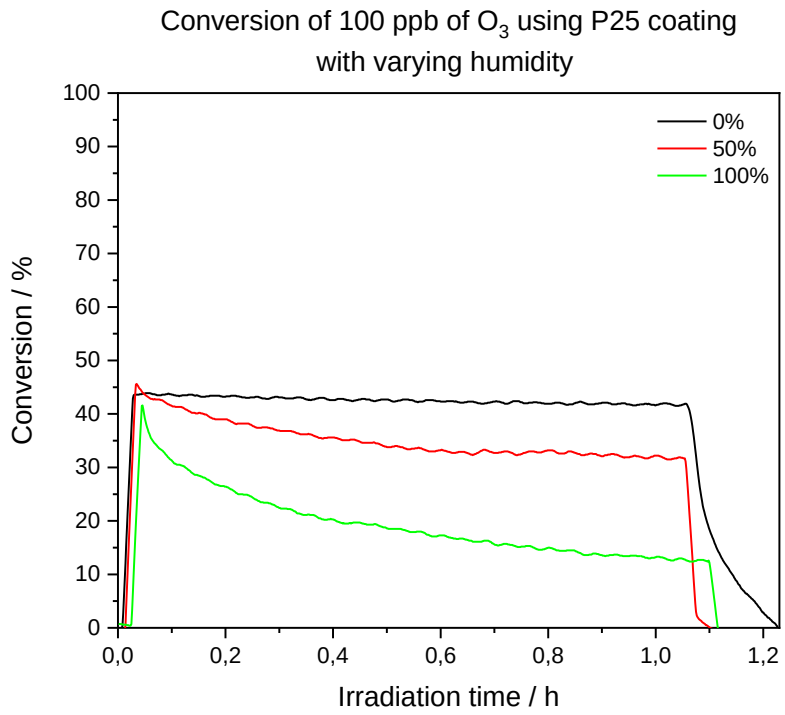



**Fig. 3** Dependence of $O_3$ conversion with inlet concentration of 100 ppb on the irradiation time at each humidity for functional coating: a) FN2; b) P25

Measurement results for each humidity and both functional coatings are summarized in Tab. 1. We can notice that at concentration of 10 ppb the P25 has better results even though its activity decreases with increasing relative humidity unlike the FN2. At the higher (100 ppb) concentration it is just the opposite, the FN2 brings better results than the P25, especially at higher humidities where decrease of activity while using the P25 is very significant.

**Tab. 1** Effect of relative air humidity on photocatalytic ozone degradation by FN2 and P25 functional coatings

| **Photocatalyst** | **Relative humidity** | **$[O_3]_{in}$** | **$[O_3]_{out}$** | **Conversion** | **$\Delta O_3$** | **$\Delta O_3$** |
|---|---|---|---|---|---|---|
| | % | ppbv | ppbv | % | $\mu mol\ m^{-2}\ h^{-1}$ | $\mu g\ m^{-2}\ h^{-1}$ |
| **FN2** | 0 | 10 | 9,1 | 9 | 1 | 65 |
| | 50 | | 9,2 | 8 | 1 | 58 |
| | 100 | | 9,2 | 8 | 1 | 58 |
| | 0 | 100 | 58,7 | 41 | 62 | 2974 |
| | 50 | | 60,5 | 40 | 59 | 2844 |
| | 100 | | 67,7 | 32 | 48 | 2326 |
| **P25** | 0 | 10 | 8,6 | 14 | 2 | 101 |
| | 50 | | 9,0 | 10 | 2 | 72 |
| | 100 | | 9,1 | 9 | 1 | 65 |
| | 0 | 100 | 58,4 | 42 | 62 | 2995 |
| | 50 | | 67,8 | 32 | 48 | 2318 |
| | 100 | | 86,8 | 13 | 20 | 950 |

a) b)

