Improved Visible Light Response of Metal/Non-Metal Doped TiO_2 Nanoparticles Utilization in Organic Pollutants Degradation

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Introduction

Titania (TiO_2) based materials are well known semiconductors able to be activated under light irradiation and therefore catalyze several chemical processes. This photocatalytic performance in combination with their chemical stability, low toxicity and low cost of precursors, render such materials as potential candidates for environmentally friendly processes such as wastewater treatment and air purification. These performance capabilities find application, among others, in novel façade coatings.

Objective

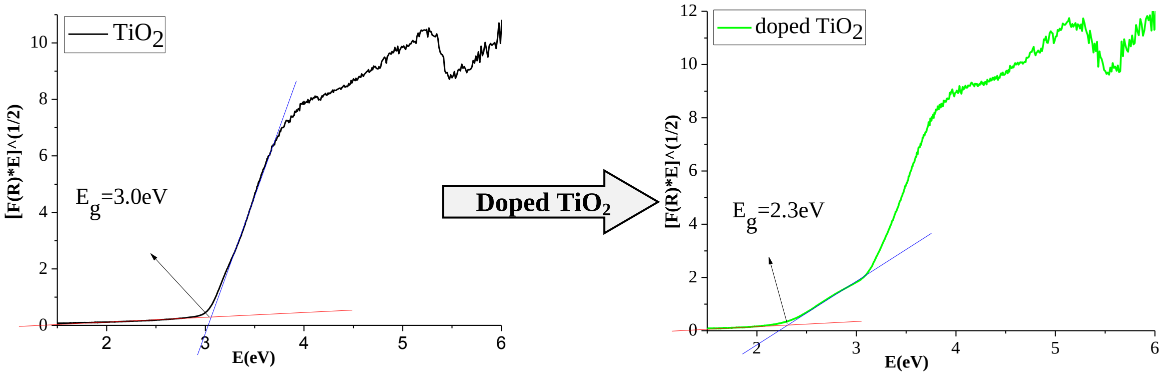
Since TiO_2 absorbs only a minor part of the active solar spectrum that constitutes only the 5% of solar light spectrum, primary objective of this study is to improve light harvesting of these materials making them absorb in the visible range of the electromagnetic spectrum and thereby improving their efficiency. For this purpose TiO_2 was modified via doping with metal and non metal elements that have the potential to stimulate the visible light response of particles synthesized.

Materials and methods

Non metal and/or metal doped TiO_2 photocatalysts as well as pure TiO_2 powders were synthesized via sol-gel method, using titanium precursors with non metal [N or S,N] and metal [Ag] doping elements. The synthesized powders have been imposed to different heating cycles at several temperatures above 400^{o}C. Structural and morphological characterizations have been accomplished through X-ray powder diffractometry (XRD), scanning electron microscopy (SEM), dynamic light scattering (DLS), BET, DR-UV-Vis and IR spectroscopy. Band gap energy (E_g) measurements have been performed via UV-Vis spectroscopy and accordingly calculated from a plot of modified Kubelka–Munk function versus the energy of exciting light by converting the scanning wavelength (λ) into photon band gap energies (E_g). Each of the parameters mentioned above are expected to contribute in different ways to the desired photocatalytic performance of TiO_2 based nanostructured particles. Concerning the photocatalytic activity determination, several experiments have been conducted in a photoreactor, where the activity of the doped nanostructured TiO_2 catalysts were evaluated through the degradation of two model pollutants, namely Methylene Blue (MB) and Methyl Orange (MO).

Results

According to XRD analysis, doped TiO_2 powders consisted mainly of the TiO_2 anatase phase, which is considered to be the most important in terms of the visible light photocatalytic activity. This observation is applicable especially in the case of calcinations temperature less than 600^{o}C. XRD data also demonstrated that the synthesized doped powders can be characterized as nanocrystalline with crystalline size ranging between 8–30nm. Furthermore, the band gap energy was estimated to be less than 2.5 eV, therefore the photocatalytic performance of doped TiO_2 powders is extended in the visible range. Consequently, the new powders exhibited significantly improved photocatalytic performance in MO and MB in comparison to the non-doped TiO_2 and reference compounds by reducing up to 90% the model pollutants tested.



Band gap (E_g) reduction via doping of TiO_2

Conclusions

A series of sol-gel synthesized and accordingly thermally treated doped TiO_2 nanoparticles exhibit favorable structural and morphological characteristics as well as functional properties especially through visible light irradiation. This first evaluation renders these catalysts as promising TiO_2 based photocatalytic materials ready to be exploited in various applications such as metal matrix composite coatings, paints and/or plastics, harvesting their self-cleaning and antimicrobial properties.

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