CHAPTER 3

EFFECT OF ANNEALING TEMPERATURE AND CHARACTERIZATION OF TbMnO$_3$ NANOPARTICLES FOR PHOTOCATALYTIC APPLICATIONS

3.1 INTRODUCTION

Multiferroic materials, which exhibit both ferromagnetic and ferroelectric property, have received an intensive attention in the recent years (Cuartero 2009, Zhang et al 2013, Kumar et al 2013, Bator et al 2012). Due to the simultaneous presence of both ferroelectric and ferromagnetic property multiferroics have potential applications in novel electronic devices such as data storage, transducers, actuators, nonvolatile memory, and gate ferroelectrics in field-effect transistors and possibly in spintronics based applications (Lin et al 2012, Das et al 2011, Perez et al 2007, Cui et al 2006, Wang et al 2011). Recently, multiferroic effects have been found in some rare earth manganites (RMnO$_3$). Generally RMnO$_3$ possesses orthorhombic (space group Pbnm) perovskite structure for larger rare earth ions R=La-Dy and a non-centrosymmetric hexagonal structure (space group P6$_3$cm) for the smaller rare earths (R=Ho-Lu and Y).

Nanomaterials are regarded as one of the most promising new materials in the 21st century. One significant reason is that nanomaterials have large surface area along with interfacial state, hence electrical, optical and magnetic properties of nanomaterials are different from bulk materials. It is well known that the size and shape controlled synthesis is gaining tremendous
interest in nanostructure materials research, since ultra-small dimensions usually exhibit superior properties. Recently, the photocatalytic activity of perovskite oxides has attracted significant attention, such as YMnO₃, LaMnO₃, BiFeO₃, YFeO₃, LaFeO₃ and TbFeO₃ (Wang et al 2011, Li et al 2009, Wang et al 2011, Stevens et al 2014, Thirumalairajan et al 2012, Yang et al 2013). In this work, we report a novel perovskite photocatalyst TbMnO₃ which is active under UV light excitation.

Recently, considerable efforts have been taken for the controlled synthesis of perovskite ABO₃ nanostructures and also investigation on the correlation between the materials properties and their shapes. Generally TbMnO₃ can be prepared by solid-state reaction method (Cui et al 2006, Dyakonov et al 2012, Cui et al 2007, Yang et al 2006), but it required high temperature (>800 °C) for long duration which results in poor homogeneity with micrometer particles. Several chemical routes have been proposed, including co-precipitation (Kharrazi et al 2006, Khule et al 2012), polyacrylamide gel (Lin et al 2012), microwave-assisted (Acharya et al 2011), hydrothermal methods (Das et al 2011, Han et al 2006) were commonly used to synthesize perovskite oxides nanoparticles; but, the fundamental strategy for tailoring the particle size has been based on the heat treatment at different temperatures. Among the various methods, hydrothermal method is one of the facile dominant tool for the synthesis of uniform and size controlled nanoscale material. The main advantages of this method are controlled size, low heat treatment, simple and cost effective. In general, citric acid is a common and good chelating agent for metal ions to form uniform coordination complexes. Here we have synthesized different sized TbMnO₃ nanoparticles by hydrothermal route for the first time to the best of our knowledge. The samples were subjected to thermal, structural, morphological and optical studies. The photocatalytic activity of the as-prepared TbMnO₃ nanoparticles has been evaluated by the degradation of methyl orange dye.
under UV light irradiation. Further the possible reaction mechanism for the formation of TbMnO$_3$ nanoparticles was discussed in detail.

3.2 EXPERIMENTAL DETAILS

All procured chemicals were of analytical grade and used without further purification. TbMnO$_3$ nanoplates were synthesized by hydrothermal method using nitrates as metal precursors with post-annealing in air at 700 °C, 800 °C and 900 °C. Stoichiometric amounts of terbium (III) nitrate hydrate [Tb(NO$_3$)$_3$.H$_2$O], manganese (II) nitrate tetra hydrate [Mn(NO$_3$)$_2$.4H$_2$O] and an equal amount of citric acid (C$_6$H$_8$O$_7$) (metal/citric acid molar ratio=1/1) were dissolved in de-ionized water so that the metal ions can be uniformly complexed together. The transparent solution obtained was electromagnetically stirred for 5 h followed by dropwise addition of ammonia solution to neutralize the unreacted citric acid as well as to raise the pH value of the solution near 9.2 resulting in the sol formation which was stirred for 3 h. The final homogeneous solution was transferred into 60 ml teflon-lined stainless steel autoclave with 80 % of the volume filled. The autoclave was placed into a resistive heating furnace for the hydrothermal treatment at 180 °C for 20 h. After the system was cooled down to room temperature the resultant products were washed with distilled water several times and dried at 100 °C for 3 h. Finally the as-synthesized white powder was subjected to thermal analysis and based on that result the sample was annealed at 700 °C, 800 °C and 900 °C in air for 6 h. The annealed samples were further subjected to structural, morphology, magnetic and photocatalytic property studies.

