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Visible light driven photocatalytic activity of copper sulfide nanoparticles

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CuS nanoparticles are unique among copper based nanocomposites owing to its numerous applications such as sensing, imaging, photothermal abalation, supercapacitors, solar cell, drug delivery etc. In this report, simple thermal assisted synthesis of CuS nanoparticles was attempted. The material was analyzed for its structural property from XRD analysis and optimized to yield single phase of CuS semiconductor. Optical property of as-synthesized CuS semiconductor was studied using UV-Vis spectroscopy and band gap was calculated. The photocatalytic activity of the CuS was studied using crystal violet as model pollutant.

Keywords: Semiconductor, photocatalysis, CuS.

Introduction

Textile dyes which are more than 10,000 in number are a major threat to the biosystem as it is a harmful water pollutant. Common ways to treat the effluents include adsorption, sedimentation, chemicoagulation and biological methods. However many of these approaches have longer degradation time, production of colloids in wastewater etc.[1]. Hence the advanced oxidation method such as photocatalysis can be effective and cheaper to treat the textile dyeing wastewater. Copper sulfide (CuS) semiconductor has attracted much attention in photo degradation application due to its band gap, less toxicity and porosity[2,3]. This study investigates the degradation of crystal violet dye under visible light using prepared copper sulfide material.

Experimental

Copper sulfide nanoparticles synthesis was attempted using hydrothermal and simple wet chemical methods. In the hydrothermal method 0.099 *M* of copper acetate was dissolved in 80 mL of water. 0.298 *M* of Na_2S and 0.001 *M* of PVA was added and stirred for a while and kept inside an autoclave under for 24 h at 180°C. In the second method, to 0.2 *M* of $CuCl_2$ in 20 mL of water 3.1216 g of tri sodium citrate is added. 1.6 mL of Na_2S is added dropwise. The precursors are taken in the ratio 1:10. The prepared solution is maintained at 80°C under magnetic stirring for 1 h. X-Ray diffraction patterns of the prepared samples were analysed from GE X-Ray Diffraction System-XRD 3003 TT for 2θ = 20–60° with $CuK_{\alpha 1}$ radiation (λ = 1.5406 Å). The absorbance of dye in the solution was obtained using LAMBDA 650 Perkin-Elmer UV-Visible spectrophotometer.

Results and discussion

X-Ray diffraction analysis: Fig. 1(a) shows the XRD pattern of the material using hydrothermal synthesis. The results show dual phase formation. The peaks at 27.86° and 46.24° with plane values (0015), (110) confirms the Cu_9S_5 phase (JCPDS No. 47-1748) and the peak values 29.39°, 32.12° and 47.96° shows the CuS phase formation (JCPDS No. 06-0464). The Fig. 1(b) shows the formation of single phase of CuS and this phase is confirmed by the observed peaks at 2θ values of 27.14°, 29.39°, 32.12° and 47.96° with corresponding plane values (101), (102), (103) and (110) respectively (JCPDS No. 06-0464)[4]. The formation of hexagonal phase with covellite structure is observed and the crystallite size is calculated as 5 nm.

UV-Visible analysis: Fig. 2 shows the UV-Visible spectrum for single phase CuS nanoparticles. The maximum emission is observed at 514 nm with the corresponding energy band gap of about 2.44 eV which is calculated using Tauc's equation reported elsewhere[5,6].

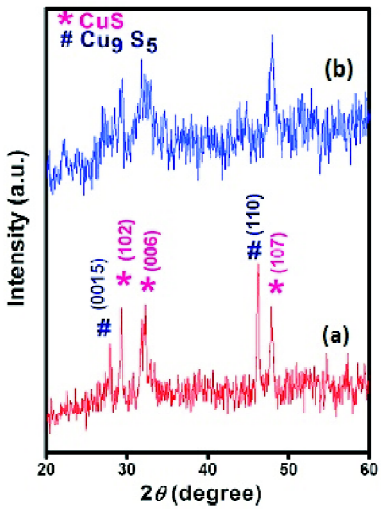

Fig. 1. XRD pattern of CuS via (a) hydrothermal synthesis and (b) wet chemical synthesis.

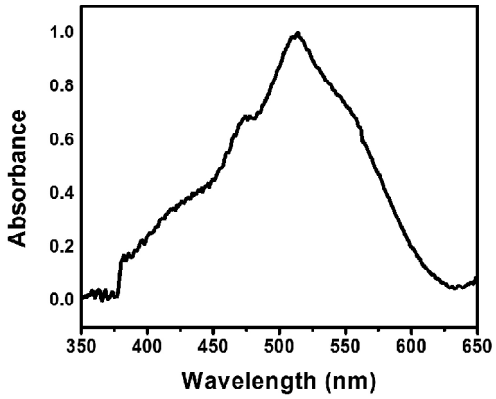

Fig. 2. UV-Vis spectra of CuS nanoparticles.

Photodegradation: Photocatalytic degradation of dye (crystal violet) under visible light illumination has been carried out. The decrease in intensity of the dye under visible light irradiation for different time intervals is observed. The suppression of peak at 590 nm indicates that CuS nanomaterial is a good catalyst. When the system is irradiated with visible light, CuS absorbs the photon and transports the excited electrons to the π^* orbital. Thus the electron hole pair production accelerates the degradation of the dye. The results demonstrate that nearly 36% of the dye was degraded within 150 min. The time coarse degradation curve of CuS is shown in Fig. 3. Thus the composite exhibits better photocatalytic efficiency which may be due to the slow recombination rate and dispersion[7].

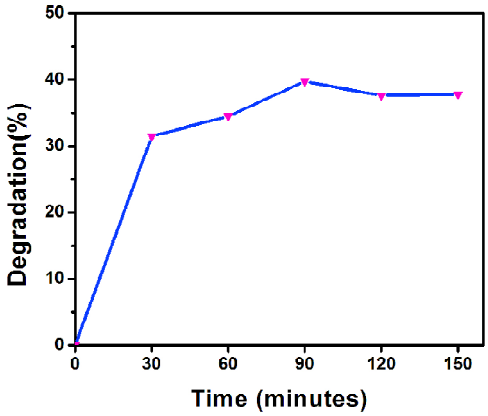

Fig. 3. Time coarse degradation curve of crystal violet.

Conclusion

Copper sulfide nanoparticles were synthesized via simple wet chemical method and characterized using XRD and UV-Vis studies. The photodegradation of crystal violet was studied and a degradation of 36% was obtained from visible light irradiation for a period of 150 min.

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