10 March 2022

Arak University

1th National Seminar of
Development of Nanotechnology
in Basic Science and Engineering

Photo-Degradation of Acid Blue: Photocatalyst and Magnetic Investigation of CoFe2O4-CdS and CoFe2O4-CdS-Ag-Doped Nanocomposites

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Introduction

Photocatalytic oxidation is a promising technology for organic dye removal in wastewater due to its strong capacity of oxidization and environmental friendliness. Semiconductor materials have attracted considerable interest in many areas such as photoluminescence, solar photovoltaic cells, and water splitting devices. In particular, cadmium sulfide (CdS), belonging to the II-VI group, is one of the first semiconductors discovered. It has been of growing interest due to its suitable band gap (approximately 2.4 eV), strong photoresponse in the visible region, and prominent applications, such as solar cells, light emitting diodes, environmental and biological sensors, water purification systems.

Introduction

Photocatalytic oxidation is a promising technology for organic dye removal in wastewater due to its strong capacity of oxidization and environmental friendliness. Ferrite nanoparticles have a strong magnetic property, which can be easily used for magnetic separation after degradation. The present study describes the synthesis and characterization of nanosized cobalt ferrite particles using precipitation method. Then cadmium sulphide with doping Ag were prepared. Finally Ag doped CoFe2O4-CdS nanocomposites were prepared by a fast chemical procedure.

Experimental

1. Materials and methods

$Co(CH_3COO)_2\,4H_2O$, $FeCl_3\,6H_2O$, $AgNO_3$, $Cd(NO_3)_2\,4H_2O$, NaOH, NH_3 32% , thiourea and acetone were purchased from Merck or Aldrich and all the chemicals were used as received without further purifications. A multiwave ultrasonic generator (Bandeline MS 73), equipped with a converter/transducer and titanium oscillator, operating at 20 kHz with a maximum power output of 150 W was used for the ultrasonic irradiation.

Experimental

2. Synthesis of $CoFe_2O_4$ nanoparticles

0.2 g of $Co(CH_3COO)_2\ 4H_2O$ and 0.43 g of $FeCl_3\ 6H_2O$ were dissolved in 100 ml of deionized water. 30 ml of NaOH solution (1M) was then slowly added to the solution until reaching pH to around 10. A brown precipitate was then centrifuged and rinsed with distilled water. Finally the obtained precipitate was calcinated at 80ºC and its colour goes from brown to black.

Experimental

3. Synthesis of $CoFe_2O_4$-CdS nanocomposite

0.1 g of $CoFe_2O_4$ was dispersed in 50 ml of deionized water by ultrasonic waves (150 W, 60min). Then 0.2 g of $Cd(NO_3)_2$ and 50 ml of deionized water was added to the mixture containing $CoFe_2O_4$. After 20 minutes the mixture of 0.05 g of thiourea and 100 ml of deionized water was transferred into the mixture. NaOH solution was slowly added to the aqueous solution and was stirred for 15 minutes.

Experimental

4. Synthesis of CdS-Ag-doped nanocomposite

0.9 g (90%) of Cd(NO3)2 and 0.1g (10%) of AgNO3 were dissolved in 50 ml of deionized water. After 20 minutes of stirring, 0.05 g of thiourea (dissolved in 100 ml of deionized water) was added to the solution. Then sodium hydroxide solution (1M) was slowly added to the solution (pH:10) and it was stirred for 15 minutes.

Experimental

5. Synthesis of $CoFe_2O_4$-CdS-Ag -doped (100:90:10 %) nanocomposite

0.1 g (100%) of $CoFe_2O_4$ was dispersed in 50 ml of deionized water by ultrasonic waves (150 W, 60min).Then 0.18 g (Yield of CdS: 0.9g, 90%) of $Cd(NO_3)_2$ and 0.02g (10%) of $AgNO_3$ and 50 ml of deionized water was added to the mixture containing $CoFe_2O_4$. After 20 minutes the mixture of 0.05 g of thiourea (dissolved in 100 ml of deionized water) was transferred into the mixture. NaOH solution was slowly added to the aqueous (pH:10) solution and was stirred for 15 minutes.

