Chapter 5

Synthesis, characterization and applications of silver loaded zinc oxide nanoparticles

The synthesis of silver loaded zinc oxide (ZnO) nanoparticles was done in two steps. In first step, ZnO was synthesized by sol gel method as mentioned in earlier chapter IV. In second step silver ions were loaded on zinc oxide, subsequently reduced by *Ocimum tenuiflorum* (Tulsi) leaf extract. It was found that loading of appropriate concentration of silver nanoparticle on zinc oxide enhances its antimicrobial activity as well as improves its photocatalytic activity. The Ag loaded ZnO nanoparticles were characterized with XRD, FT-IR, diffuse reflectance UV-visible, Photoluminance, FE-SEM, EDAX, TEM, Particle size analysis and zeta potential. The antibacterial activity of Ag loaded ZnO was studied for three representative classes of bacteria viz *E. coli*, *S. aureus* and *P. aeruginosa*. The photocatalytic activity was also investigated for degradation of Rhodamine B in presence of sunlight. This investigation shows that there is enhancement of antibacterial and photocatalytic activity by silver loaded zinc oxide than bare zinc oxide. Hence, loading of small amount of silver nanoparticles on zinc oxide nanoparticles enhances its antibacterial and photocatalytic activity largely.

The work presented in this chapter is communicated to Nanotechnology.
Chapter 5

5.1 Introduction

The application of nanoscale materials and structures, usually ranging from 1 nm to 100 nm, is an emerging area of nanoscience and nanotechnology. Nanomaterials also provide solutions to technological and environmental challenges in the areas of solar energy conversion, catalysis, medicine, water treatment etc. [1, 2]. The mechanism of formation of composite materials is one of the most active areas of nanoparticle research [3-6]. The interest in hybrid nanostructures is aimed at the exploitation and tuning of the properties of the individual components and the development of novel functionalities. Nanocomposite materials involving metals and semiconductors as building blocks are especially attractive, as they provide the opportunity to modulate optical phenomena including harvesting, emission, and concentration of electromagnetic radiation [7-9]. These features are of practical relevance for the optimization of photovoltaic and photocatalytic systems and for the development of optoelectronic and sensing devices [10-13]. Although several successful synthetic routes exist for M@TiO$_2$ [4, 11, 12, 14], the production of M@ZnO nanocomposites is still challenging [15]. With the steady and fast growing field of nanoscience and nanotechnology, nanostructured zinc oxide (ZnO) has become a promising photocatalyst for its high catalytic activity, low cost, and environmental friendliness [16-19]. Major limitation to achieving high photocatalytic efficiency in the ZnO nanostructure systems is the quick recombination of charge carriers. The design and modification of ZnO photocatalysts with high sensitivity and reactivity has attracted much attention. It was found that the photocatalytic performance can be greatly improved by developing ZnO-based heterostructures or composites [20-23]. The prospect of developing novel photocatalysts of metal silver hybridized with ZnO boosts relevant research because of the increase in the rate of electron-transfer process by silver [24-25]. Nanoparticles of Ag and ZnO are being used industrially for several purposes [26]. Zinc oxide has found many applications in daily life such as drug delivery, cosmetics, medical devices, etc. [27] due to its strong antimicrobial effect on a broad spectrum of microorganisms [28].
We have developed a facile method to prepare Ag loaded ZnO. Although, antibacterial activity of silver nanoparticles and zinc oxide is known since long, present study explores the surface modification of zinc oxide with silver nanoparticles, which leads to synergetic effect on antibacterial activity as well as photocatalytic activity. The extent of nanotoxicity depends on charge, size and nature of nanoparticles. The antibacterial efficiency was evaluated by three representative classes of bacteria gram positive, gram negative and non ferment gram negative. The resultant heterostructure that is silver loaded zinc oxide could promote the charge separation of the photogenerated electrons (e\textsuperscript{-}) and holes (h\textsuperscript{+}), allowing both of the e\textsuperscript{-} and h\textsuperscript{+} participating in the overall photocatalytic reaction. Thus, the sunlight-induced degradation of Rh B in our work can be evaluated as a real photocatalytic activity of the Ag loaded ZnO. When Ag was coupled in ZnO nanoparticles, a remarkable enhancement in photocatalytic activity was observed.

