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The effect of Co dopant on TiO_2 structure of sol–gel nanopowders used as photocatalysts

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Abstract

Un-doped and Co-doped sol–gel TiO_2 nanopowders have been prepared and structurally characterized. Three Co mass concentrations related to TiO_2 content have been used: 0.5, 1 and 2 wt%. The morpho-structural changes due to the thermal treatment and dopant presence were followed by: thermal analysis methods, X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), transmission electron microscopy (TEM) and magnetic measurements. A detailed XRD analysis, based on an own calculus program, has established the lattice constants, the average size of the crystallites, $< D >$, and the average lattice strains, $< S >$, which can give some information about the structural disorder. The values of the lattice constants lead to the conclusion that a solid solution of the $Co_xTi_{1-x}O_2$ form was obtained. The Co concentration imprints the paramagnetic behavior to the solid solutions. It influences the evolution of the $< D >$ and $< S >$ factors by the competition between: the deficit of oxygen acquired by un-doped TiO_2 in the sol–gel process (influenced by temperature), the dopant diffusion in the host lattice (influenced by ionic radius and valence) and the super-exchange interactions between the magnetic moments of the molecules of the solid solution (influenced by the concentration of Co). The sample with 1 wt% Co thermally treated at 400 °C ensures the best photocatalytic activity in the advanced degradation of nitrobenzene from water.

Keywords: A. Sol–gel processes; B. X-ray methods; D. TiO_2; Photocatalysts

1. Introduction

Chemical methods, such as sol–gel process, allow various possibilities of synthesis of oxide materials with different structures, compositions and morphologies and provide especially an attractive route for TiO_2 nanomaterials recognized for their photocatalytic properties. TiO_2 is well-known as an excellent photocatalyst that permits the degradation and finally the mineralization of xenobiotic compounds from water. The Advanced Oxidation Processes (AOPs) represent a promising technology for the treatment of wastewaters polluted with non-easily removable organic compounds due to its potential to oxidize organic compounds into nontoxic CO_2 and H_2O, as well as the possibility to decompose NOx and to reduce CO_2 under UV light irradiation [1,2]. TiO_2 is used for a large variety of organic compounds, including the nitroaromatic ones [3–6]. This is due to its special properties, such as high chemical stability and ability to be activated by sunlight, as well as efficiency in the catalysis of pollutant degradation, easiness of synthesis and lack of risks in use for both environment and humans.

The doping with metals (Pt, Pd, Au, Ag, Zn, Ni, Fe) and non-metals (C, N, S) improves the photo-oxidant properties of TiO_2 due to the higher ability of doped TiO_2 catalysts to separate the hole–electron pairs and to the higher rate of

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