Experimental

6. Photo-catalytic degradation process

20 ml of the dye solution (10 ppm) was used as a model pollutant to determine the photocatalytic activity. 0.05 g catalyst was applied for degradation of 50 ml solution. The solution was mixed by a magnet stirrer for 1 hour in darkness to determine the adsorption of the dye by catalyst and better availability of the surface. The solution was irradiated by a 40 W UV lamp which was placed in a quartz pipe in the middle of reactor. It was turned on after 1 hour stirring the solution and sampling (about 10 ml) was done every 15 min. The samples were filtered, centrifuged and their concentration was determined by UV-Visible spectrometry.

Results and Discussion

The structure and composition of the CoFe2O4 nanoparticles was investigated. Fig.1 shows XRD pattern of sample including cobalt ferrite nanoparticles. The XRD pattern of CoFe2O4 reveals the typical diffraction pattern of pure cubic phase (JCPDS No.: 22-1086) with Fd-3m space group which is consistent with pure cobalt ferrite.

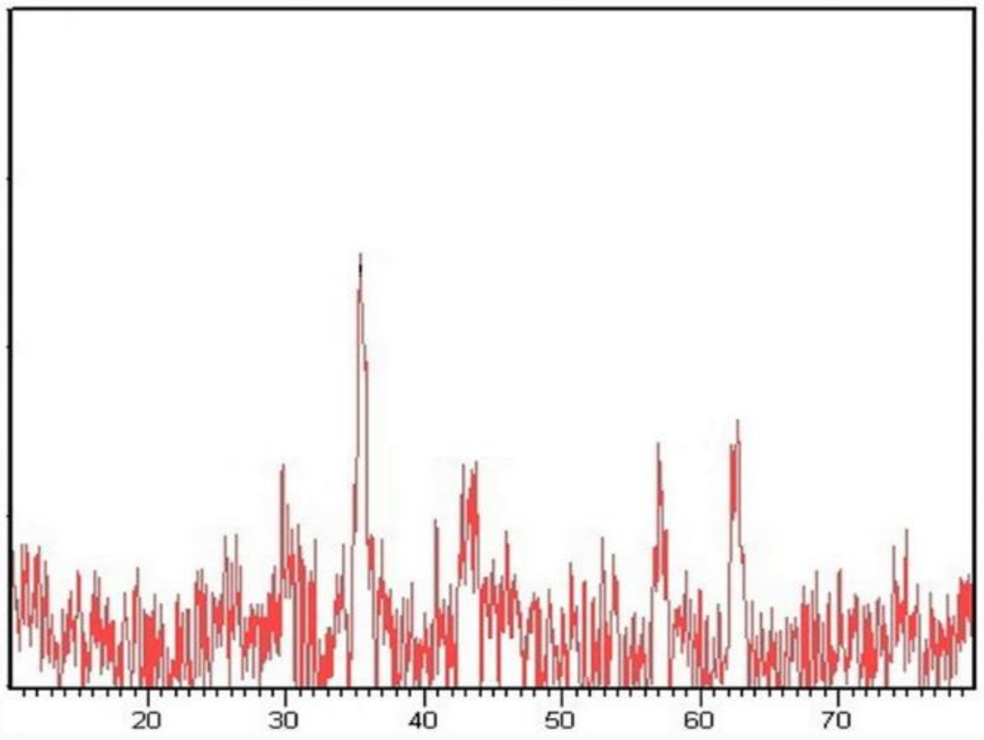

Fig. 1: XRD pattern of CoFe2O4 nanoparticles.

Results and Discussion

The composition of the $CoFe_2O_4$-CdS nanocomposite was also investigated. Presence of both cubic phase (JCPDS No.: 22-1086) and pure hexagonal phase (JCPDS No.: 75-1545) was confirmed and are illustrated in Fig.2.