5.2 Experimental

2.1 Material

The chemical silver nitrate used was of AR grade, purchased from Merck, India and used without further purification. ZnO nanoparticles synthesized as discussed in Chapter IV (4.2.2). All solutions were prepared in double distilled water.

2.2 Preparation of plant extract

The leaves of Ocimum tenuiflorum were obtained from botanical garden, Shivaji University, Kolhapur. The obtained leaves were washed thoroughly several times with deionised water. 5 g of leaves were weighed, boiled for 5 min in 100 mL deionised water and the extract was filtered through Whatman filter paper No-1. The filtered extract was stored in refrigerator at 4 °C and was used for the synthesis of nanoparticles.
2.3 Synthesis of silver loaded zinc oxide nanoparticles

One gram of zinc oxide powder of particle size ~ 25 nm was weighed and dispersed in 10 mL 0.01 M aqueous solution of silver nitrate. The whole solution was sonicated for 20 min to get uniform dispersion. The solution was then stirred for one hour and then 5 mL leaf extract was extracted and further stirred for one hour. The whole material was centrifuged and washed three times by distilled water and two times by ethanol to ensure the removal of unbounded silver. The series of reactions were carried out at different silver nitrate concentration as 0.01, 0.03 M and 0.05 M. The appropriate loading was observed for 0.05 M concentration of silver. This loaded sample was characterized and used to study applications.

Powder X-ray diffraction (XRD) analysis was carried out by using Cu Kα radiations (λ=1.54 Å) on Bruker AXS D8. Field emission scanning electron microscopy (FE-SEM) image was obtained by JSM-6301F equipped with EDAX. The TEM observations were carried out with a JEOL TEM 2010 microscope. For TEM characterization, the powder sample was dispersed in methanol by ultrasonication for 20 min and loaded on copper grid. The Fourier transformed infrared (FT-IR) spectra, in the range of 4000-400 cm⁻¹, were recorded on Perkin Elmer Spectrum GX infrared spectrophotometer. The sample for FT-IR was prepared using the KBr technology. Diffuse reflectance UV-visible analysis was carried out with Variance Cary UV-visible NIR spectrophotometer (model-5000). Photoluminescence (PL) measurements were carried out at room temperature using 285 nm wavelengths as the excitation wavelength and emission was observed from 350 to 500 nm with spectro fluorimeter JASCO, F. P. 750, Japan with a Xe lamp as the excitation source. Particle size of synthesized silver loaded zinc oxide nanoparticles were analyzed through photon correlation spectroscopy. Light scattering measurements were carried out at 90° on a photon correlation spectrometer (PCS) – Zetasizer 3000 HAS equipped with a digital autocorrelation from Malvern Instrument UK.
2.4 Antibacterial testing of silver loaded zinc oxide nanoparticle

The bactericidal tests were performed with bacterial strains as *E. coli*, *S. aureus* and *P. aeruginosa*. Nutrient agar and Type-I agar were used as media to grow bacterial culture. The bacterial solution was prepared in 0.86 % saline. The antibacterial activity of silver loaded zinc oxide nanoparticle sample was assayed by following standard well diffusion technique. The bacterial suspension was spread on nutrient agar in Petri plate to create confluent lawn of bacterial growth. The wells of 6 mm were prepared by borer. The solutions of 2000 ppm concentrations of Ag loaded zinc oxide as 10 μL, 15 μL, and 20 μL were poured into three different wells. The well without sample was treated as control (methanol- the solvent used for dispersion of Ag loaded zinc oxide). These plates were incubated to 24 hrs at 35 °C. The lowest concentration at which the Petri plate did not show any visible growth after microscopic evaluations was considered as minimum inhibitory concentration (MIC). The susceptibility of test organisms was determined after 24 hrs by measuring zone of inhibition around each well. In control no zone of inhibition was observed. This proves that the antimicrobial activity is due to silver loaded zinc oxide nanoparticles. All antimicrobial parameters were optimized by running the experiment in triplicate.

