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# Photocatalytic hydrogen production using mesoporous $TiO_2$ doped with Pt

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ABSTRACT

A series of mesoporous $TiO_2$ (meso-$TiO_2$) were synthesized using the sol-gel technique. A *Pluronic F127* triblock-copolymer, a structure-directing agent, was incorporated as a soft template into the sol-gel. In addition, and during a separate synthesis, the sol-gel was doped with a Pt precursor. Semiconductors were prepared with 1.00 wt.%, 2.50 wt.%, 5.00 wt.% Pt nominal loadings, respectively. They were calcined at 500 °C and 550 °C following synthesis. Morphological and structural properties were studied by: a) X-ray diffraction, b) UV–vis spectrophotometry, c) $N_2$ adsorption-desorption (BET, BJH), and d) X-ray photoelectron spectroscopy (XPS). Optical band gap values for meso-$TiO_2$ and Pt-meso-$TiO_2$ were calculated by *Kubelka-Munk (K-M)* function coupled with Tauc plot methodology. It was observed that the prepared semiconductors displayed pore sizes in the 10–40 nm range with bimodal distributions. Their photocatalytic activity for hydrogen production via water splitting was established in a *Photo-CREC Water-II* reactor under near-UV light irradiation. The aqueous solution contained 2% v/v ethanol, employed as a renewable organic scavenger. The prepared semiconductors showed that the mesoporous 2.50 wt.% Pt-$TiO_2$ has the highest photoactivity for hydrogen generation. This suggests the important role played by the loading of platinum as a $TiO_2$ dopant, reducing the optical band gap, increasing electron storage and diminishing, as a result, electron-hole recombination. The measured Quantum Yield (QY), obtained using a rigorous approach, was established for the mesoporous 2.50 wt.% Pt-$TiO_2$ at a promising level of 22.6%.



## 1. Introduction

Currently, fossil energy resources are used extensively to satisfy most of the world's energy requirements. Projection of energy use and availability suggests that in the near future, there will be major issues and challenges to be faced with energy supply and demand. Additionally, combustion of fossil fuels leads to atmospheric emissions of carbon particles, $CO_2$ and noxious gases such as $NO_x$, $SO_x$. Thus, environmentally friendly fuels, that are both cost-effective and easily storable, are of great importance for the world's sustainable development [1].

Hydrogen is, in this respect, an ideal candidate as an energy vector [2]. Numerous technologies can be used to generate hydrogen. However, only a few of them can be considered as truly environmentally friendly. Steam hydrocarbon reforming is the current dominant technology for hydrogen production. It requires high temperatures (700–1100 °C) and emits large amounts of $CO_2$ [3]. Hence, efforts focused on water splitting are of great potential significance. Water splitting using solar energy is one of the most attractive approaches to produce hydrogen. Water splitting is an eco-friendly process that can be operated at ambient temperature and pressure. This process can take advantage from sunlight; an abundant and inexpensive renewable energy source [4–6].

The most important issue still to be addressed is the low quantum efficiency of photocatalytic materials in photocatalytic hydrogen production. This is related with restrictions in band gap excitation as well as recombination of charge carriers in semiconductor photocatalysts. Thus, promoting to low hydrogen evolution rates, which up to date have limited the practical application of this technology on a large scale.

In photocatalytic water splitting, photons are absorbed by semiconductors, and as a result, water splits into hydrogen and oxygen. Nevertheless, water splitting is not thermodynamically favourable. Current research focuses on increasing both the efficiency and

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