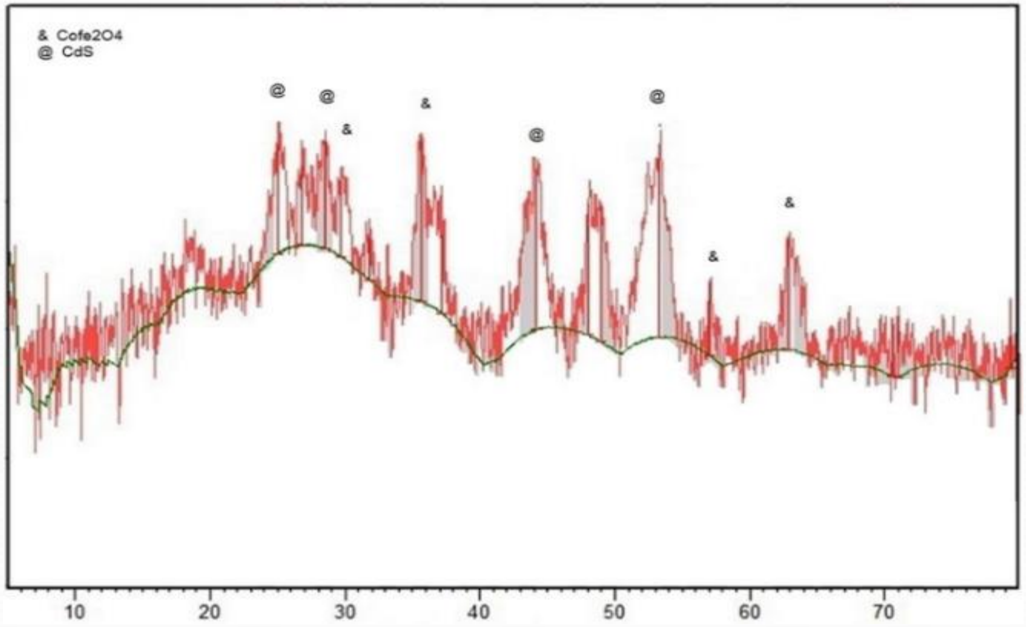

Fig. 2: XRD pattern of $CoFe_2O_4$-CdS nanocomposite.

Results and Discussion

The composition of the CoFe2O4-CdS-Ag doped nanocomposite was also investigated. Presence of both cubic phase (JCPDS No.: 22-1086) and pure hexagonal phase (JCPDS No.: 75-1545) was confirmed and are illustrated in Fig.3.

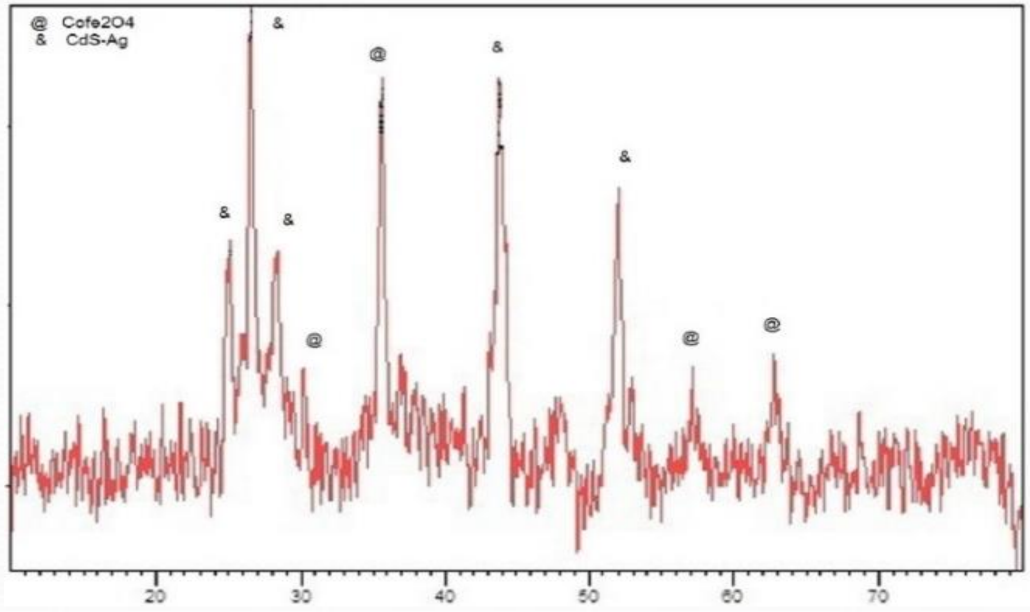

Fig. 3: XRD pattern of CoFe2O4-CdS-Ag-doped nanocomposite.

Results and Discussion

Scanning electron microscopy was employed for estimation of morphology and particle size of the products. Figs.4. illustrate SEM images of the as-synthesized surfactant-free CoFe2O4 nanoparticles obtained at 80◦C in 100 ml of solvent. The particle size and magnetic properties can be easily controlled by changing in precursors. The balance between nucleation and growth rates, determines final particle size so the morphology depends on the preparation conditions.

