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Photodegradation of cobalt anime dye by using ZnO- AgCl nanocomposites

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Abstract

AgCl–ZnO nanocomposites were successfully prepared by usingsimple one-pot refluxing method.TheseNanocomposites were preparedand characterized by using X-ray diffraction (XRD), Scanning electron microscopy (SEM) and UV-Visible spectroscopy.Photocatalyticactivityof nanocomposites were evaluated in the degradation of cobalt amine dye (used as model pollutant) in aqueous solution under solar light and atmospheric oxygen. The decolorization efficiency of cobalt amine on the surface of nanocomposite and solar light in presence of atmospheric oxygen is about 93.2%.Influence of various operational parameters on the degradation reaction was studied and the results were discussed. The mechanism of ZnO-AgClnanocompositeillumination to produce oxidizing species and the effect of these species on the photodegradation activity in aqueous solution was suggested.

Keywords: Photodegradation, cobalt anime dye, ZnO-AgCl nanocomposites.

Introduction

Photocatalytic reaction of toxic dyes and organic compounds from waste water has studied over the years[1]. Semiconductor photocatalysis is one of the most important methods used for the complete degradation of organic dyes and toxic chemicals[2].ZnO semiconductor a wide band gap is suitable for diverse applications including UV-visible irradiation[3]. ZnO is stable to photocorrosion and nontoxic and inexpensive. The band gap energy of ZnO is 3.2 *ev* and therefore absorbs in near UV- light ((λ<387 nm.)[4].ZnO nanostructures suffer from many problems such as a high electron–hole recombination rate and the inefficient using of sun light, which limit their photocatalyticactivity[5;6]. Surface modification of ZnO with noble metal nanoparticles was used to increase the photocatalyticactivity of ZnO by decreasing the rate of recombination of electrons and holes [7; 8]. Silver nanoparticles decorated ZnO nanostructures is the best method to increase photocatalytic efficiency for the degradation ofenvironmental pollutants[9-12]. Xie*et al*[13]. Was showed that loading Ag on ZnOnanoparticlsdevelops its photostability and enhances the photocatalytic activity due to increased efficiency for separation of excited electrons and holes. Liu *et al*[14]. Was studied the photocatalytic degradation of rhodamine B (RhB) by using Ag loading on ZnO on and showed that the degradation of RhB over pure Ag nano wires was negligible as compared to ZnO, the degradation efficiency of which further was increased due to the decoration with Ag nanoparticles.

Materials and Methods

Zinc nitrate hexahydrateand ($Zn(NO_3)_2\_6H_2O$), sodium chloride, silver nitrate, sodium hydroxide, and absolute ethanol were supplied from Merck and employed without further purification. The cobalt amine dye was obtained from Shanghai and used without any purification. Molecular structure of cobalt amine [15] can be illustrated in Fig. 1

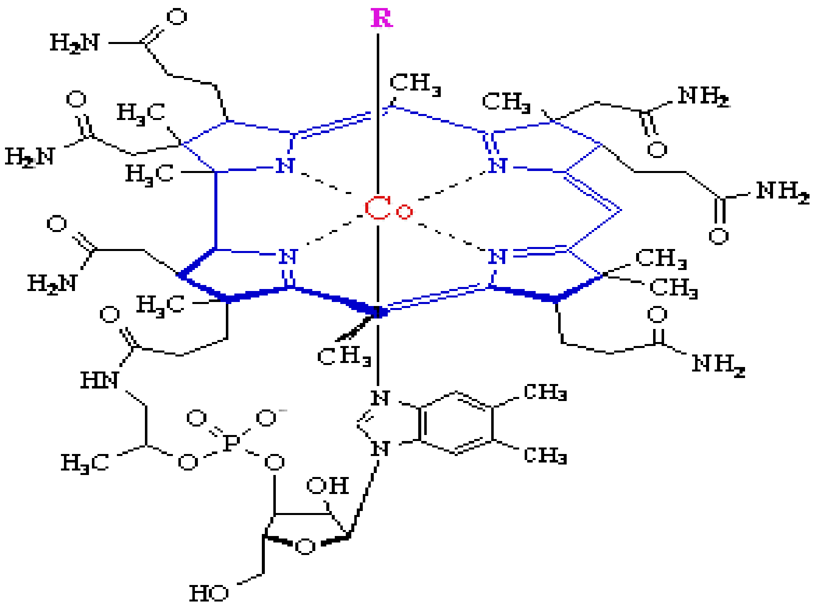

Fig.1: Chemical structure of cobalt amine dye.

