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Photocatalytic Degradation of Basic Red in Aqueous Medium by Ag_3PO_4

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ABSTRACT

The semiconductor Ag_3PO_4 was successfully used for the photo-degradation of Basic Red (BR), a hazardous and recalcitrant dye. The Ag_3PO_4 was prepared by precipitation route and characterized by X-ray diffraction XRD, SEM / EDS. The quenching experiments were carried and the results demonstrate that the radical OH is the responsible active specie for the BR photooxidation. The solar photocatalysis over the Ag_3PO_4 exhibits an increased performance in the BR degradation due to activation by the UV_A part of the solar light. An elimination conversion of 97% was obtained after 4 h at room temperature for a BR concentration of 20 mg/L.

Keywords: photo-degradation, precipitation, Basic Red, solar light.

1 Introduction

Dyes are extensively used in printing, food products, cosmetic and textile industries for their chemical stability and variety of colors. However, they cause large scale pollution once released in water and present a serious risk for the environment and human health owing to their toxicity and mutagenic effects [1]. Physic-chemical techniques (adsorption, coagulation/flocculation, electro-coagulation etc.) are commonly used for the treatment of effluents. However, despite their rapidity, some of them become unsuitable for the elimination of hazardous organics. In order to limit the arrival of persistent contaminants in the environment [2], efficient and ecological treatments have been developed like the advanced oxidation processes (AOPs). The heterogeneous photocatalysis is an inexpensive and environmentally friendly alternative; it uses the sun as energy source, which is available, consistency and can be exploited thermally, electrically and chemically. The photocatalysis is used to remove the pollutants in air, soil, and water as well as hydrogen production. In this respect, the photodegradation is attractive for the environmental protection and occurs by initiating oxidation reactions through the formation electron/hole (e^-/h^+). These free species act as reductor / oxidant to reduce the heavy metals and mineralize the organic molecules respectively. The wide band gap semiconductors (SCs) like SnO_2 , ZnO and TiO2 mainly in the photo-electrochemical (PEC) conversion are stable against corrosion but their gap (Eg) is greater than 3 eV, making them technically not interesting for the conversion of solar energy, accounting for less than 5% of the UV part. Accordingly, intense researches were focused on narrow band gap SCs. They are durable materials used in various applications, including catalysis, ceramic, magnetism [4] and sensors. Among the candidates. Some techniques of its synthesis are reported such as hydrothermal, Pechini, sol-gel and solid state reaction. Our attention is being paid to the preparation by chemical route due to its simplicity and enhanced active surface area, resulting in a better photo-activity [5].

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2 Experimental

2.1 Syntheses of Ag_3PO_4

The two solutions of $AgNO_3$ and Na_2HPO_4 were directly mixed; in all cases a yellow precipitate appeared which corresponds to Ag_3PO_4 which was recovered by filtration and dried at 80 °C overnight.

2.2 Pollutant

The dye considered in this study is Red called Basic Red (Sigma-Aldrich), of a very high degree of purity (99%); it was supplied by the company Fluka Analytical. Figure 1 show its molecular structure. It was used as supplied, without any prior purification. Colored solutions at various concentrations were prepared by diluting from a stock solution of 500 $mg.L^{-1}$, using distilled water.

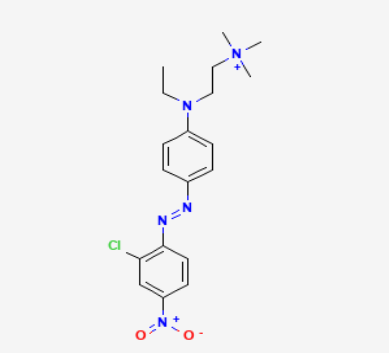

Figure1: chemical Structure of Basic Red.

3 Results and Discussion

3.1 The X-ray analysis

The phase identity and purity of Ag_3PO_4 are evaluated by X-ray powder diffraction (XRD) at room temperature. As shown in figure 2, Ag_3PO_4 exhibits a single phase and all peaks are indexed in a tetragonal crystal structure according to the map JCPDS Card N° 00-006-0505.