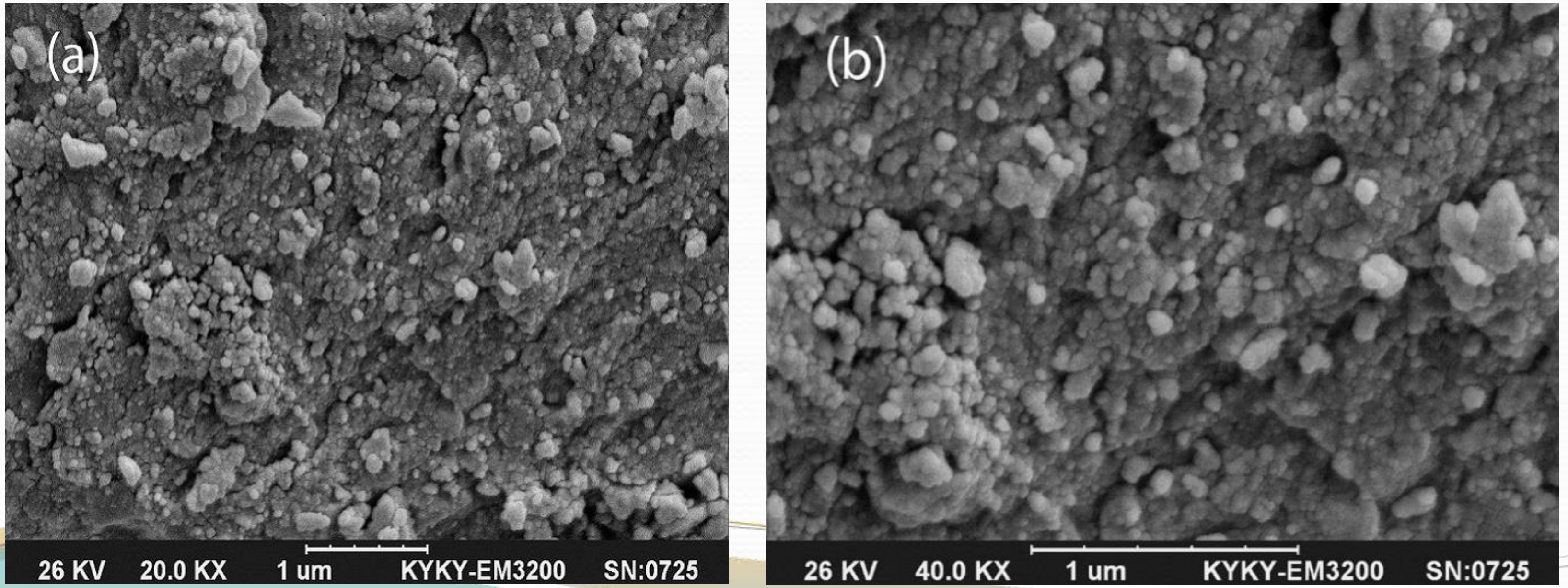

Fig. 4: SEM images of surfactant-free cobalt ferrite.

Results and Discussion

Figs.5. illustrate SEM images of the as-synthesized CoFe2O4-CdS obtained at 80◦C in 200ml of solvent. That result confirms nanocomposites with average size around 50 nm were obtained.

