

## Synthesis of Bismuth Oxide nanoparticles and its photocatalytic application

### 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.

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### 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 (Homem and Santos 2011; Rivera-Utrilla et al. 2013; Qin et al. 2021). 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 (Michael et al. 2013; Dinh et al. 2017). 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 (Kumar and Dutta 2022a; Kumar and Kumar 2022; Kumar et al. 2022a; Mukherjee and Vellenki 2022). 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 (Bisht et al. 2022; Kumar and Dutta 2022b; Kumar et al. 2022b).

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 (Durán-Álvarez et al. 2016; Calvete et al. 2019; Akbari et al. 2021).

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 (Nenavathu et al. 2013; Schneider et al. 2014). 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 (Sharma et al. 2022). 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 (Zhang et al. 2011). 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 (Wang et al. 2014).

## Experimental Section

### Synthesis of Bi<sub>2</sub>O<sub>3</sub> 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<sub>2</sub>O and C<sub>2</sub>H<sub>5</sub>OH 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.

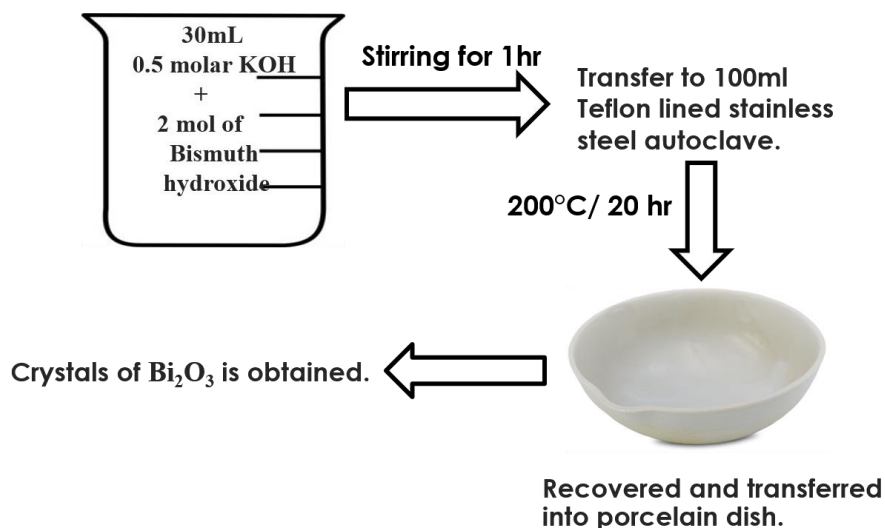


Figure 1. Preparation route of Bi<sub>2</sub>O<sub>3</sub> nanoparticles

### Methodology for photocatalytic experiment

The photocatalytic performance of the Bi<sub>2</sub>O<sub>3</sub> photocatalyst was determined by observing the degradation of RhB dye (5 mg/L) solutions under exposure to natural sunlight radiation. Typically, 100 mL aqueous solution of 5 ppm RhB dye is taken into a 500 mL beaker, followed by the addition of 100 mg of Bi<sub>2</sub>O<sub>3</sub> photocatalysts into it, which was then subjected to continuous stirring for 60 min under the dark condition. After 60 min of dark study, the beaker was kept under sunlight. 2 mL aliquot was taken from the beaker at certain intervals. The change in concentration of the RhB molecule was recorded by UV-vis spectrophotometer (UV-1800, Shimadzu, Japan) at absorbance  $\lambda = 553$  nm.

## RESULTS AND DISCUSSIONS

### Characterization of Bi<sub>2</sub>O<sub>3</sub>

#### XRD analysis

The XRD peaks for Bi<sub>2</sub>O<sub>3</sub> were detected at  $2\theta = 28.9^\circ, 32.8^\circ, 48.2^\circ, 55.2^\circ, 58.6^\circ$ , which are matched to (111), (100), (102), (121), (062), and (112), and monoclinic planes of Bi<sub>2</sub>O<sub>3</sub> (JCPDS Card No.- 12 1445) (Figure.1).

