Noble metal-modified TiO_2 obtained by the sol-gel method: Ethanol photodegradation

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INTRODUCTION & AIM

This work aimed to prepare by the sol-gel method TiO_2 and Pt-modified TiO_2 with photocatalytic activity for the oxidative degradation of ethanol in gaseous phase under simulated solar light irradiation.

Nanopowders with different compositions, sizes, and dimensional distributions can be obtained using the sol-gel method. The dopant was added either during synthesis (in a single step, TiO_2-Pt_R) or by post-synthesis impregnation (TiO_2-Pt_Imp) to the sol-gel method used for obtaining the powder photocatalysts.

The following is an increasing order of powder reactivity in the photocatalytic tests: TiO_2, TiO_2-Pt in-situ, and TiO_2-Pt by post-synthesis impregnation.

METHOD

The characterization methods were infrared spectroscopy (FT-IR), transmission electron microscopy (TEM), X-ray diffraction (XRD), X-ray fluorescence (XRF), UV-Vis and the determination of the BET-specific surface area. The samples were tested as photocatalysts in the oxidative degradation of ethanol in the gaseous phase and under solar simulated light irradiation.

The samples was noted TiO_2, TiO_2-Pt_R (doped in-situ) and TiO_2-Pt_Imp (doped by impregnation post-synthesis).

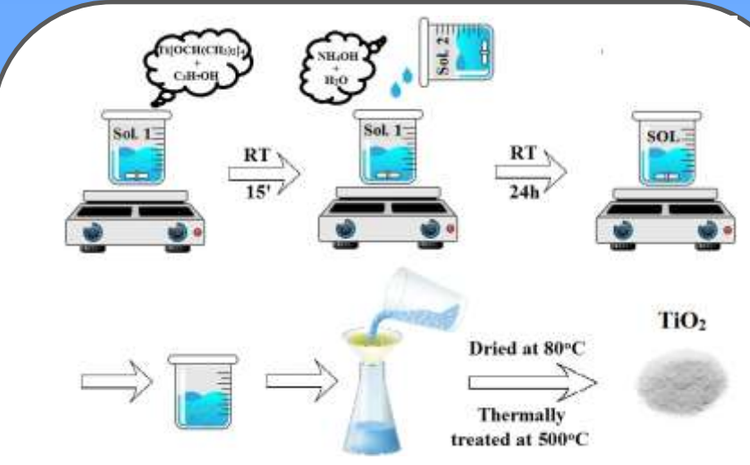
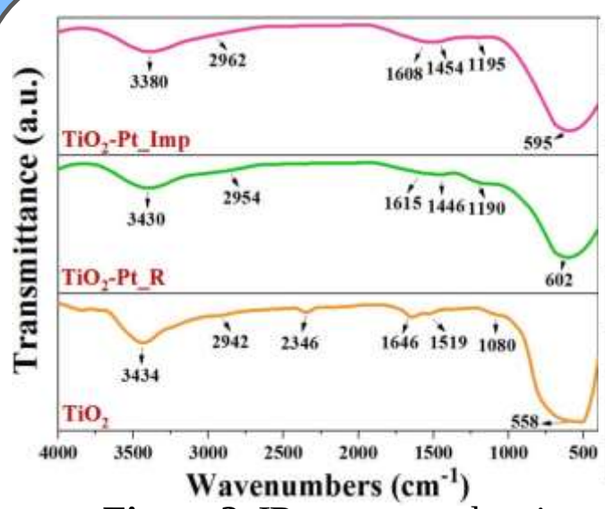


Figure 1. TiO_2 preparation by the sol-gel method.

Reagents: titanium isopropoxide for TiO_2 source and $PtCl_4$ for dopant (1 mol%).

Resulted powders are white for TiO_2 and light grey for Pt doped TiO_2.

RESULTS & DISCUSSION



Wavenumbers (cm^{-1})			Assignments and vibration mode
TiO_2	TiO_2-Pt_R	TiO_2-Pt_Imp	
558	602	595	Ti-O stretching vibration of TiO_6
1080	-	-	C–O
-	1190	1195	
-	1446	1454	$\nu_s(CO_3)^{2-}$
1519	-	-	$\nu_{as}(CO_3)^{2-}$
1646	1615	1608	δH_2O adsorbed water
2346	-	-	CO_2 absorption
2942	2954	2962	C-H, $\nu_{as}(CH_3)$
3434	3430	3380	νOH structural OH group

Figure 2. IR spectra and assignment of vibration bands of thermally treated powders.