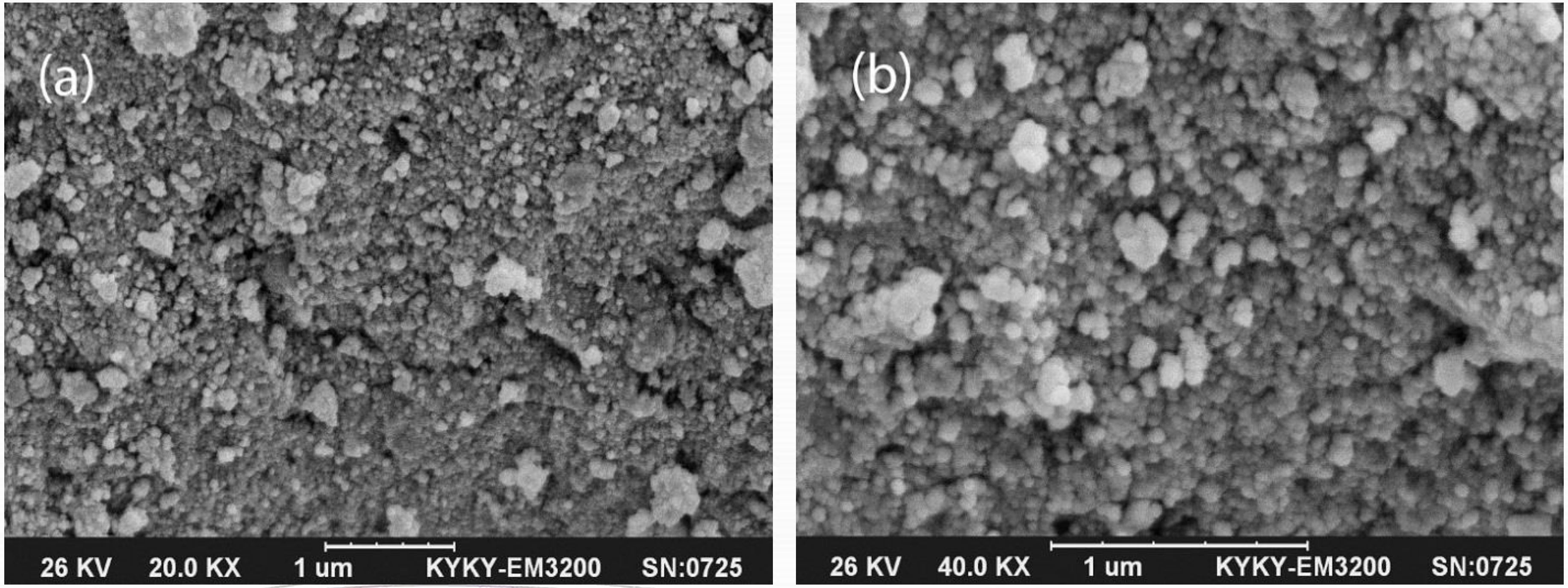

Fig. 5: SEM images of CoFe2O4-CdS nanocomposite.

Results and Discussion

Figs.6. illustrate SEM images of the as-synthesized CoFe2O4-CdS-Ag obtained at 80◦C in 200ml of solvent. That result confirms nanocomposites with average size around 45 nm were obtained.