3.3 CHARACTERIZATION STUDIES

The as-synthesized sample was first subjected to thermal analysis in order to find the decomposition, stability and phase formation of the material using SII TG/DTA 6300 thermal analyzer. The TGA curve was recorded in
the range from 27 to 925 °C with a heating rate of 20 °C/min under nitrogen atmosphere. Powder X-Ray diffraction analysis (XRD) was carried out for the annealed samples with a GE Inspection Technologies 3003TT model diffractometer at room temperature with CuKα radiation (λ=1.5405 Å) at 40 kV, and 30 mA. The X-ray diffraction pattern was obtained in the 2θ range from 20° to 70° and was inspected using JCPDS data to identify the crystallographic phases. The FT-IR measurements have been performed in the potassium bromide mode (KBR) using the model 6300 FT-IR spectrophotometer. The vibrational characteristics of the LaFeO₃ powders were investigated using Renishaw invia Raman microscope, Leica DMLM, RL663 laser. The surface morphology and elements present in the sample were studied by High resolution scanning electron microscope (HRSEM) using FEI Quanta FEG 200 equipped with an Energy dispersive x-ray analysis (EDX). The particles size and morphology of the synthesized sample has been studied by high resolution transmission electron microscopy (HRTEM) using Tecnai G2 model T-30 s-twin electron microscope with an accelerating voltage of 300 kV. The atomic force microscopy (AFM) and magnetic force microscopy (MFM) measurements of the synthesized sample have been performed in non-contact mode at room temperature using XE 70 Park system. The particle size distribution of the samples were analysed by particle size analyser using Malvern Zetasizer Nano-S instrument. X-ray photoelectron spectroscopy (XPS) has been done to confirm the oxidation state of Mn³⁺ and oxygen present in the annealed samples. The XPS data were collected using Omicron Nanotechnology instrument with a binding energy resolution of 0.7 eV. Magnetic measurements were analysed using superconducting quantum interference device (SQUID) Quantum Design, MPMS-5. The optical absorption study of the synthesized sample has been carried out in the range of 200-800 nm using Cary 5E high resolution spectrophotometer.
3.4 RESULTS AND DISCUSSION

3.4.1 Thermal Studies

Figure 3.1 TGA curve of as-synthesized TbMnO$_3$ sample

The as-synthesized sample was first subjected to thermal analysis in order to find the decomposition, stability and phase formation of the material. Figure 3.1 shows the thermal analysis of TbMnO$_3$ as-synthesized sample. During the calcinations process, the organic group presence in the sample was released from the matrix and decomposed, along with the formation of perovskite oxide phase. TGA curve showed four main weight loss processes. The first weight loss (15%) from room temperature to 120 °C is mainly due to the decomposition of water and some organic molecules. The second strong weight loss (32%) from 120 °C to 400 °C corresponds to nitrate group which has a melting point at ~ 310 °C. The third weight loss (5%) from 400 °C to 800 °C is mainly caused by desorption of residual hydroxyl (OH) group. Further heat treatment in the fourth process gave no major weight loss.
anymore which confirms the formation of oxide phase. Therefore, with respect to thermal analysis result we have selected 800 °C and 900 °C as the final calcinations temperature for the preparation of pure TbMnO₃ nanoparticles.