♦ The small displacement to higher wavelength values in case of doped samples is assigned.

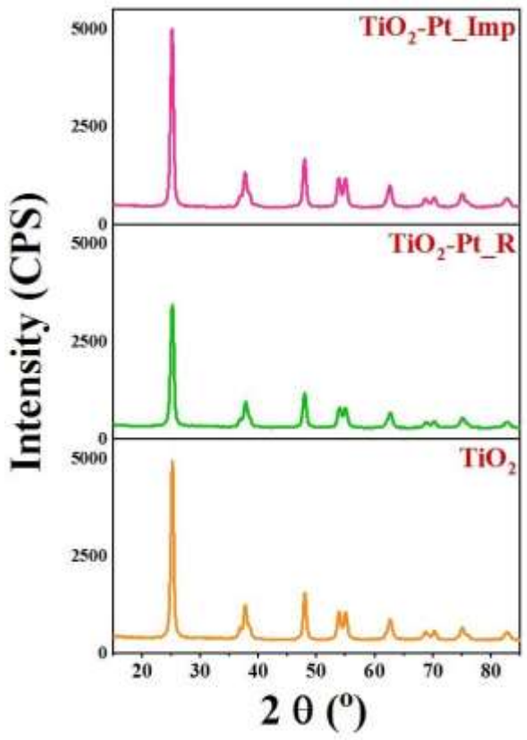


Figure 4. XRD patterns of the samples.

♦ All samples exhibit a single anatase phase.

♦ Doping with Pt does not alter the structure.

Table 1. The lattice parameters of the thermally treated samples.

Sample	Crystalline phase	Lattice parameters (Å)			Crystallite size (nm)
		a	b	c	
TiO_2	Anatase	3.786	3.786	9.506	12.9
TiO_2-Pt_R	Anatase	3.789	3.789	9.495	12.8
TiO_2-Pt_Imp	Anatase	3.789	3.789	9.515	13.8

Table 2. Elemental composition of the powders.

Sample	Composition	Values (Mass %)	Line
TiO_2	Ti	59.25	Ti-KA
	O	39.57	O-KA
	Traces	1.18	
TiO_2-Pt_R	Ti	58.72	Ti-KA
	O	39.41	O-KA
	Pt	0.51	Pt-LA
	Traces	1.36	
TiO_2-Pt_Imp	Ti	59.32	Ti-KA
	O	38.25	O-KA
	Pt	1.05	Pt-LA
	Traces	1.38	

♦ The XRF confirmed the presence of Pt in the doped samples indicating successful incorporation of Pt.

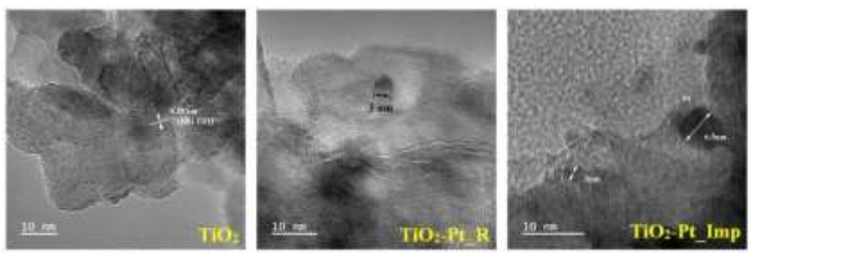


Figure 3. TEM micrographs of the nanopowders.

♦ The TiO_2 sample is formed by aggregates of crystallites with dimensions of 20-60 nm.

♦ In case of TiO_2-Pt_R the surface of the aggregates is smoother.

♦ TiO_2-Pt_Imp present Pt nanoparticles are spherical and have dimensions from 2.5 nm to 7 nm.

