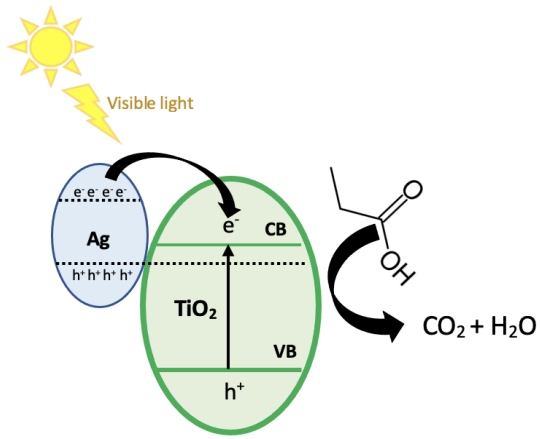
# Decomposition of Propionic acid under the visible light, by enhanced noble metal decorated titanium-based catalysts

***Haghshenas Niloofar***, *Bianchi Claudia Letizia, Falletta Ermelinda, Falcone Giacomo*
*Università degli studi di Milano, Milan, Italy. Niloofar.haghshenas@yahoo.com*




Unpleasant odours are the most frequent reason for complaints in urban and industrial areas. In recent years, problems linked to odour pollution have been a big concern due to the population increase in many urban areas. These pollutants come from food production companies, pharmaceuticals and pesticides, biogas plants, animal and human waste, animal feed production, and the plastic industry.

In this work, the effect of enhanced photocatalysts, for the decomposition of propionic acid, as one of the main organic compounds responsible for the unpleasant odours, under the visible light, was studied.

## Background

Titanium dioxide ($TiO_2$) is one of the most efficient and industrially favourable photocatalysts due to its low cost, long-term stability, and chemical inertness.[1] However, this photocatalyst is still widely used in practical applications because of some critical drawbacks such as its high bandgap energy and poor electron-hole separation efficiency that makes it less photocatalytically active.

For the past few years, many attempts have been made to improve the photocatalytic activity of TiO2, including doping or decorating it with metallic or non-metallic elements. Among them, silver nanoparticles have shown promising, enhanced growth of the photoactivity by declining the energy of the photocatalyst's bang gap and making it more active under the visible light..[2 3]

Starting from a $TiO_2$-based catalyst decorated with silver nanoparticles, which is quite active under visible light, some research has been carried out, and they have shown a significant improvement in the catalytic activity, further decorating the material with other noble metals. [4] The presence of noble metals, such as platinum or gold, in the form of nanoparticles has shown significant change on photodecomposition of organic compounds.[5 6]

The following research aims to study the photodecomposition of propionic acid under visible light using different $TiO_2$-based photocatalysts modified by means of the first decoration with Ag and a subsequent decoration with other noble metals (Pt, Au). It has been shown that, as regards the second decoration, decoration with only Pt or Au leads to an inhibition of the photodegradative properties of the catalyst. Conversely, a decoration performed using both metals, Au, and Pt leads to a remarkable improvement in photocatalysis.

Many studies in the past few years have reported the bimetallic nanoparticles(BNPs) and trimetallic nanoparticles (TNPs) enhancement in catalytic activity and selectivity than the corresponding monometallic ones (MNPs).[4 7]

## Method

In this study, TiO2 1077 by Kronos was decorated with 8%(wt) Ag nanoparticles by the wet impregnation method. Finally, the material was calcinated in the air at 400°C and used as support for decoration by other metals. Au, Pt, and AuPt NPs were prepared by the impregnation method starting from the corresponding salts in the presence of proper stabilizers.

The samples were individually coated on glass surfaces and placed inside a closed 5L Pyrex reactor, containing an initial 0.5 ppm concentration of propionic acid, in vapour phase, under the LED (P= 2450 LUX), for 350 minutes. Tests were monitored by Gas chromatography (Shimazu GC-2025, FID detector).

## Results

Characterization analysis was done on all the samples.

**UV-Vis-NIR** diffuse reflectance spectra were

recorded between 200-700 nm range, investigated through Tauc plot, and all the band gaps are around 3.2 eV.

**Energy dispersive spectroscopy (EDS)** was done for all the synthesized photocatalysts, Fig.1, shows the EDS mapping of Ti, Ag, Pt and Au particles for the $Ag/TiO_2$ photocatalyst which was decorated with bimetallic PtAu nanoparticles.