3.4.2 X-ray Diffraction Studies

![XRD patterns of TbMnO₃ nanoparticles](image)

**Figure 3.2 Powder XRD patterns of TbMnO₃ nanoparticles annealed at different temperatures**

The XRD spectra of as-synthesized and different temperature annealed TbMnO₃ nanoparticles were shown in Figure 3.2. The pattern corresponding to as-synthesized prefired at 100 °C indicates the amorphous nature of the sample. The powder pattern of samples annealed at 700 °C also confirms the amorphous nature with very low intensity. The XRD patterns recorded for a sample annealed at higher temperatures (800 and 900 °C) has no traces of other impurity phase, suggesting that the obtained TbMnO₃ was highly pure. All the characteristic peaks observed for both 800 and 900 °C
annealed powders were indexed to orthorhombic unit cell with space group Pbnn according to the reported data JCPDS (72-0379). In addition while increasing the annealing temperature from 800 to 900 °C intensity of the sample increases indicates the better crystallization. The average crystal grain size of the powders was estimated, by means of the Scherrer equation,

\[ D = K\lambda/(\beta\cos\theta) \]

Where, D is the average diameter of the crystal grains, K is a particle shape factor and taken as 0.9 for spherical nanoparticles, \( \lambda \) is the wavelength of CuK\( \alpha_1 \) radiation (\( \lambda = 1.5405 \) Å), \( \theta \) is the corresponding Bragg angle and \( \beta \) is the angular half-width of the reflection at 2\( \theta \). The average crystallite size D is 45 nm for 800 and 60 nm for 900 °C annealed sample calculated using the Scherrer formula.

### 3.4.3 FT-IR Studies

![FT-IR spectra of TbMnO\(_3\) nanoparticles annealed at different temperatures](image)

*Figure 3.3 FT-IR spectra of TbMnO\(_3\) nanoparticles annealed at different temperatures*
Figure 3.3 shows FT-IR spectra of TbMnO$_3$ samples annealed at different temperatures. The nitrate and organic compounds such as C-H, C-N, C=O were decomposed due to higher temperature treatment and it was already confirmed by thermal analysis. The broad absorption peaks in the range 600–400 cm$^{-1}$ corresponds to stretching and bending mode of metal oxygen bonds. The broad absorption peak at 596 cm$^{-1}$ is due to Mn–O stretching vibration, the sharp absorption peak at 535 cm$^{-1}$ corresponds to Tb–O stretching vibration, and another sharp absorption peak at 499 cm$^{-1}$ is attributed due to O-Mn-O bending vibration (Khule et al 2012). The stretching and bending vibration of all the three bands in both 800 and 900 °C indicates the formation of TbMnO$_3$ phase. The absence of this absorption band for the sample thermally decomposed at 700 °C suggests that no perovskite phase was formed in this sample.

### 3.4.4 Raman Studies

![Raman Spectra](image.png)

**Figure 3.4** Raman spectra of TbMnO$_3$ nanoparticles annealed at different temperatures

Raman scattering is an excellent tool to study the crystal symmetry and lattice distortion. Raman active modes in RMnO$_3$ come from the
deviation from the ideal perovskite structure. The activation of each Raman mode can be assigned to rotation of the MnO$_6$ octahedra around (101) or (010) direction and John–Teller (JT) distortion. Figure 3.4 shows the Raman spectra of TbMnO$_3$ nanoparticles annealed at different temperatures. The peaks indicated in the spectra correspond to the following modes: the symmetric stretching of the basal oxygens O(2) of the octahedra around 612 cm$^{-1}$ ($B_{1g}$); the asymmetric stretching around 490 cm$^{-1}$ ($A_g$) associated with the JT distortion, which involves basal oxygens O(2) and apical ones O(1); the bending modes ($A_g+B_{1g}$) at 510 and 525 cm$^{-1}$ in TbMnO$_3$, and the tilt of the octahedra at around 375 cm$^{-1}$ ($A_g$) (Das et al 2011).

3.4.5 High Resolution Scanning Electron Microscopy Studies

Figure 3.5 HRSEM images of TbMnO$_3$ nanoparticles (a,b) annealed at 800 °C and (c,d) annealed 900 °C
Figure 3.5 shows HRSEM images of TbMnO$_3$ samples annealed at 800 °C and 900 °C. The images show that TbMnO$_3$ samples consist of uniform plate-like morphology and its average size is between 45-60 nm, which was similar to the crystallite size obtained by Scherrer’s equation calculated from the powder XRD pattern. Further it was observed from the images that there is no significant change in morphology of the samples but there is a gradual improvement in size of the nanoparticles when the temperature increases from 800 to 900 °C.