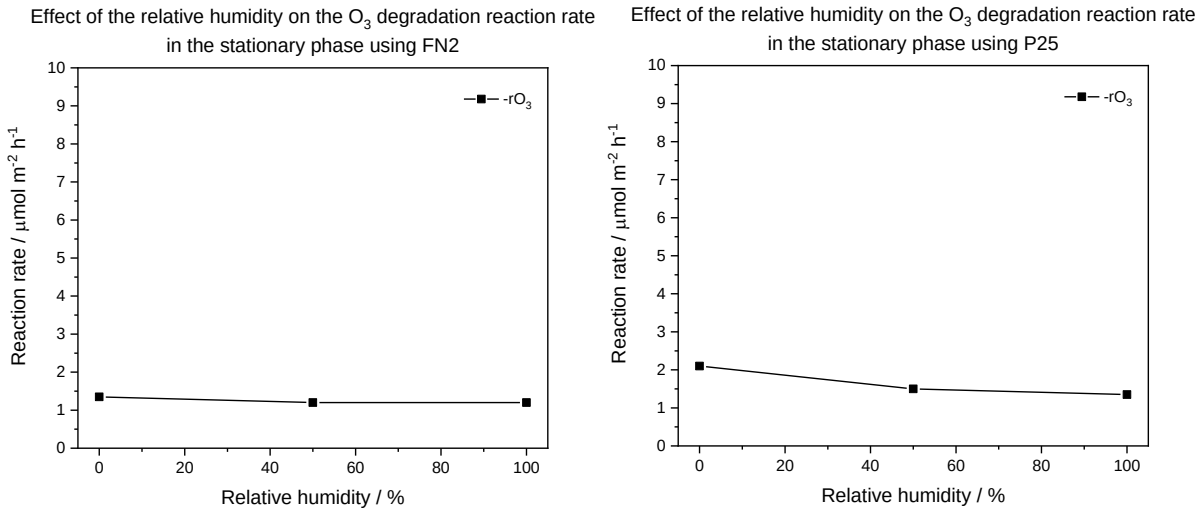



**Fig. 4** Dependence of reaction rate of ozone degradation with inlet concentration of 10 ppb on relative air humidity for functional coating: a) FN2; b) P25

a) b)