Methods of Analytical

The UV-vis spectra of cobalt amine solution were recorded from 190 to 1000 nm using a UV/Vis spectrophotometer (UV752, China). Fig.2 shows there is three maximum absorbance wavelengths of cobalt amine were found at (361-520-550) nm. In the whole reaction process, it was found that the measure of concentration of cobalt amine is not interfered by the decolorization products. The maximum absorbance(361 nm) was used to determinedthe concentration cobalt amine dye in reaction mixture at different times. The decolorization efficiency of dye was defined as follows:

$$\text{Decolorization efficiency} = \left(1 - \frac{C_t}{C_0}\right) X\ 100\%$$

Where C_0 is the initial concentration of Cobalt amine, C_t is the concentration of Cobalt amine at reaction t time (min).

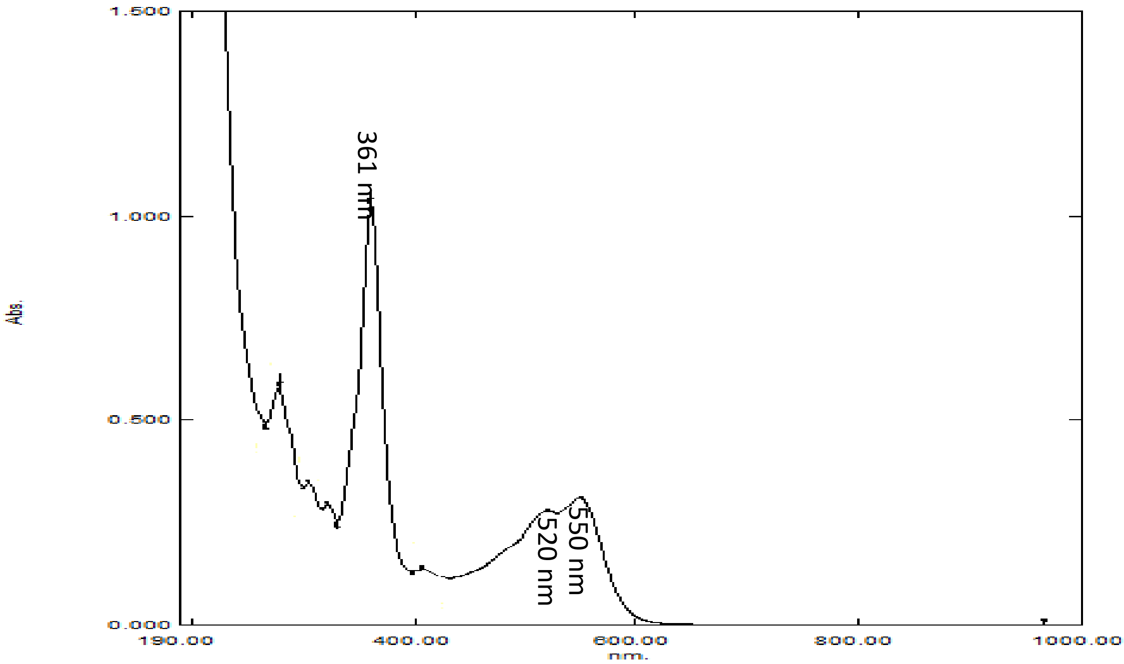

Fig. 2: UV-Visible spectrophotometery of cobalt amine dye.

Characterizations

X-ray diffraction patterns were collected from 20° to 80° in 2θ by a XRD with Cu Kα radiation (D8-Advanced, Bruker, Germany). scanning electron microscope (SME Qnanta 450 FEI USA) was used to determineSurface morphology of samples. UV–vis diffuse reflectance spectrophotometer (U-41000, HITACHI, Tokyo, Japan).The optical absorption was studied using a UV-vis spectroscopy (UV-1800 SHIMADZU).

Photocatalytic experiments

Aqueous solution of cobalt amine (40 ppm) was prepared. The reaction mixture was carried out by using 500 ml Pyrex glass beaker reservoir placed in the laboratory temperature (25 C^0). The suspension was kept homogenously by stirring on the magmatic stirrer. Pyrex glass beaker was surrounded by cellophane cover to keep solar light inside vessel and this cover provided with hole to pass atmospheric air.

Preparation of the nanocomposites

ZnO-AgClnanocomposite with chloride was be prepared by dissolving 50 ml Certain amount of zinc nitrate hex hydrate with silver nitrate solution (50 mM) under stirring at room temperature. Afterward NaOH (5 M) solution was drop wise added to the solution under stirring with speed of 1250 rpm at room temperature until pH of the solution became 10. Then, sodium chloride solution (1.450 g dissolved in 20 ml of water) was added slowly to the suspension. The suspension was refluxed at 90 C^0 for 3 h. The precipitate was collected by using centrifuge, thenthe precipitate was washed with water and ethanol to remove the un reacted reagents and dried in an oven at 60C^0 for 24 h[16].