3.4.6 High Resolution Transmission Electron Microscopy Studies

![Figure 3.6](image)

Figure 3.6 TEM images of (a,c) TbMnO$_3$ nanoparticles annealed at 800 and 900 °C (b,d) HRTEM images of TbMnO$_3$ nanoparticles with corresponding SAED patterns
Figure 3.6 shows typical TEM and HRTEM images of TbMnO$_3$ nanoparticles annealed at 800 °C and 900 °C respectively. The average particle size is 45 nm for 800 °C and 60 nm for 900 °C which was similar to obtained HRSEM images. HRTEM image clearly exhibits (110) plane (Figure 3.6b) with a lattice spacing of about 0.392 nm and (002) plane (Figure 3.6d) with a lattice spacing of about 0.370 nm, indicating that TbMnO$_3$ nanoparticles is single crystal in nature, consistent to the SAED pattern inserted in Figure 3.6(c,d).

### 3.4.7 Elemental Studies

In order to determine the chemical composition of prepared TbMnO$_3$ sample, EDS analysis was performed over the sample. Figure 3.7 show EDS spectrum of TbMnO$_3$ sample which confirms the presence of all elements in the sample Tb, Mn, and O with Tb to Mn molar ratio of about 1:1, close to the nominal composition.

![Figure 3.7 EDS analysis of TbMnO$_3$ nanoparticles](image)
3.4.8 Atomic Force Microscopy Studies

Figure 3.8 shows 2D and 3D AFM images of TbMnO$_3$ nanoparticles annealed at 800 °C and 900 °C with 2 X 2 μm$^2$ areas. The 2D images confirm that the nanoparticles were uniformly present in surface of the sample and hence the size of the nanoparticles increases as the annealing temperature. From the 3D image it is clearly seen that height of the sample was estimated to be about 45 and 60 nm for 800 and 900 °C annealed samples respectively. The increase in particle size agrees well with both HRSEM and HRTEM results.

Figure 3.8 2D and 3D AFM images of TbMnO$_3$ nanoparticles (a) annealed at 800 °C and (b) annealed at 900 °C
3.4.9  Magnetic Force Microscopy Studies

Figure 3.9 shows 2D MFM images of TbMnO$_3$ nanoparticles annealed at 800 °C and 900 °C. The MFM images reveal that majority positions of the samples were interact magnetically with the MFM probe. The magnetic domains of TbMnO$_3$ nanoplates were clearly seen in image hence it reveals that all the domains stay in different direction with respect to the magnetic field and each domain was separated by well-defined domain walls.

Figure 3.9  MFM images of TbMnO$_3$ nanoparticles (a,b) annealed at 800 °C and (c,d) annealed at 900 °C
3.4.10 Formation Mechanism of TbMnO$_3$ nanoparticles

The formation of TbMnO$_3$ nanoparticles can be obtained by the following reaction mechanism,

$$6[\text{Tb(NO}_3\text{)}_3\cdot\text{H}_2\text{O}] + 6[\text{Mn(NO}_3\text{)}_2\cdot4\text{H}_2\text{O}] + 8[\text{C}_6\text{H}_8\text{O}_7] \rightarrow 6\text{TbMnO}_3 + 15\text{N}_2 \uparrow + 48\text{CO}_2 + 68\text{H}_2\text{O}$$

Tb(NO$_3$)$_3$, H$_2$O and Mn(NO$_3$)$_2$ .4H$_2$O dissolved in deionized water with 1:1 ratio followed by that 1 ratio of citric acid was added to the solution. They readily react with each other and finally produce TbMnO$_3$ after heating it with 800 °C with the elimination of nitrogen, carbon dioxide and water.

![Figure 3.10 Schematic representation of formation mechanism of TbMnO$_3$ nanoparticles](image)

Figure 3.10 shows the schematic representation of formation mechanism of as-synthesized and different temperature annealed TbMnO$_3$ sample. Agglomerated spherical nanoparticles were observed for the as-synthesized samples as in Figure 3.10 (Pre-fired). When the powders were annealed at 800 °C agglomerate spherical nanoparticles were completely
converted to ellipsoidal shape. While further increasing the annealed temperature from 800 to 900 °C, there is a gradual improvement in size of the nanoparticles. Therefore, the result indicates that the annealing temperature was another significant factor that controlled the morphology and structure.

3.4.11 Particle Size Analysis

Figure 3.11 shows a size distribution histogram of TbMnO₃ nanoparticles annealed at 800 and 900 °C. It reveals that the average size of the nanoparticles of 800 °C sample would be about ~45 nm and for 900 °C the size was about ~60 nm respectively, which was consistent with both XRD and HRTEM analysis results.