2.5 Measurement of photocatalytic activity

The evaluation of photocatalytic activity of as prepared samples for the photocatalytic degradation of Rhodamine B aqueous solution was performed at room temperature by measuring both adsorption and degradation. Experiments were done as follows:

1) 100 mL 20 ppm Rh B + 0.1 gm silver loaded ZnO → sunlight
2) 100 mL 20 ppm Rh B + 0.1 gm silver loaded ZnO → dark
3) 100 mL 20 ppm Rh B → Sunlight

After irradiation from 0 hr to 5 hrs, 3 mL of Rh B solution from each flask was collected, centrifuged and the remaining dye concentration was determined using a UV-visible spectrophotometer.
Chapter 5

5.3 Results and discussion

The reaction taking place during synthesis is given by following equation,

Step I-\(\text{Zn (CH}_3\text{COO)}_2 + 2\text{KOH} \rightarrow \text{ZnO (powder) + 2CH}_3\text{COOK + H}_2\text{O}\)
Step II-\(\text{ZnO (powder) + AgNO}_3 + \text{leaf extract} \rightarrow \text{Silver loaded ZnO}\)

5.3.1 X-ray diffraction pattern of silver loaded ZnO

Fig. 5.1 shows XRD pattern of silver loaded ZnO nanoparticles. The observed diffraction peaks of the pure silver loaded ZnO can be indexed to those of hexagonal wurtzite structure. No impurity phases were detected. The high intensity of (10\(\bar{1}\)) peak suggests that the growth of nanoparticles has taken place along the easy direction of crystallization of material and the same has been reported by Lin et al. [29].

![X-ray diffraction pattern](image-url)

**Fig.5.1** X-ray diffraction pattern of silver loaded zinc oxide nanoparticles
The average crystallite size is determined according to Scherrer formula, and was found to be 30 nm.

\[ D = \frac{K\lambda}{\beta \cos \theta} \]

5.3.2 FE-SEM and EDAX analysis of silver loaded ZnO

The morphologies of the synthesized silver loaded zinc oxide sample were observed by field emission scanning electron microscopy (FE-SEM). Fig. 5.2 shows FE-SEM image of silver loaded zinc oxide. The morphology was irregular less or more spherical or elliptical in nature. The grain size from the FE-SEM was found to be 45 nm. FE-SEM also reveals that the particles were uniformly distributed.

![FE-SEM image of synthesized silver loaded zinc oxide nanoparticles](image)

**Fig. 5.2** FE-SEM image of synthesized silver loaded zinc oxide nanoparticles

**Table 5.1**: EDAX results at 0.01 M silver nitrate concentration

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic %</th>
</tr>
</thead>
<tbody>
<tr>
<td>O K</td>
<td>80.24</td>
</tr>
<tr>
<td>Ag L</td>
<td>1.38</td>
</tr>
<tr>
<td>Zn K</td>
<td>18.38</td>
</tr>
</tbody>
</table>
The EDAX spectrum obtained at different silver loading is given as follows,

**Fig.5.3a** EDAX spectrum of Ag loaded ZnO by using 0.01 M silver nitrate concentration

**Fig.5.3b** EDAX spectrum of Ag loaded ZnO by using 0.03 M silver nitrate concentration
Chapter 5

Table 5.2: EDAX results at 0.03 M silver nitrate concentration

<table>
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<th>Element</th>
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</tr>
</thead>
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<td>O K</td>
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</tr>
<tr>
<td>Ag L</td>
<td>2.03</td>
</tr>
<tr>
<td>Zn K</td>
<td>22.54</td>
</tr>
</tbody>
</table>

