Visible Light driven Tin Titanate Photo-Catalyst Prepared by Co-Precipitation Method

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Abstract

Visible light activated tin titanate (SnTiO3) nano powders were synthesized by a simple and organic free co-precipitation method. The synthesized titanate was analyzed by X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and Thermo gravimetry (TG). The particle size of tin titanate calculated based on the Scherer equation was found to be 100 nm in size. The photocatalytic activity was measured based on the degradation of methyl orange in aqueous solution. The results show that SnTiO3 nano particles exhibit good photocatalytic activity under visible range condition.

Keywords: Tin titanate, Co-precipitation, Photocatalysis, X-ray diffraction, Nano particles

1. Introduction

The visible light driven photocatalyst was got more attention because it needs only the sun light for the excitation process. Metal oxides particularly titanium dioxide has been commonly used as photocatlyst in various applications including solar cells. The major advantage of titanium dioxide over other metal oxide was its chemical inertness, very good stability and compatibility with other materials [1-4]. The application of titanium dioxide in the field of visible light photocatalyst was limited because it is activated only under UV light irradiation which accounts for only a small fraction of the solar irradiance compared to the visible region [1]. An UV response TiO2 can be converted into visible light by doping with C, N and S into TiO2 particles, which enable the red shift absorption edge [5 -8]. Another method to stimulate the TiO2 under visible light is made by incorporation transition metal ions into TiO2 particles [9 -11]. Photocatalytic activity of nickel titanate [12], barium titanate
strontium titanate and bismuth titanate [13-14] were already reported in the literature. The SnTiO₃ have been widely used in the field of ferroelectric substances [15-19]. The ferroelectric properties of pervoskite type tin titanate (SnTiO₃) have similar as that of barium titanate (BaTiO₃) [15]. The common solid-state method for the preparation of tin titanate can produce large SnTiO₃ particles with poor compositional homogeneity and uncontrolled structural morphologies. However co-precipitation technique has much advantage over other technique, such as homogeneity in the phase of reactant, stoichiometric control, high purity and ease of processing. The aim of the paper is to synthesize nano sized tin titanate photocatlyst by co-precipitation method.

2. Experimental procedures

For preparing SnTiO₃, stannous chloride and titanium tetrachloride were used as the starting material. TiCl₄ (0.1mol) and SnCl₂ (0.1mol) are respectively dissolved in 100 ml of distilled water. An aqueous solution containing ions of titanium and tin in an equi-molar ratio is prepared by admixing 100 ml TiCl₄ solution and 100 ml of SnCl₂ solution. To this mixed solution of titanium tetrachloride and tin chloride solution, 50 ml of 0.1mol oxalic acid solution is added. Another 200 ml mixed solution of is prepared by admixing 30 ml of 30% H₂O₂ solution, 15 ml of 20% aqueous ammonia solution, 20 ml of 10% urea solution and rest of distilled water. The second mixed solution is added drop wise to the aqueous solution containing ions of titanium and tin in an equimolar ratio with stirring to precipitate complex peroxide corresponding to tin titanate. The oxalic acid and urea present in the solution will act as the nuclei for the precipitation process, which controls the particle size. The precipitate is washed dried and calcined at 850°C to obtain nano crystalline SnTiO₃.

X-ray diffraction was performed on SnTiO₃ powders using CuKα radiation (Phillips Analytical). The Scherer equation is used to calculate the particle size. A thermal study was performed for the dried (50 °C) precipitated sample by using TGA Versa thermo gravimetric analyzer. FTIR spectra of SnTiO₃ have been recorded in Bruker FTIR instrument. Thermal studies were conducted using TGA Versa thermo gravimetric analyzer. The Photocatalytic decolourization of methyl orange was monitored by measuring the absorbance of light (465 nm) by methyl orange solution with tin titanate, exposed to sunlight for different irradiation time, using UV-Visible Spectrophotometer of Shimadzu. The initial concentration of methyl orange was 10.0 ppm. During the irradiation time, the solution was bubbled with air.
3. Results and discussion

3.1. X-ray analysis

Table 1 shows the XRD results of SnTiO$_3$ powders calcined at 850 °C. All the peak values are well matched with tin titanate particles. The formation of tin titanate is evidenced by the characteristic peak of tin titanate in the XRD spectrum. The particle size calculated using the Scherer formula and the average particle size was found to be 100 nm.

<table>
<thead>
<tr>
<th>Peak at 2θ</th>
<th>Peak corresponding</th>
<th>$\beta$ ½ (radians)</th>
<th>Particle size (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.8</td>
<td>SnTiO$_3$</td>
<td>0.001428</td>
<td>95.6</td>
</tr>
<tr>
<td>33.5</td>
<td>SnTiO$_3$</td>
<td>0.001260</td>
<td>108</td>
</tr>
<tr>
<td>39.8</td>
<td>SnTiO$_3$</td>
<td>0.001488</td>
<td>92</td>
</tr>
</tbody>
</table>

3.2. Thermal analysis

Thermo gravimetric analysis was performed for the dried (40 °C) precipitated sample and the results are shown in figure 1. The first step of weight loss was due to the evaporation of water. The second step of weight loss is due to the elimination of hydrogen peroxide present in the complex, results the formation of amorphous tin titanate. On further heating above 500 °C, the amorphous phase will convert to crystalline from.
3.3. Infrared spectral analysis

FTIR spectra recorded for SnTiO$_3$ powders calcined at 850 °C is shown in figure 2. IR peaks below 800 cm$^{-1}$ were assigned to the Ti-O stretching and bending mode of O-Ti-O bond vibration corresponding to the formation of tin titanate. No other peak in the IR spectrum shows that nickel titanate synthesized were, free from impurities.
3.4. Photocatalytic activity

The photodegradation of methyl orange was performed by adding varying amount of tin titanate nano particle in 10.0 ppm methyl orange solution exposed under visible light irradiation. Figure 3 shows the photobleaching of methyl orange with different mount of tin titanate exposed to visible light irradiation for different duration. The photo-bleaching of methyl orange was strongly affected by the presence of tin titanate present in the system. As the exposure time increases, the degradation of methyl orange also increases. This is due to increased photon absorption by tin titanate leads to more transfer of photoelectrons and photo holes between valance band and conduction band and there by generating hydroxyl radical and super radical oxygen in the photo catalysis cell. These radical ions are responsible for the degradation of the methyl orange. As the concentration of tin titanate increased, more absorption of photon from the visible light leads to more degradation of methyl orange. The concentration of methyl orange was decreased to 2.0 ppm when solution containing 0.2% of tin titanate under the visible light exposure of 90 minutes.
Fig. 3. Photo bleaching of methyl orange solution with tin titanate (○–0.05 %, ■-0.1%, ●-0.2%) exposed to sun light for different duration of time.

4. Conclusions

Tin titanate nano powders were synthesized by a simple and organic free co-precipitation method. The tin titanate prepared was characterized by XRD, IR and TG studies. Thermo-gravimetric studies showed that crystalline formation of SnTiO₃ is completed at above 500 °C. The average particle size of the tin titanate was found to be 100 nm. The concentration of methyl orange was degraded from 10.0 ppm to 0.2 ppm by introducing 0.2% tin titanate exposed to sun light for 90 minutes duration. The photo bleaching of methyl orange under visible light with SnTiO₃ confirms the photocatalytic activity of tin titanate under visible light condition.
References