![Particle size distribution of TbMnO₃ nanoparticles](image)

**Figure 3.11 Particle size distribution of TbMnO₃ nanoparticles (a) annealed at 800 °C and (b) annealed at 900 °C**

3.4.12 X-Ray Photoelectron Spectroscopy Studies

XPS was performed in order to verify the oxidation states of Tb 3d, Mn 2p and O 1s in the TbMnO₃ samples annealed at 800 and 900 °C. The binding energy resolution of the instrument is 0.7 eV and the recorded spectrum was shown in Figure 3.12 & 3.13. The peak position was reference to carbon at 284.6 eV.
Figure 3.12 XPS spectra of TbMnO$_3$ nanoparticles (a) wide scan survey (b) core level of Tb 3d region (c) core level of Mn 2p region (d) core level of O 1s region annealed at 800°C

Figure 3.12a & 3.13a shows a wide scan spectrum of the sample, where peaks of Tb, Mn, O, and C were detected. Figure 3.12b & 3.13b shows the narrow scan spectra for Tb 3d region where two characteristic peaks of Tb were observed at the binding energy of 1242.5 eV (Tb 3d$_{5/2}$) and 1277.9 eV (Tb 3d$_{3/2}$), which are very close to the already reported binding energy values (Chen et al 2010). Figure 3.12c & 3.13c shows peaks at 641.9 and 653.5 eV which were the characteristic peaks of Mn$^{+3}$ 2p$_{3/2}$ and 2p$_{1/2}$ respectively (Das et al 2011). Generally Mn is characterized to be $+3$ oxidation state in Mn based perovskite oxide materials. The absence of additional or shoulder peaks were found in Mn 2p XPS spectrum, which strongly indicates that Mn exists in $+3$ oxidation state in the prepared samples. From Figure 3.12d & 3.13d it
was found that the splitting of O 1s peak into two at 529.6 and 531.5 eV for both the samples shows the existence of oxygen in two kinds of chemical states. The binding energy at 529.6 eV is mainly due to the contribution of the crystal lattice oxygen (O$_L$). The binding energy at 531.5 eV arises from the chemisorbed oxygen species (O$_H$). The O$_L$ signal at 529.6 eV is attributed to the contribution of Tb-O and Mn-O in TbMnO$_3$ crystal lattice. The O$_H$ signal at 531.5 eV is closely related to the hydroxyl groups resulting mainly from the chemisorbed water. Generally for nanosized perovskite oxides, oxygen vacancies have been formed at the particle surface may be due to the destroyment of the long-range order in the lattice (Yang et al 2013).

![Figure 3.13](image)

**Figure 3.13** XPS spectra of TbMnO$_3$ nanoparticles (a) wide scan survey (b) core level of Tb 3d region (c) core level of Mn 2p region (d) core level of O 1s region annealed at 900 °C
3.4.13 Magnetic Property Studies

In order to study the magnetic properties of the samples, the dependence of magnetization M(H) on the applied magnetic field has been measured for both 800 and 900 °C annealed samples. Figure 3.14(a,b) shows the M(H) curve of 800 and 900 °C annealed samples, recorded between ± 45 kOe. The curve was measured at the temperatures 5 K, 10 K, 25 K, 85 K and 300 K respectively. From the result it was obtained that anti-ferromagnetic behavior was observed for 5 K and 10 K and the corresponding coercivity (H_C) was 141 Oe and 47 Oe for 800 °C and 235 Oe and 145 Oe for 900 °C annealed samples respectively, which was measured from Figure 3.14(c,d) (zoom view), the H_C value gradually decreases with increase in temperature for both the samples. The M(H) at 5 K shows a two-step magnetization process, which may be due to the spin reorientation of Tb^{3+} ions in Mn^{3+} sites owing to Tb^{3+} spin reversal (Han et al 2006, Khule et al 2012). From the Figure 3.14(e,f) it was observed that magnetization of 900 °C annealed sample was found to be 0.47 emu/g for the applied field 5 K and the magnetization of 800 °C annealed sample was about 0.35 emu/g for the applied field 5 K and hence it was found that magnetization of 800 °C annealed sample was low when compared with 900 °C annealed sample. At higher temperatures (< 60 K) both the 800 and 900 °C annealed samples shows linear behavior indicating that phase transition from anti-ferromagnetic to paramagnetic, which was further confirmed in Figure 3.14(e,f) with zoom view. A slight magnetic hysteresis curve is observed at lower Kelvin, and the magnetization is almost saturated at high field, which is due to a weak ferromagnetism of Mn arrays (Han et al 2006). Finally from the M(H) curve it was confirmed that while increasing the annealing temperature from 800 to 900 °C the magnetization and coercivity of the sample increases with respect to the applied magnetic field.
Figure 3.14  (a,b) M(H) curve of TbMnO₃ nanoparticles annealed at 800 and 900 °C for different Kelvin’s (c,d) and (e,f) M(H) curve of TbMnO₃ nanoparticles annealed at 800 and 900 °C (zoom view)
3.4.14 UV-Vis Absorption Spectral Studies