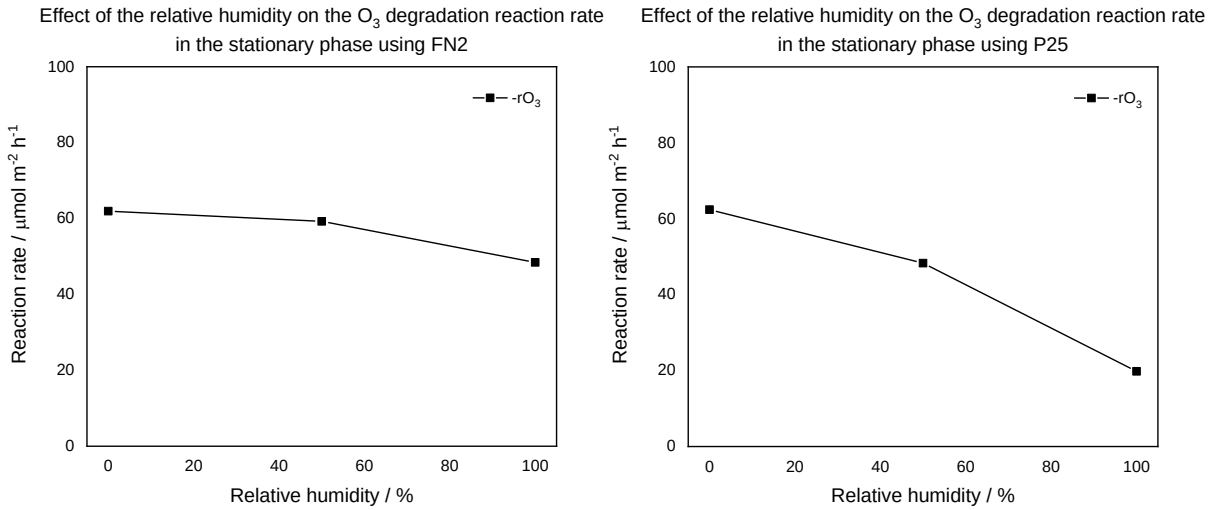


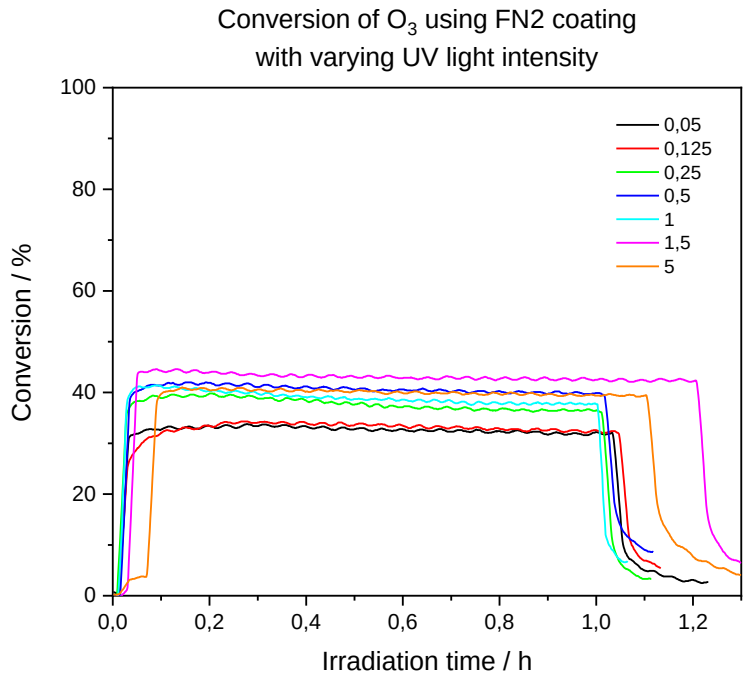

**Fig. 5** Dependence of reaction rate of ozone degradation with inlet concentration of 100 ppb on relative air humidity for functional coating: a) FN2; b) P25

## 4.2 Irradiation intensity

In Fig. 6 we can observe comparison of ozone conversion at each intensity while using both photocatalysts. In both cases it is apparent that the conversion doesn't depend on irradiation intensity very much. The FN2 reaches plateau at intensities of 0.25 mW cm$^{-2}$ and higher. The P25 reaches it even at intensity of 0.125 mW cm$^{-2}$.

The comparison of both photocatalysts works better for the FN2. Even at the lowest intensities the conversion over 30 % is reached, after reaching plateau the conversion is around 40 %. The P25 has comparable initial activity but in time the conversion stabilizes between 20 and 30 %.

a)



b)

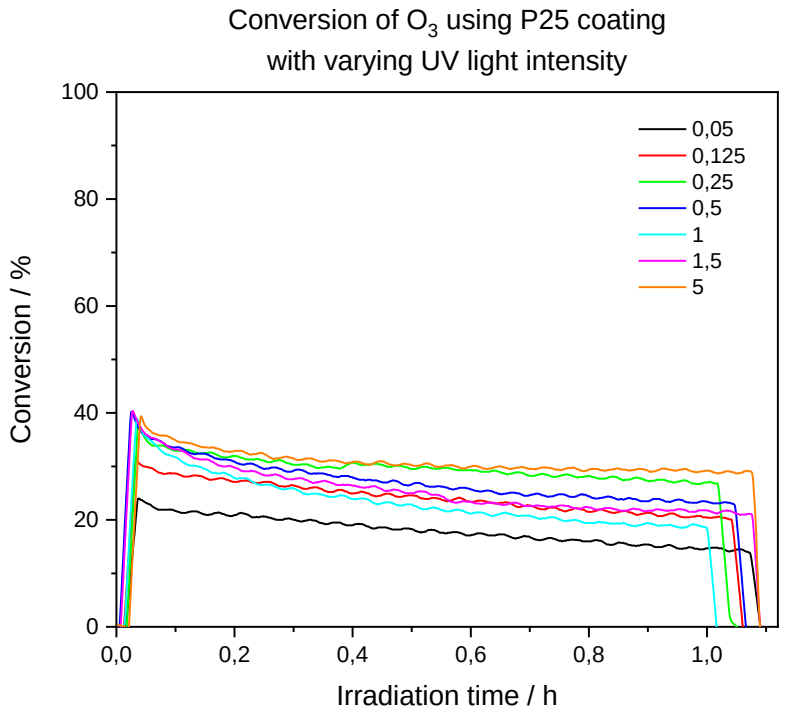



**Fig. 6** Dependence of $O_3$ conversion on the irradiation time at each UV intensity (in mW $cm^{-2}$) for functional coating: a) FN2; b) P25

Measurement results for each UV irradiation intensity and both photocatalysts are summarized in Tab. 2. Therefore, we can observe that at each of intensities the FN2 has better results than the P25.

