

# Photocatalytic degradation of acetone in gas-phase: comparison between nano and micro-sized TiO<sub>2</sub>

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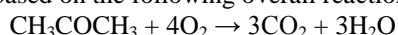
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## 1 Introduction

Volatile Organic Compounds (VOCs) are widely used in industrial processes and for domestic activities, so generating water and air pollution. Well-known indoor sources of VOCs include cigarette smoke, building materials, paints, lacquers, glues and cleaning products [1]. In particular, the use of paints in industrial processes is responsible for the widespread utilization of organics solvents, such as acetone. Acetone (CH<sub>3</sub>COCH<sub>3</sub>) is a common chemical used extensively in a variety of industrial and domestic applications. Therefore, we chose it as a model contaminant. Photocatalytic oxidation of acetone is based on the following overall reaction:



The reaction occurs through radical mechanism carried out by hydroxyl radicals, with the formation of several intermediate products such as formaldehyde, formic acid, methanol and acetaldehyde [2].

The TiO<sub>2</sub> photodegradation of organic compounds has been proposed as an alternative Advanced Oxidation Processes (AOP) for the decontamination of air, since the photocatalytic oxidation of organic compounds in gas phase appears to be a promising process for the remediation of polluted air.

In this paper the photocatalytic efficiency towards acetone degradation of four commercial samples, two micro-sized and two nano-sized TiO<sub>2</sub> powders is compared. The purpose of this study is to evaluate the feasibility of using micro-sized TiO<sub>2</sub> instead of nanometric particles, which results in a greater environmental impact and higher production costs if compared to the former one.

## 2 Experimental

### 2.1 Preparation

Four commercial samples of titanium dioxide, two nanometrics (AEROXIDE<sup>®</sup> TiO<sub>2</sub> P 25 by Evonik Ind. And PC105 by CrystalGlobal) and two micrometrics (Tiona AT-1 by CrystalGlobal and 1007 by Kronos), were chosen as photocatalysts and used without any treatment or activation.

TiO<sub>2</sub> powders (0.050 g) were first suspended in 2-propanol (50 ml) so obtaining a homogeneous suspension and then deposited by drop casting onto one side of the laminas. The solvent was simply evaporated at room temperature without any further treatment. The samples consisted in a thicker layer, obtained by overlapping three TiO<sub>2</sub> coatings (labelled as T, standing for triple layers, followed by the substrate abbreviation) [3].

### 2.2 Characterization

All samples were characterized by TEM in order to evaluate the particles size and the agglomeration degree of the used samples.

Powder samples of nano and micro-sized TiO<sub>2</sub> were also characterized by FTIR-ATR analysis, performed with FTS-40 BIO RAD. The analyses were performed before and after the degradation reaction to evaluate the byproducts adsorbed onto the photocatalysts surface.

### 2.3 Testing procedure

Photocatalytic degradations of acetone were conducted in a Pyrex glass cylindrical reactor with diameter of 200 mm and effective volume of 5 L. The total amount of catalyst used in the tests was 0.05 g. The gaseous mixture in the reactor was obtained by mixing hot chromatographic air, humidified at 37%, and a fixed amount of volatilized (60 °C) acetone, in order to obtain an initial concentration of 2000 ppmV, without condensation phenomena. The actual concentration of acetone in the reactor is determined directly by micro-GC sampling. Photon sources were provided by a 500 W iron halogenide lamp (Jelosil, model HG 500) emitting in the 315-400 nm wavelength range (UV-A) [4].

Acetone adsorption onto TiO<sub>2</sub> layer was determined through dark experiments: no appreciable amount was detected. CO<sub>2</sub> formation was detected through micro-GC analysis.

## 3 Results and Discussion

The samples are commercial white powders characterized by different chemico-physical features summarized in Tab. 1:

Samples	Phase composition	BET (m <sup>2</sup> /g)	Crystallites size (nm)
P25	85% anatase 15% rutile	50	23
PC105	Anatase	80	20
TionaAT-1	Anatase	10	300
1007	Anatase	11 [5]	n.d.

Tab. 1 – Chemico-physical features of samples TiO<sub>2</sub>

The amount of degraded acetone is reported in Tab. 2. As it can be seen, the percentage of degradation of the pollutant obtained with nanometric and micrometric

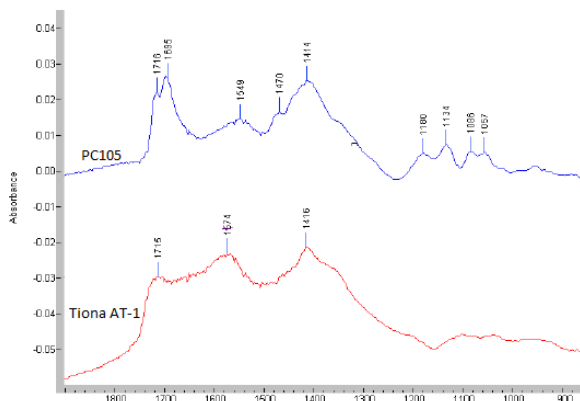
TiO<sub>2</sub> samples is quite similar, ranging from 48 to 60%. As a consequence, this result demonstrates that micro-sized TiO<sub>2</sub> powders are good candidates for the photocatalytic degradation of organic molecules in the gas phase, giving a percentage of degradation comparable to nano-sized TiO<sub>2</sub> samples.

Samples	Degradation% acetone in 6 h	% CO <sub>2</sub> product in 6h
P25	60	29
PC105	55	25
Tiona AT-1	57	9
Kronos 1007	48	28

**Tab. 2 – Percentage of acetone degradation and CO<sub>2</sub> after 6 hours.**

Tab.2 also shows the %CO<sub>2</sub> formation in 6 h, calculated dividend the CO<sub>2</sub> formation from the acetone degradation expressed both in ppm. The value is very similar for the two nanoTiO<sub>2</sub> and for one of the micro-sized sample while it is realatevely low for the Tiona AT-1, notwithstanding the good conversion degree. This result does provide that on the surface on all samples, but in particular on Tiona At-1 a large number of by-products are adsorbed as already observed with other polluting molecules [5].

FTIR-ATR spectra registered after the photodegradation, and to which the parent spectra of the same samples before the catalysis were subtracted. Fig.1 reports two spectra from one nano-sized and one micro-sized TiO<sub>2</sub>. The spectra profiles are extremely different confirming once more the different molecules adsorbed on the samples. The peak of acetone is evident at 1715 cm<sup>-1</sup> [6]. Moreover, at 1415 cm<sup>-1</sup> carbonates can be observed suggesting that during the kinetic of degradation carbon dioxide may be formed and then adsorbed on the catalyst surface as carbonate. Thus, there is no evidence of the presence of any other reaction intermediate in large amount.



**Fig. 1 – FTIR-ATR spectra of post-catalysis samples (subtracted with parent pre-catalysis sample spectra) of PC105 and Tiona AT-1.**

#### 4 Conclusions

Both micro-sized and nano-sized samples of TiO<sub>2</sub>, irradiated by UV lamp, led to a remarkable acetone degradation. Since nano-sized powders are more harmful to the environment than micro-sized ones, the results reported in Fig.2 demonstrate that micrometric TiO<sub>2</sub> is a

possible alternative to nanometric TiO<sub>2</sub> in acetone removal from the ambient air.

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