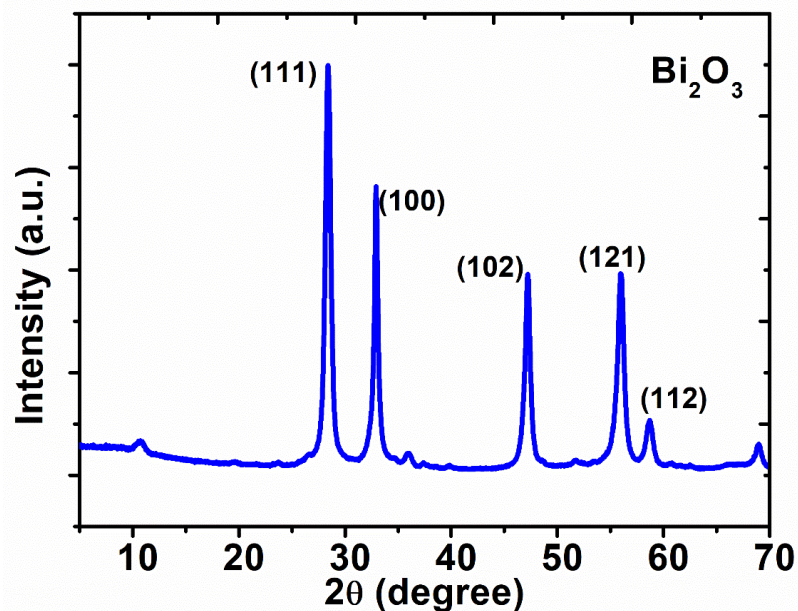


Figure 2. XRD of as-synthesized Bi<sub>2</sub>O<sub>3</sub>

#### Morphology of Bi<sub>2</sub>O<sub>3</sub>

The FE-SEM image of Bi<sub>2</sub>O<sub>3</sub> nanoparticles was taken by scanning electron microscope shows agglomeration of nanoparticles (Figure. 2). [21-22]. 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.

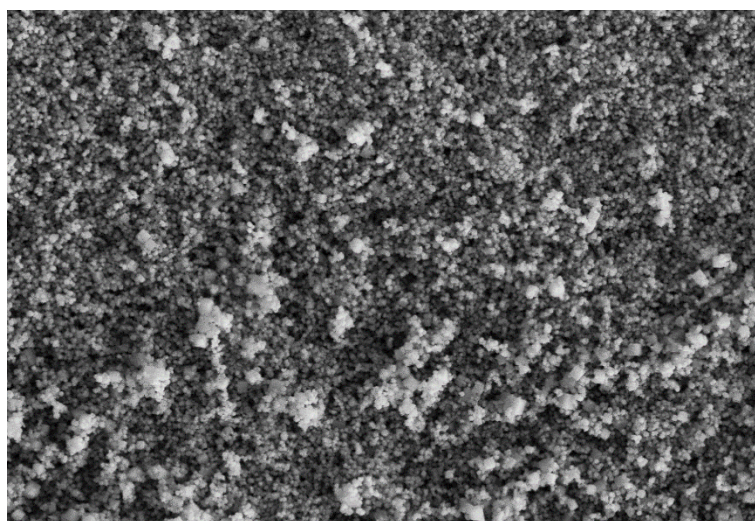


Figure. 3 FE-SEM image of Bi<sub>2</sub>O<sub>3</sub>

### Band Gap analysis

The pure  $\text{Bi}_2\text{O}_3$  nanoparticles absorb in the visible light region. The UV-vis DRS spectra were changed into absorption spectra by using (K-M function) Kubelka-Munk (Kortüm 1969), and the energy band gap was evaluated from the Taucs plots, Figure. 3 shows Tauc's plots of  $\text{Bi}_2\text{O}_3$  photocatalyst. The optical band gap of  $\text{Bi}_2\text{O}_3$  was determined to be 2.2 eV.