Table 5.3: EDAX results at 0.05M silver nitrate concentration

<table>
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<th>Elements</th>
<th>Atomic %</th>
</tr>
</thead>
<tbody>
<tr>
<td>O K</td>
<td>75.21</td>
</tr>
<tr>
<td>Ag L</td>
<td>3.25</td>
</tr>
<tr>
<td>Zn K</td>
<td>21.54</td>
</tr>
</tbody>
</table>

Fig.5.3c EDAX spectrum of Ag loaded ZnO by using 0.05 M silver nitrate concentration
5.3.3 TEM analysis of silver loaded ZnO

Fig. 5.4 shows transmission electron microscopic (TEM) images of silver loaded zinc oxide nanoparticles. TEM clearly demonstrates that, particles were spherical and elliptical in nature, particle size ranging from 45 nm to 50 nm. It shows that silver was loaded on zinc oxide indicating formation of uniform composite.

Fig. 5.4 TEM images of silver loaded zinc oxide nanoparticles
5.3.4 FT-IR spectra of silver loaded zinc oxide

Fig. 5.5 shows FT-IR spectra of silver loaded zinc oxide nanoparticles. The spectra showed a strong band at 428 cm\(^{-1}\) which is characteristic of Zn–O vibrational band [30]. The broad absorption at 3400-3600 cm\(^{-1}\) corresponds to the O-H stretching vibrations and was accompanied by in-plane deformation vibrations 1661 cm\(^{-1}\) [31, 32]. The band at 1661 cm\(^{-1}\), 1510 cm\(^{-1}\) and 1384 cm\(^{-1}\) were due to different amino acids present in the leaf extract which causes the surface modification of zinc oxide, this surface modification was also confirmed by the zeta potential measurement. The biomolecules responsible for surface modification gives more stability to synthesized material.

![FT-IR spectra of synthesized silver loaded zinc oxide nanoparticles](image)

**Fig. 5.5** FT-IR spectra of synthesized silver loaded zinc oxide nanoparticles

5.3.5 DRUV-visible spectra of silver loaded zinc oxide

Fig. 5.6 is the DRUV-visible absorption spectra of silver loaded zinc oxide nanoparticles. The silver loaded zinc oxide exhibit absorption band between 400 nm to 800 nm which is attributed to the characteristics absorption of surface plasmon resulting from the metallic Ag clusters and or nanoparticles in the Ag loaded ZnO nanoparticles. The absorption band from 270 nm to 400 nm was due to absorption of zinc oxide.
Fig. 5.6 DRUV-visible spectra of silver loaded zinc oxide nanoparticles

The normal SPR absorption of silver nanoparticles is about 420 nm but silver loaded zinc oxide show red shift of 20 nm indicating decrease in particle size. The plasmon absorption of silver was represented by the following equation

\[ \lambda_p = \left[ \frac{4\pi^2 e^2 m_{\text{eff}}\varepsilon_0}{Ne^2} \right]^{1/2} \]

where \( m_{\text{eff}} \) is the effective mass of the free electron of the metal and \( N \) is the electron density of the metal. The position of plasmon absorption is related to the electron density of the metal. With the decrease of the electron density of the metal, the plasmon absorption \( \lambda_p \) of metal was increased, which results in the red shift of the plasmon absorption band [33].

5.3.6 Photoluminescence spectra of silver loaded zinc oxide

Fig. 5.7 shows room temperature photoluminescence spectra of silver loaded zinc oxide nanoparticle. The emission spectrum of the excitation at 285 nm was observed from 350 to 500 nm gives single peak at 410 nm, which is the shoulder of the broad peak. It is well-known that the photoluminescent property of ZnO was sensitive to its defects [34]. A strong visible emission with three
peaks in the range 400 nm to 500 nm was observed for pure zinc oxide. The visible emissions were due to transition in various kinds of defect states [34].

