Obtaining metallic centers on semiconductors in a hydrogen-reducing atmosphere

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Introduction

Up today, scientists work on the obtaining a highly active photocatalytic material, whose band excitation would be possible primarily using visible light (Domen, Kudo, & Onishi, 1986; Lei, Yu, Tang, & Zhu, 2017; Ni, Leung, Leung, & Sumathy, 2007). Such an achievement would allow to minimize the costs of energy used during photocatalytic processes. The most commonly used semiconductor for photocatalytic processes is TiO₂. However, due to the considerable width of band gap (3.2 eV), it is necessary to modify it in order to achieve satisfactory photocatalytic reaction efficiency (Binas, Venieri, Kotzias, & Kiriakidis, 2017). One of the modification is the deposition on the semiconductor of precious metals, e.g. platinum, and the most commonly used methods for this purpose is photodeposition or chemical reduction. However, the proposed method of reduction with using hydrogen at elevated temperature after optimization is more precise and a cleaner method in the context of samples obtained on its way. Today, the literature presents few reports on the method of producing metallic centers on semiconductors under hydrogen reducing atmosphere, therefore it is necessary to optimize method.

Materials and Methods

At the initial stage of the experiment, the appropriate weight of TiO₂ (Degussa P25) was suspended in water, and then the appropriate volume of platinum salt solution was added to the slurry thus obtained. TiO₂ was modified with 0.05 mol% of platinum. After thorough mixing of the TiO₂ aqueous suspension and Pt compound on the magnetic stirrer, the vessel was placed in an oven to completely evaporate the water (overnight at 80°C). Next, the powders were placed in a crucible and then in a pipe furnace with the possibility of connecting and controlling the gas flow (H₂/Ar, v:v 1/19) during heating. Two series of TiO₂/Pt were made in this way, first was obtained in a process carried out at a constant temperature (300°C) but at different time of heating (1, 2.5, 5, 10 h), and the second (after selecting the optimal heating time) was obtained at different temperature of the process. In order to characterize the obtained samples, spectroscopic UV-Vis/DRS analysis was performed, luminescence was measured and morphology analysis performed using

scanning electron microscopy (SEM). In the final stage, the photocatalytic activity of the obtained samples in the phenol degradation reaction under UV-Vis and visible irradiation was examined. The concentration of phenol in the collected samples during the processes was determined by HPLC.

Results

The obtained nanomaterials were analyzed in terms microscopic morphology, spectroscopic characterized and photocatalytic properties. SEM images show that the morphology of nanoparticles calcinated with different temperatures and times have not changed the size and we cannot also see very small platinum centres. Figure 1. presents (a) absorbance, (b) photoluminescence and (c) photocatalytic properties of TiO₂/Pt. First graph shows increasing of irradiation absorption for all TiO₂/Pt nanoparticles and second graph shows decreasing photoluminescence properties TiO₂/Pt compared to the unmodified sample (P25). Last graph (c) shows that all modified photocatalyst exhibited increase photocatalytic activity in the range of visible light. The highest activity was observed for TiO₂/Pt obtained at 300°C after 5h calcinating.

Figure 1. Images present (a) absorbance, (b) photoluminescence and (c) photocatalytic properties of obtained TiO₂/Pt samples at different temperature and time carrying out the process under hydrogen atmosphere.

Discussion

Absorbance and photoluminescence spectrum confirmed the success of the carried out processes. The increasing of absorbance in the range of visible light contributed to increase photocatalytic activity in this range. Furthermore, all samples modified with Pt show a significant decrease in luminescence intensity compared to unmodified TiO₂. This trend is sometimes combined with photoactivity because the energy absorbed by the photocatalyst is more effectively used in the photocatalytic process and not immediately lost in the way of emitting luminescence (Lavand & Malghe, 2015).

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