**Tab. 2** Effect of UV irradiation intensity on photocatalytic ozone degradation by FN2 and P25 functional coatings

| **Photocatalyst** | **UV intensity** | **$[O_3]_{in}$** | **$[O_3]_{out}$** | **Conversion** | **$\Delta O_3$** | **$\Delta O_3$** |
|---|---|---|---|---|---|---|
| | mW $cm^{-2}$ | ppbv | ppbv | % | µmol $m^{-2}$ $h^{-1}$ | µg $m^{-2}$ $h^{-1}$ |
| **FN2** | 0,05 | 100 | 68 | 32 | 48 | 2318 |
| | 0,125 | | 67 | 33 | 49 | 2347 |
| | 0,25 | | 64 | 36 | 55 | 2628 |
| | 0,5 | | 60 | 40 | 60 | 2878 |
| | 1 | | 62 | 38 | 57 | 2714 |
| | 1,5 | | 58 | 42 | 64 | 3060 |
| | 5 | | 61 | 39 | 59 | 2837 |
| **P25** | 0,05 | 100 | 85 | 15 | 22 | 1058 |
| | 0,125 | | 80 | 20 | 31 | 1469 |
| | 0,25 | | 73 | 27 | 41 | 1944 |
| | 0,5 | | 77 | 23 | 35 | 1685 |
| | 1 | | 82 | 18 | 28 | 1332 |
| | 1,5 | | 78 | 22 | 33 | 1570 |
| | 5 | | 71 | 29 | 44 | 2102 |

a) b)

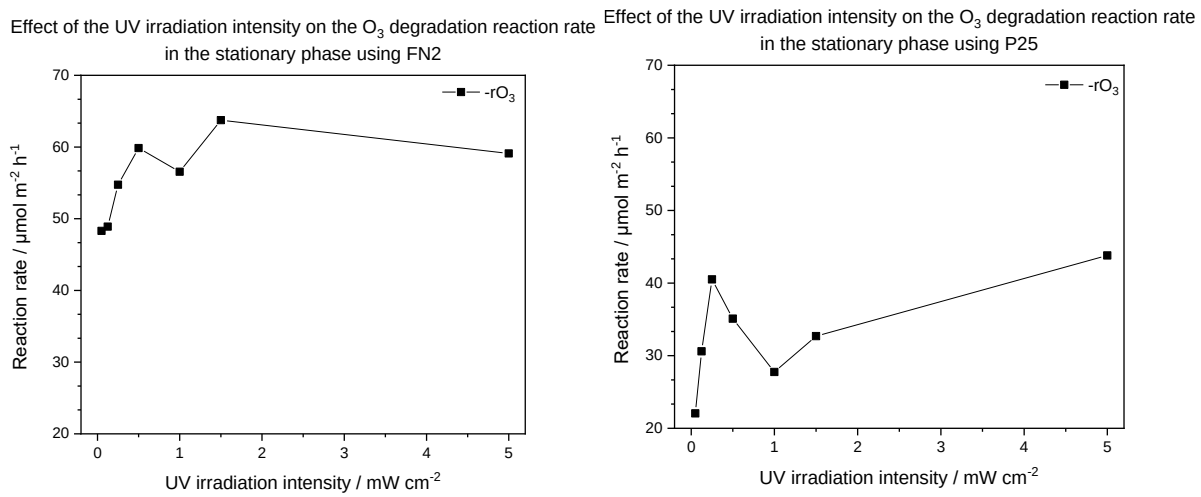



**Fig. 7** Dependence of reaction rate of ozone degradation on the UV intensity (in mW $cm^{-2}$) for functional coating: a) FN2; b) P25

## 5. Conclusion

The aim of this series of experiments was to find out whether photocatalytic degradation of ozone is possible. The results show that the photocatalytic degradation is possible. The degradation is even very effective.

The next goal was to assess the effect of the relative air humidity and the UV irradiation intensity on the degradation activity of the functional coatings. It was found that the effect of both parameters isn't very significant. The only exception is the P25 dependence on the humidity where significant decrease of activity is observed with increasing humidity.

The comparison of both materials works better for the FN2. At the 0% humidity the conversion rates are equal for both coatings but with the increasing humidity the FN2 stands significantly better. This trend is confirmed by subsequent measurement of the dependence on irradiation intensity which took place at 50% relative humidity and where the FN2 photocatalyst had better results at each of the intensities. Regarding relative humidity normally being between 50 and 100 %, this difference is very important.