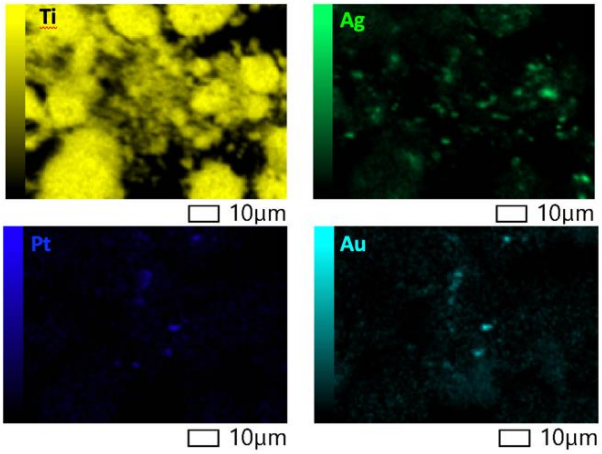



Fig. 1 Energy dispersive spectroscopy (EDS) mapping of $Ag/TiO_2$ decorated with bimetallic PtAu

Fig.1 indicates the presence of silver, platinum, and gold on the support.

**Photodegradation of Propionic acid**

Five-hour monitoring of propionic acid photodecomposition in the presence of the different photocatalysts under visible light irradiation can be observed in Fig.2.

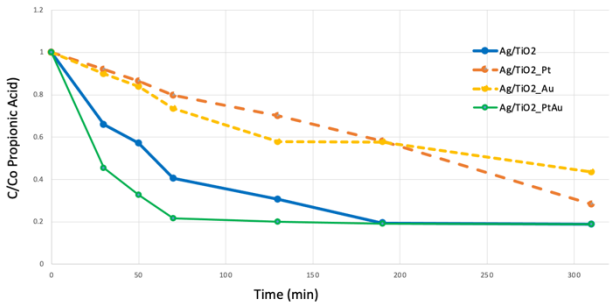



**Fig. 2** Propionic acid photodecomposition of different enhanced photocatalyst under the visible light

The results show a decrease in the photodecomposition efficiency of $Ag/TiO_2$ when decorated individually by Pt or Au metals. In contrast, $Ag/TiO_2$ decorated by bimetallic PtAu photocatalyst demonstrated a significant improvement in photoactivity (green graph).

This improvement in photocatalytic activity could be explained by higher active surface of the $Ag/TiO_2$ photocatalyst decorated with bimetallic PtAu and electron transfer enhancement in comparison with those decorated individually by Pt or Au.

Keywords: Propionic acid, Photodecomposition, Bimetallic decoration

**References**

1. Reddy, K. R., Hassan, M. & Gomes, V. G. Hybrid nanostructures based on titanium dioxide for enhanced photocatalysis. *Appl. Catal. A Gen.* **489**, 1–16 (2015).
2. Ansari, S. A., Khan, M. M., Ansari, M. O. & Cho, M. H. Silver nanoparticles and defect-induced visible light photocatalytic and photoelectrochemical performance of Ag@m-TiO2 nanocomposite. *Sol. Energy Mater. Sol. Cells* **141**, 162–170 (2015).
3. Song, C. *et al.* Preparation and characterization of silver/TiO2 composite hollow spheres. *J. Colloid Interface Sci.* **272**, 340–344 (2004).
4. Zhang, H. & Toshima, N. Preparation of novel Au/Pt/Ag trimetallic nanoparticles and their high catalytic activity for aerobic glucose oxidation. *Appl. Catal. A Gen.* **400**, 9–13 (2011).
5. Yuan, D., Gong, X. & Wu, R. Decomposition pathways of methanol on the PtAu(111) bimetallic surface: A first-principles study. *J. Chem. Phys.* **128**, (2008).
6. Shiraishi, Y., Toi, S., Ichikawa, S. & Hirai, T. Photocatalytic NH3 Splitting on TiO2 Particles Decorated with Pt-Au Bimetallic Alloy Nanoparticles. *ACS Appl. Nano Mater.* **3**, 1612–1620 (2020).
7. Yadav, N. *et al.* Trimetallic Au/Pt/Ag based nanofluid for enhanced antibacterial response. *Mater. Chem. Phys.* **218**, 10–17 (2018).