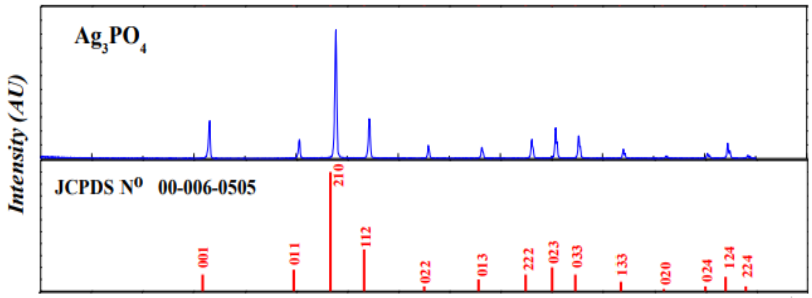

Figure2: XRD Spectrum of Ag_3PO_4.

3.2 The SEM Analysis

The SEM image of Ag_3PO_4 shows homogenous morphology (Fig. 3) and the presence of agglomerated particles with uniform and fine grains. The synthesis of Ag_3PO_4 from the precipitation has the advantage of producing a narrow particle size distribution. Furthermore, the grains are spherical in nature; the coarse morphology provides more reactive sites than the smooth one which thereby favor the Basic Red photo-oxidation.

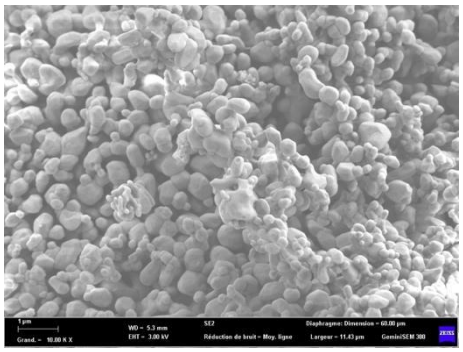

Figure 3: SEM Image of Ag_3PO_4.

3.3 Effect of pH

The pH has a considerable effect on the photocatalytic degradation of organic compounds. It is therefore necessary to study its influence during the photodegradation of the pollutant. For this, a series of experiments was carried out by varying the pH of the solution (3, 6 and 10).

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The curves which represent the variation in pH show that the photocatalytic treatment is very efficient, and that after 240 min of treatment the degradation rate obtained is greater than 96%. It is also noticed that the pollutant degrades more quickly for pH = 6.7, this is explained by the forces of attraction existing between the negatively charged catalyst and the cationic dye. At pH = 3, the rate of degradation decreases slightly, this is probably due to the presence of ions in the solution, which leads to a decrease in electron / hole recombination. So for the rest of our work, a pH of 6.7 was chosen.

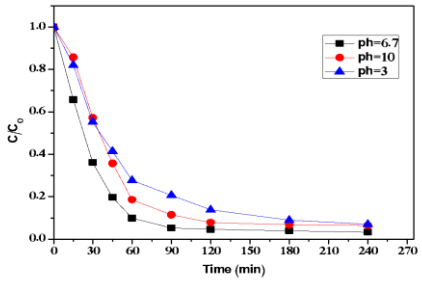

Figure 4: Effect of pH on the photocatalytic performance of BR onto Ag_3PO_4 under visible light (catalyst dose = 0.75 g/L and C_o ~ 10 mg/L).

3.4 Effect of catalyst dose

To set the optimal dose of the catalyst Ag_3PO_4, we have varied the dose in the range (0.2 - 1 g/L) at 25 °C for BR concentration at 10 mg/L and pH ~ 6.7. One can see from Fig. 5 that the degradation yield increases with augmenting the dose up to 1 g/L above which a plateau region is reached. Such improvement is due to the increased reception surface for incident photons, producing more radicals •OH and O_2•. The regression in the activity is due to the shadowing effect which limits the reception space. The light diffusion also accounts for this saturation.

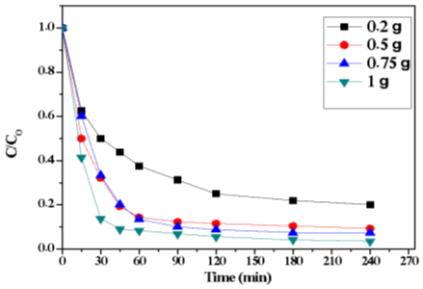

Figure 5: Effect of catalyst dose on the photodegradation of BR with Ag_3PO_4 under visible light (pH ~ 7.3 and C_o ~ 10 mg/L).

4 Conclusion

By a co-precipitation method followed by heat treatment, the developed Ag_3PO_4 photocatalyst with excellent light absorption characteristic was successfully synthesized. The application of this photocatalyst for the treatment of water polluted with a dye showed excellent photocatalytic activity for the degradation of Oll, reaching 97% efficiency after 240 min of visible light.

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