Characterization and photocatalytic activity of Au/TiO₂ thin films for azo-dye degradation


Abstract

Surface modification of rough, high-surface area, nanocrystalline titania thin-film photocatalysts was performed by gold deposition via electron beam evaporation, with an attempt to enhance the decomposition reaction rate of industrial water pollutants. The materials were characterized and their photocatalytic activity was tested for methyl orange photodegradation. The surface deposition of gold particles improves the photocatalytic efficiency of the titania films by the synergetic action on the charge separation process onto the semiconductor. The most advantageous surface concentration of gold particles in the composite Au/TiO₂ photocatalyst was found to be 0.8 µg cm⁻², leading to a two times faster degradation of methyl orange with respect to the rate obtained with the original TiO₂ material. Higher surface loadings result in an efficiency decrease, and this can be understood in terms of an optimum gold particle size and surface characteristics as well as the semiconductor availability for light absorption and pollutant adsorption. No deactivation of the catalyst was observed after five consecutive photocatalytic experiments of new added pollutant.

Keywords: TiO₂ nanocrystalline thin films; Doctor-blade technique; Gold deposition; Photocatalyst activity; Azo-dyes; Methyl orange; Pollutant degradation

1. Introduction

Heterogeneous photocatalysis based on TiO₂ is one of the most active and the most promising advanced oxidation processes (AOPs), as this semiconductor is a low-cost, nontoxic, and stable material. It has been the focal point of numerous investigations in recent years particularly because of its application on the quantitative destruction of undesirable chemical contaminants [1–3]. The applicability of the process depends on its operating cost and efficiency. In the case of aqueous powder dispersions, one significant drawback is the cost of separating TiO₂ from the water after treatment, by either sedimentation and/or ultrafiltration. To overcome this obstacle, recent investigations on TiO₂ photocatalysis are oriented toward the photocatalyst immobilization in the form of thin films [4,5]. The photocatalyst immobilization/stabilization technique eliminates the majority of the problems encountered with slurries (particle aggregation, need for filtration) and enables the development of self-cleaning and self-sterilizing surfaces [6].

Gold, dispersed as ultrafine particles and supported on metal oxides, exhibits an extraordinary high activity for low-temperature catalytic combustion, partial oxidation of hydrocarbons, hydrogenation of unsaturated hydrocarbons, and reduction of nitrogen oxides [7–13]. A series of titania–metal composite nanoparticles (mainly noble metals and noble/transition metal ions) have been used in order to increase the efficiency of the photocatalytic process [14–16]. Dawson and Kamat [17], by a laser flash photolysis study, proved that there is an enhancement in the hole transfer of gold-capped TiO₂ nanoparticles; however, the authors obtained only a 10–15% increase in photocatalytic efficiency in the case of the corresponding thin films [8] and raised the question as to what extent do gold nanoparticles improve the photocatalytic activity of TiO₂ films. Recent investigations on gold titania nanocomposite particles show that metal ion doping extended the response of the photocatalyst into the visible; however, a significant decrease in