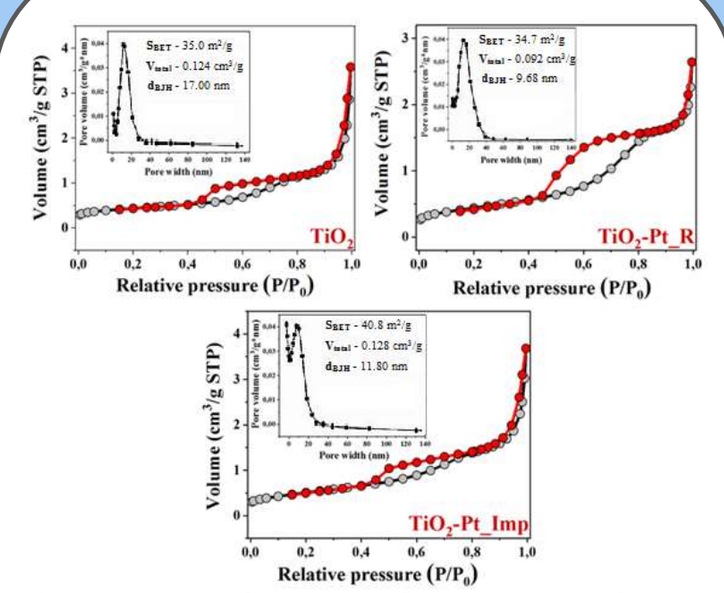


Figure 5. N_2 adsorption-desorption isotherms and pore size distributions of powders.

♦ All three samples exhibit type IV(a) isotherms with H3 hysteresis loops which is characteristic of mesoporous materials.

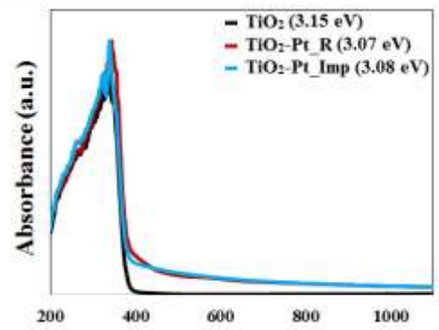
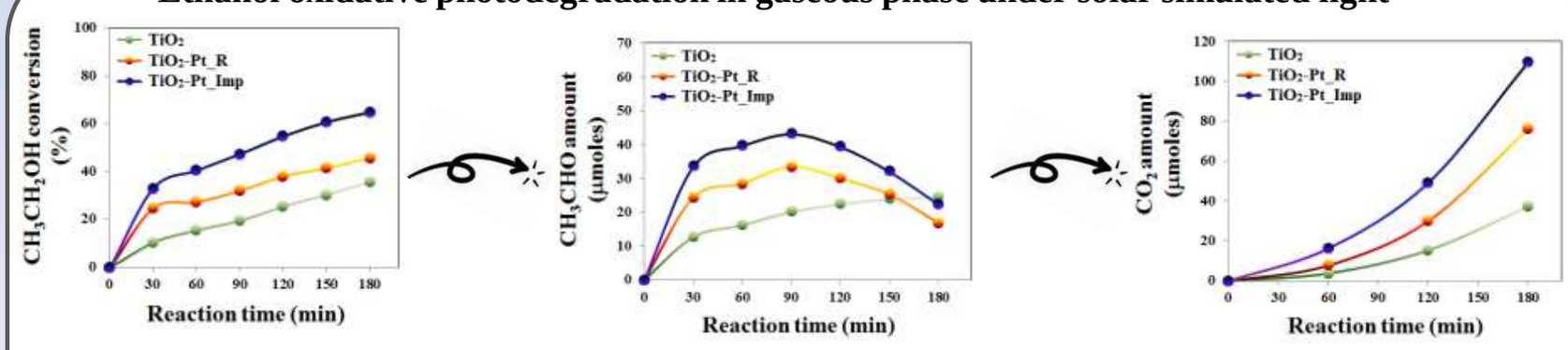


Figure 6. UV-Vis absorption spectra.

♦ A strong absorption in the UV region accour.

Ethanol oxidative photodegradation in gaseous phase under solar simulated light



♦ Oxidative degradation of ethanol leads to acetaldehyde (CH_3CHO) and then, through successive reactions, to the intermediate formation of formic acid (HCOOH - in trace amounts) and finally to CO_2.

CONCLUSIONS

♦ TiO_2 nanopowders were obtained using the sol-gel method, and doping with Pt was done in-situ or followed by impregnation post-synthesis.

♦ The structural, morphological, and optical characterizations of the obtained nanopowders were analyzed in according to their photocatalytic activity.

♦ After 3 hours of solar simulated light irradiation, TiO_2-Pt_Imp powder achieved the highest conversion of ethanol photodegradation (64.82%).

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