As compared to the bare ZnO, loading Ag on ZnO leads to a decrease of the visible emissions indicating decrease in defects produced in the crystal lattice, suggesting that the metallic Ag was deposited on the defect sites. Thus silver loaded zinc oxide is good photocatalyst because in a photocatalytic process, the separation and recombination of photoinduced electron and hole are competitive pathways, and photocatalytic activity is effective when the recombination is prevented. The extent of recombination can be probed by the intensity of photoluminescence.

Fig. 5.7 Room temperature photoluminescence spectra of silver loaded zinc oxide nanoparticles

5.3.7 PSD and zeta potential measurements of silver loaded zinc oxide

Fig. 5.8 shows particle size distribution histogram of silver loaded zinc oxide nanoparticles the particle size is distributed in between 35 nm to 50 nm. This particle size was same as observed in FE-SEM.
Fig. 5.9 shows zeta potential of silver loaded zinc oxide nanoparticles. Zeta potential was found to be $+20.2$ mV which indicates that the charge on particles was positive. The zeta potential of bare zinc oxide is $+4.96$ mV, after loading of silver, zeta potential was increased indicating surface modification of zinc oxide takes place by silver. Also the stability of zinc oxide nanoparticles is increased after loading of silver nanoparticles on it.

**Fig. 5.8** Particle size distribution histogram of silver loaded zinc oxide nanoparticles

**Fig. 5.9** Zeta potential of silver loaded zinc oxide nanoparticles
5.3.8 Antibacterial activity of silver loaded zinc oxide nanoparticles

The antibacterial activity of silver loaded zinc oxide nanoparticle was studied against three representative pathogenic bacteria viz. *E. coli*, *S. aureus* and *P. aeruginosa*. The silver loaded zinc oxide nanoparticles were dispersed in methanol by ultrasonication and 2000 ppm concentration was prepared. Out of that 10 μL, 15 μL and 20 μL were used for antibacterial testing. The table 5.4 shows the results of antimicrobial activity of tested bacteria. The control (methanol - the solvent used for dispersion of Ag loaded zinc oxide) shows no zone of inhibition indicating that the activity was due to silver loaded zinc oxide nanoparticles.

**Table 5.4: Results of antibacterial activity showing zone of inhibition**

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Bacterial strains</th>
<th>Zone of inhibition shown by silver loaded zinc oxide nanoparticles (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Control</td>
</tr>
<tr>
<td>1</td>
<td><em>E. coli</em></td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td><em>S. aureus</em></td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td><em>P. aeruginosa</em></td>
<td>0</td>
</tr>
</tbody>
</table>

*E. coli* shows zone of inhibition of 12 mm, 20 mm, 26 mm. For *S. aureus* zone of inhibition was 16 mm, 22 mm, 26 mm and *P. aeruginosa* shows 12 mm, 16 mm, 20 mm zone of inhibition for 10 μL, 15 μL and 20 μL of 2000 ppm zinc oxide solutions respectively. The photograph shows antibacterial effect of silver loaded zinc oxide nanoparticles on above three bacteria (Fig.5.10a, 5.10b, 5.10c).
Fig. 5.10a Photograph of antibacterial effect of silver loaded zinc oxide nanoparticles on *E. coli*.

Fig. 5.10b Photograph of antibacterial effect of silver loaded zinc oxide nanoparticles on *S. aureus*.
Fig. 5.10c Photograph of antibacterial effect of silver loaded zinc oxide nanoparticles on *P. aeruginosa*

