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Synthesis, Characterization and Photocatalytic Application of Bi_2O_3 Nanoparticles

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ABSTRACT
Bismuth Oxide photocatalyst were developed by a simple hydrothermal synthetic route at 160 °C, and it is efficiently characterized by various techniques: such as powder XRD, FESEM, and UV-Vis DRS. The removal efficiency of the Bismuth Oxide nanoparticles is tested against the removal of RhB under natural sunlight irradiation. About 70 % removal of RhB is observed in 120 min.
Keywords: Bi_2O_3, Photocatalyst, Rhodamine B

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1. INTRODUCTION

Worldwide, water contamination is due to the presence of organic dyes in water is increasing day by day. Therefore, we urgently need to investigate the matter to check out for this problem. The main reason of the issue is growing industrialization as well as urbanization. Consequently, we are required to solve it on an immediate basis [1]. We can do so by the help of existing effective & reliable method to treat pollutants and microbial contamination. Photocatalysis is one of the safest methods which has gained appreciable popularity in the last few years [2]. Photocatalysis is cost-effective, safe & sustainable. It is being widely used to treat air and water pollution. One of the advantages of applying this method is that it mineralizes organic contaminants without formation of unnecessary byproducts. Organic pollutants are efficiently mineralized to carbon dioxide and water which is a simple process. Bismuth oxide and other complex oxides semiconducting materials are often reported as effective visible light photocatalysts. These are said to have a narrow band gap which enables them to operate under visible region [3]. If we talk about the photocatalytic activity of bismuth complex oxides, we can see a high rate of visible light photocatalytic activity in bismuth tungstate, vanadate, molybdate & titanate. Incredible properties such as high amount of solar photocatalytic activity is found in Bismuth tungstate, also having appropriate band gap and shows good stability. Bismuth Tungstate is, thus, the most studied bismuth metalate. It can degrade a large range of contaminants including volatile organic compounds, inorganic dyes, pharmaceuticals as well as nitric oxides [4-5]. Now, as we know that water treatment is of immense importance, we need efficient photocatalysts for the process of water treatment at the earliest possible. Bismuth oxide & bismuth tungstate have lately been reported to be effective in carrying out visible light photocatalysis for water treatment. Disinfection, apart from decontamination, is equally important for efficient water treatment processes [6-8].

Bismuth oxide coatings are highly efficient photocatalytic material under sunlight irradiation. They show antimicrobial activity which prevents the adhesion of microbes. Using these properties to our advantage, here we are aiming to assess antimicrobial activity of these narrow band gap semiconducting photocatalytic material [9-11] If we compare bismuth oxide to either bismuth tungstate or titanium oxide for the properties of dye degradation and antibacterial, then it is observed that bismuth oxide is a better working photocatalytic material under sunlight, which renders it superior to them [12]. Bismuth oxide coatings and to a lesser extent, bismuth tungstate show hydrophobic nature which helps or enables to prevent bacterial adhesion to the surface. One may look for the development of a photocatalyst that is not only visible-light activated, kill microorganisms, but also could breakdown organic water contaminants. Development of such a photocatalyst would prove to be holding numerous advantages in the treatment of water. Slower kinetics and low degradation activity under sunlight of the photocatalysts limits the industrial implementation of this process as a technique for the removal of pollutants and inactivation of microbes. Yet, it is a promising and sustainable technique since a wide range of small band gap semiconducting materials have been proposed, synthesized, tested and reported as potential alternatives for the future till date [13].

2. METHODOLOGY

Synthesis of Bi_2O_3 nanoparticles

2 mmol bismuth hydroxide was mixed in 30 mL of 0.5 KOH. After 45 min of constant stirring, the mixture was poured into a Teflon-lined stainless-steel autoclave and heated under a controlled temperature of 200°C for 20 h. The finally prepared material was washed with H_2O and C_2H_5OH and was dried in an oven at 50°C. The synthesized is photocatalyst is further tested for the removal of dyes. The synthesis route is display in Figure 1.

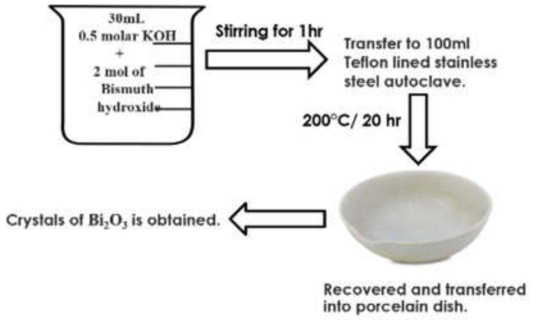

Figure 1: Preparation route of Bi_2O_3 nanoparticles

3. RESULTS AND DISCUSSIONS

Crystal Study

The XRD peaks for Bi_2O_3 were detected at 2θ = 28.9°, 32.8°, 48.2°, 55.2°, 58.6°, which are matched to (111), (100), (102), (121), (062), and (112), and monoclinic planes of Bi_2O_3 (JCPDS Card No.- 12 1445) (Figure 1).