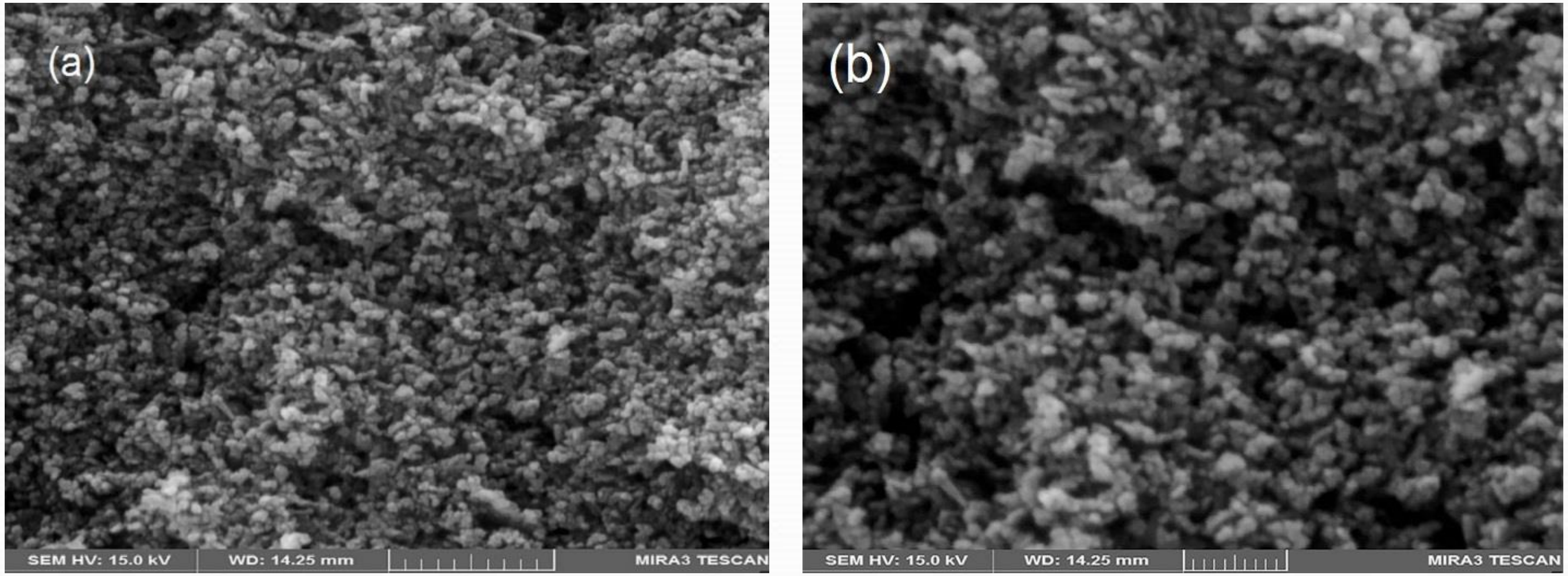

Fig. 6: SEM images of CoFe2O4-CdS-Ag-doped nanocomposite.

Results and Discussion

Acid blue was degraded at 90 min and 120 min respectively by CoFe2O4-CdS-Ag doped and CoFe2O4-CdS nanocomposite. Degradation of organic dyes with magnetic nanocomposites are shown in Fig 7.

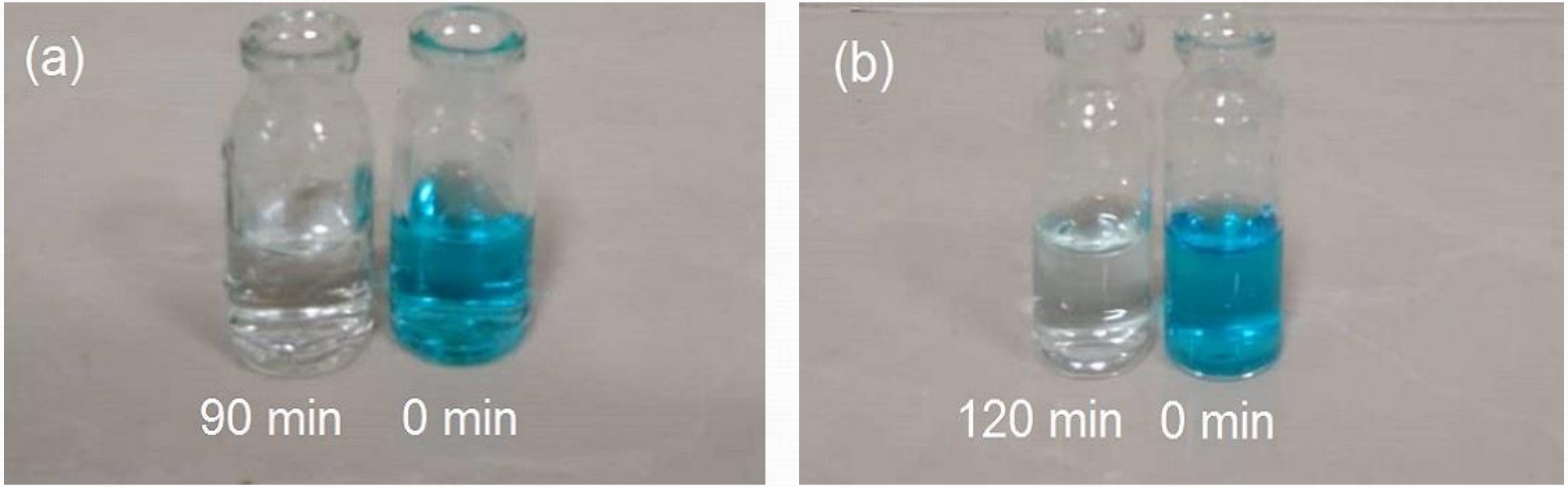

Fig. 7: Degradation of acid blue by (a) CoFe2O4-CdS-Ag-doped (b) CoFe2O4-CdS nanocomposites.

Conclusions

In conclusion, synthesis, characterization and photocatalytic activity of $CoFe_2O_4$, $CoFe_2O_4$-CdS and $CoFe_2O_4$-CdS-Ag doped nanocomposite were reported. The photocatalytic behaviour of $CoFe_2O_4$-CdS and $CoFe_2O_4$-CdS-Ag doped nanocomposite was evaluated using the degradation of Acid blue under UV light irradiation. The results show that precipitation method is a suitable method for preparation of $CoFe_2O_4$-CdS and $CoFe_2O_4$-CdS-Ag doped nanocomposites as a candidate for photocatalytic applications.