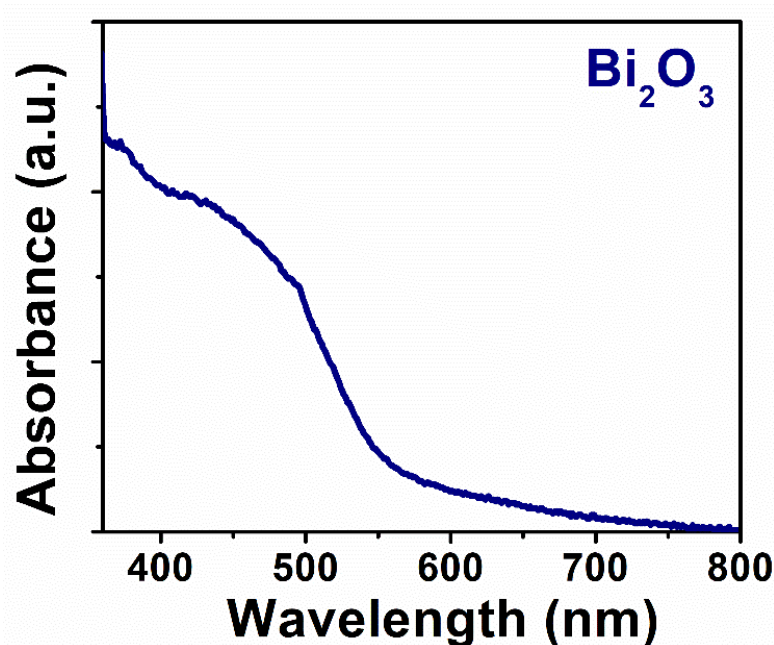


Figure. 4 Absorbance Spectra of pure  $\text{Bi}_2\text{O}_3$

### 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.

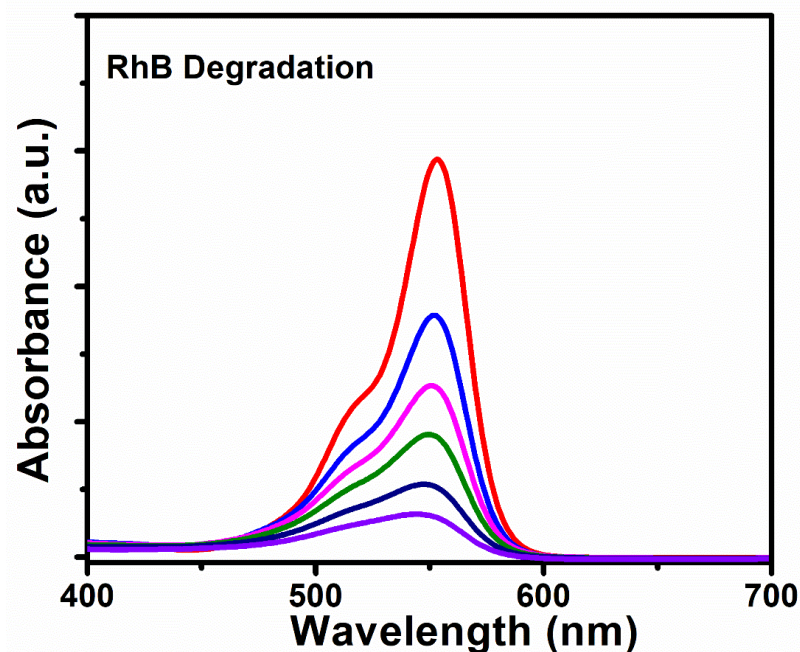


Figure. 5 UV-vis absorbance spectra of RhB dye solution.

### Conclusions

Bismuth oxide nanoparticles photocatalyst synthesis has been achieved through a straightforward hydrothermal synthetic route. The bismuth oxide photocatalyst shows photocatalytic performance towards the degradation of 70 % of RhB under sunlight irradiation. Bismuth Oxide is an effective visible light photocatalyst option for removing various organic dyes in aqueous media due to its strong photocatalytic activity.

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