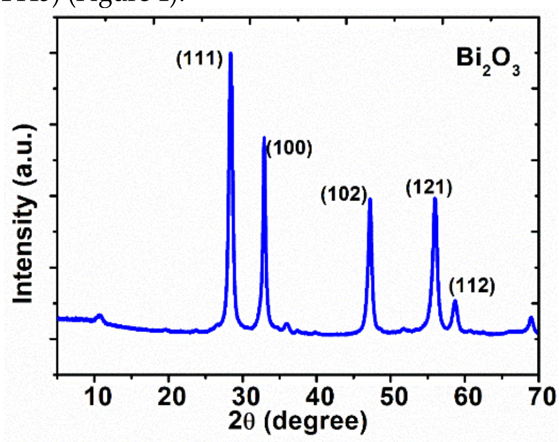

Figure 2: XRD of as-synthesized Bi_2O_3

Surface Morphology of Bi_2O_3

The FE-SEM image of Bi_2O_3 nanoparticles was taken by scanning electron microscope shows agglomeration of nanoparticles (Figure. 2). The FESEM indicates the presence of agglomerated nanoparticles of bismuth oxide, which confirm the high adsorption of dye molecules which result in the good removal of dye molecule from the waste water.

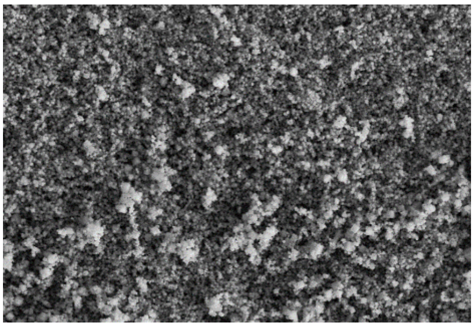

Figure 3: FE-SEM images of Bi_2O_3

Band Gap analysis

The pure Bi_2O_3 nanoparticles absorb in the visible light region. The UV-vis DRS spectra were changed into absorption spectra by using (K-M function) Kubelka-Munk [19], and the energy band gap was evaluated from the Taucs plots, Figure. 3 shows Tauc's plots of Bi_2O_3 photocatalyst. The optical band gap of Bi_2O_3 was determined to be 2.2 eV.

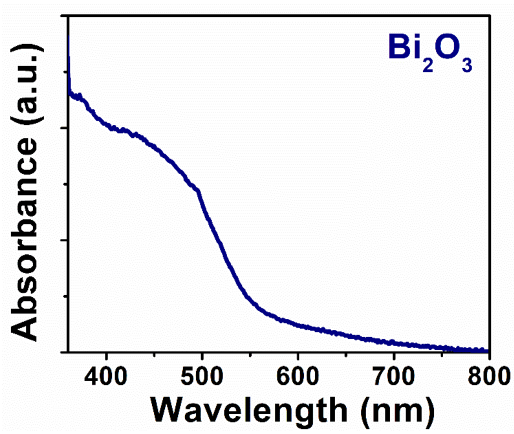

Figure 4: Absorbance Spectra of pure Bi_2O

Photocatalytic Test

The photocatalytic removal of RhB dye (5 mg/L) by the Bismuth Oxide nanoparticles is displayed in Figure. 5. The Bismuth Oxide nanoparticles show the photocatalytic performance of about 70 % RhB dye removal after 120 min of sunlight exposure. Figure.4 shows the UV-vis absorption spectra, which shows the change in concentration of RhB dye during the photocatalytic degradation. The decrease in the absorption peak of RhB dye was tested over 105 min period of sunlight irradiation.

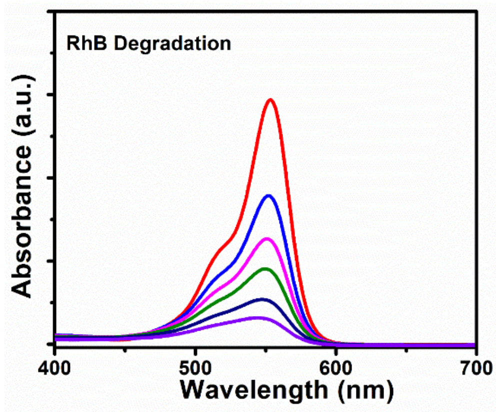

Figure 5: UV-vis absorbance spectra of RhB dye solution.

4. CONCLUSIONS

The Bi_2O_3 photocatalyst was synthesized by simple hydrothermal synthetic route. The Bismuth Oxide photocatalyst act as an efficient photocatalyst towards the removal of 70 % of RhB under sunlight irradiation. Bismuth Oxide nanoparticles is an effective sunlight active photocatalyst option for removing various organic dyes in aqueous media due to its strong photocatalytic activity.

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