Figure 3.15a shows the UV-Visible absorption spectrum of TbMnO$_3$ nanoparticles annealed at different temperatures. Both the curves exhibit a strong absorption band in the wavelength ranging from 275 to 300 nm. It was found that the absorption for 900 °C annealed sample was around 282 nm and for 800 °C it was about 277 nm. The slight shifting in the absorbance wavelength may be due to size of the nanoparticles. The calculated band gap of the prepared sample is about 4.38 eV for 900 °C annealed sample and 4.47 eV for 800 °C annealed samples respectively.

3.4.15 Photocatalytic Property Studies

Figure 3.15(b,c) shows the UV-Vis time dependent absorbance spectra during photocatalytic reaction of MO for TbMnO$_3$ samples after UV light irradiation. Under dark condition, the concentration of MO has no obvious change for long time in the presence of the catalysts. Irradiation in the absence of photocatalyst for 6 h revealed no change in the MO concentration, confirming that the MO cannot be degraded by 465 nm irradiation alone. Hence MO solution does not have any self-degradation under the radiation of UV light. The above results indicate that both the light and catalysts are necessary for effective photodegradation of MO. For both TbMnO$_3$ samples as the irradiation time was extended from 0 to 6 h, the intensity of the absorption peak starts decreases and slowly shifts to shorter wavelength; hence the result shows that the strength of the peak was reduced as the radiation time increases. After 6 h, the absorption peak was low and the intense orange colour of the starting MO solution faded (insert Figure 3.15d). As shown in Figure 3.15d, about 72.8% and 69.3% of initial MO has been decomposed while using TbMnO$_3$ samples (annealed at 800 and 900 °C) as a catalyst under UV light irradiation for 6 h. The efficiency of MO degradation is decreased with the increase of annealing temperature. Commonly, the
photocatalytic activity of an oxide material is closely related to its particle size, morphology and surface properties (Ivetic et al. 2014).

![Figure 3.15](image)

Figure 3.15 (a) UV-Vis absorbance spectrum of TbMnO$_3$ nanoparticles annealed at 800 and 900 °C. (b,c) UV-Vis time dependent absorption spectra during photocatalytic reaction of MO for TbMnO$_3$ nanoparticles annealed at 800 and 900 °C. (d) Degradation percentage of MO as the function of irradiation time (insert) Optical photograph showing gradual Color change of MO at different time intervals during photodegradation process.

3.5 CONCLUSION

TbMnO$_3$ nanoparticles were synthesized by hydrothermal method in combination with post-annealing in air at different temperatures. TGA result shows the decomposition and stability of TbMnO$_3$ sample. XRD result confirms the formation of TbMnO$_3$ orthorhombic phase. FT-IR spectra
confirm the presence of functional group present in the sample. HRSEM, HRTEM and AFM images shows the morphology for 800 °C and 900 °C annealed samples. XPS analysis confirms the oxidation state of all the elements. Both the 800 and 900 °C annealed samples shows linear behaviour at higher temperatures (< 60 K) confirms the phase transition from anti-ferromagnetic to paramagnetic. The M(H) curve further confirms that while increasing the annealing temperature from 800 to 900 °C the magnetization and coercivity of the sample increases with respect to the applied magnetic field. Optical energy bandgap of the samples has been measured by UV-Vis absorption spectroscopy it was found that with decrease in particle size, the band gap of the material increases. For the photodegradation of MO under ultraviolet radiation, the 800 °C annealed sample show higher photocatalytic activity than 900 °C annealed sample.