Results and discussion

The XRD patterns of the prepared ZnO-AgClnanocomposits were illustrated in Fig. 3. The diffraction peaks of the nanocomposites are clearly related to AgCl and ZnO and loading of silver chloride does not change the ZnO crystalline phase. All XRD patterns appears peaks at 32.1°, 34.3°, 35.9°, 46.2°, 54.8°, 56.4, 67.4°, 68.1°, 68.6°and 76.7°, which are related to the hexagonal ZnO.Appears peaks at 27.8°, 32.23°, 36.2°, 47.5°, 56.5°, 62.8°, 74.4° and 76.7°, were related to the AgCl.Surface morphology of ZnO –AgClnanocomposites was studied by Scanning electron microscope and their images are shown in Fig. 4 As can be seen, ZnO nanostructures consist of highly aggregated individual rod of ZnO and spherical shape of AgCl .

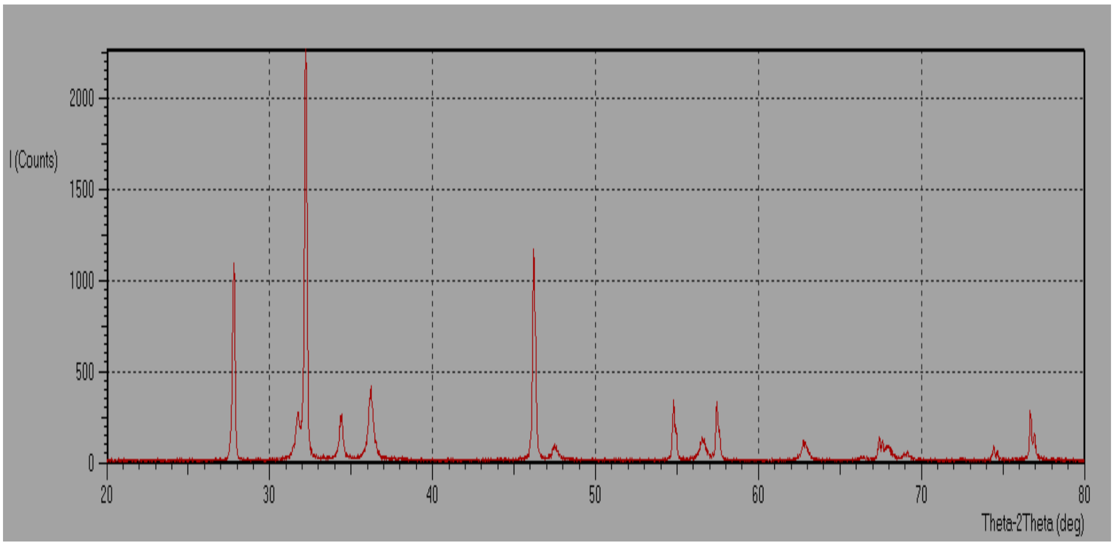

Fig. 3: XRD patterns of ZnO –AgClnanocomposites.

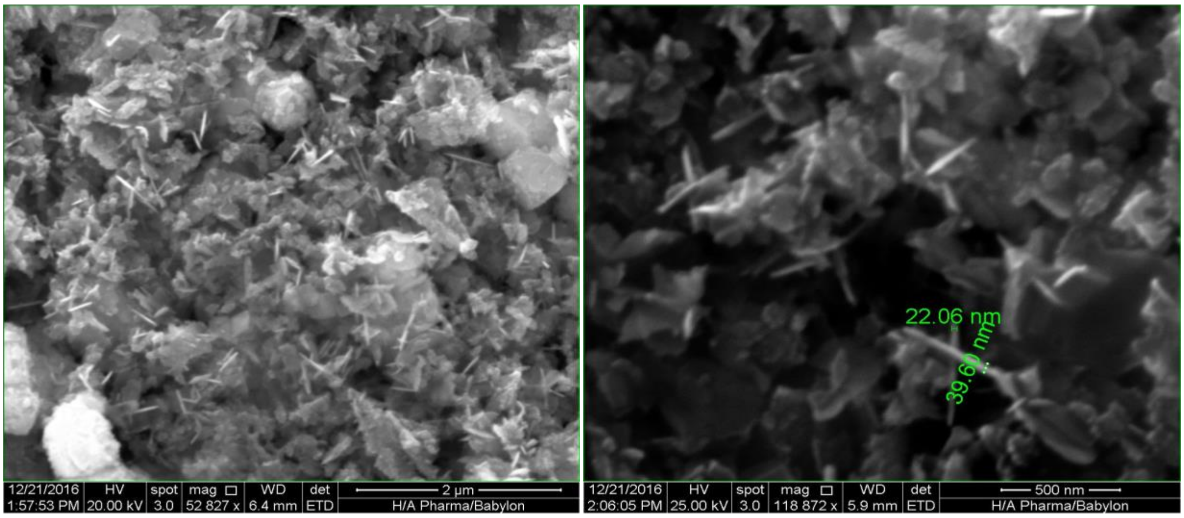

Fig. 4: SEM images of ZnO-AgClnanocomposites with the various scull.

Photodegradation of cobalt amine by ZnO-AgClnanocomposites.

A series of experiments was carried out to determine the optimum conditions for photodegradation of cobalt amine reaction without ZnO-AgClnanocompositesby using visible light. It can be seen in Fig. 5 that the dye did not undergo photodegradation due to the high stability of dye.The photocatalytic activity of the synthizedZnO-AgClnanocomposites was studied by photodecolorization of cobalt amine. The results show the photodegradationof dye by using 40 mg ZnO-AgClnanocomposites without irradiation. It can be seen that nanocomposites can remove 26.5% of cobalt amine dye from water. The lower decreasing results from the adsorption of dye on surface ofnanocomposite[17].The highest removal percentage of cobalt amine dye was obtained at 40 mg of ZnO-AgClnanocomposites in presence of solar light and atmospheric O_2 which is equal 93.7% as shown in fig (7).The suggested mechanistic of the catalysts for photocatalytic degradation of cobalt amine is proposed as follows: when photocatalyticnanocomposieds was irradiated, electron–hole pairs (e_{cb}^{-}–h_{vb}^{+}) were formed on the surface ofZnOrods[18]. Then, the $h_{vb}^{+}$was reacted with AgCl to form Ag^{+} and Cl^{0}. Some of h_{vb}^{+} generated by ZnO rod was reacted with OH^{-} to produce $\dot{O}H$. The $Cl^{0}$and OH^{-} could react with the cobalt amine dye[19]. So thatZnO-AgClphotocatalystshowed a best electron-hole pairs recombination suppression process.These reactions can be summarized as the following equations[20]:-

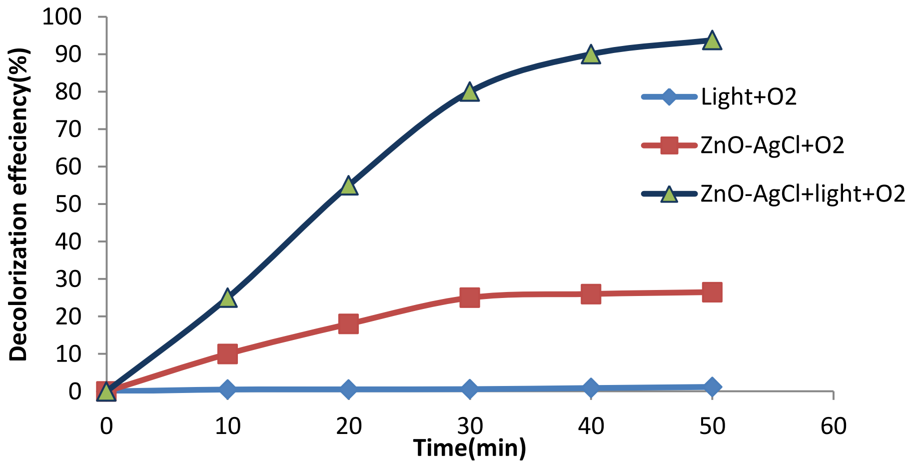

Fig.5: decolorization efficiency percentage of cobalt amine dye in aqueous solution under various conditions at 250C.

$$\mathrm{ZnO} + hv \rightarrow e^{-}_{(cb)} + h^{+}_{(vb)} ----(1)$$

$$e^{-} + O_2 \rightarrow O_2^{-} ----(2)$$

$$\mathrm{AgCl} + h^{+} \rightarrow Cl^{0} + Ag^{+} ----- (3)$$

$$Ag^{+} + e^{-}_{(cb)} \rightarrow Ag ----(4)$$

$$h^{+} + OH^{-} \rightarrow \dot{O}H ----(5)$$

$$\dot{O}H + cobaltaminedye \rightarrow degradationproducts ----(6)$$

$$\mathbf{O_2^{-} + cobaltaminedye \rightarrow degradationproducts ----(7)}$$

Conclusions

A simple one-pot refluxing method was applied for the preparation of AgCl–ZnOnanocomposites in aqueous solution at about 90C and they were characterized by different techniques. The nanocomposites have high crystalline and loading of silver chloride does not change the ZnO structure. Photocatalytic activity of the prepared nanocomposite for the degradation of cobalt amine dye by using visible light was investigated. The results on cobalt amine dye.photodegradation indicated that a prepared ZnO-AgClnanocomposites have a bestphotocatalytic activity.

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