The antimicrobial activity of these nanoparticles may be related to several mechanisms including, induction of oxidative stress due to generation of reactive oxygen species (ROS) which may cause the degradation of the membrane structure of the cell [35], membrane disorganization due to accumulation of ZnO nanoparticles in the bacterial membrane and also their cellular internalization release of Zn ions that may be responsible for antimicrobial activity by binding to the membrane of microorganisms. However, the toxicity of silver loaded ZnO nanoparticles is not directly related to their entering into the cell, rather their intimate contact onto the cell causes changes in the microenvironment in the vicinity of the organism–particle contact area to either increase metal solubilization or to generate ROS, that may ultimately damage cell membrane. Moreover, the toxicity of ZnO nanoparticles is not only affected by the light via ROS production, but may also happen in the dark although its mechanism is not yet defined [36]. Both silver and zinc oxide shows antibacterial activity so silver loaded zinc oxide nanoparticles shows synergetic effect on antibacterial activity. Loading of only small amount of silver increases antibacterial activity largely.
5.3.9 Photocatalytic activity

Dye effluents from various industries are becoming a serious environmental problem because of their unacceptable color, high chemical oxygen demand and resistance to chemical, photochemical and biological degradation. So the degradation of such dye solution is very necessary. The photocatalytic activity of synthesized silver loaded zinc oxide was studied for degradation of Rhodamine B in sunlight. The photocatalytic degradation efficiency of Rh B was calculated according to the following equation:

\[
\text{Efficiency (\%)} = \frac{A_0 - A}{A_0} \times 100
\]

where, \( A_0 \) represents the initial absorbance of the Rh B solution, \( A \) is the absorbance after irradiation. Fig. 5.11a shows time course of the decrease in the concentration for the photodegradation of Rh B under sunlight irradiation from 0 hr to 5 hrs. As compared to degradation of Rh B with pure zinc oxide, loading of small amount of silver nanoparticles leads to enhancement of photocatalytic activity.

From Fig. 5.11a it is clear that the degradation of Rh B takes place within 5 hrs irradiation of sunlight. Also the chemisorptions of molecular oxygen and the chemisorptions of atomic oxygen on Ag in the Ag-ZnO photocatalyst were observed. It was found that the metallic Ag in the Ag-ZnO nanocomposite does play a new role of \( O_2 \) chemisorption sites except for electron acceptor, by which chemisorbed molecular oxygen reacts with photogenerated electrons to form active oxygen species, and thus facilitates the trapping of photogenerated electrons and further improves the photocatalytic activity of the Ag loaded ZnO.
Fig. 5.11a The time course of the decrease in the concentration for the photodegradation of Rh B under sunlight irradiation

The mechanism involving degradation is the excitation of photocatalyst by solar energy leads to the formation of an electron–hole pair. The hole combines with water to form ‘OH radicals while electron converts the dissolved oxygen to super oxide radical (‘O₂), a strong oxidizing species. Due to presence of silver the formation of electron hole pair rate was increased and degradation becomes faster. The O²⁻ radicals are further converted into HO₂⁻ and ‘OH species. It is given below,

\[
\begin{align*}
ZnO + h\gamma & \rightarrow ZnO (h^+ + e^-) \\
h^+ + OH^- & \rightarrow OH^-
\end{align*}
\]

\[
\begin{align*}
h^+ + H_2O & \rightarrow OH + H^+ \\
Ag + e^- & \rightarrow Ag \\
e^- + O_2 & \rightarrow O_2^- \\
O_2^- + H^+ & \rightarrow OH_2 \\
2 OH_2 & \rightarrow H_2O_2 + O_2
\end{align*}
\]
The photocatalytic activities are then suppressed if the photo-induced electrons are recombined with holes as follows:

\[ h^+_{vb} + e^- \rightarrow \text{heat} \]

This proposed mechanism was supported by the photoluminescence (PL) spectra. As shown in Fig. 5.7, the room-temperature PL spectra of Ag-ZnO comprise two emission bands in the UV-visible regions under the above band-edge excitation. The narrow UV emission band centered at 410 nm was assigned to the exciton recombination while the one wide band centered at 475 nm originates from some interface traps of radiative defects at the grain boundaries between silver and ZnO grains. With the addition of silver, the PL intensity in the ultraviolet region was almost quenched as a result of the charge transfer from ZnO to Ag, which provides additional evidence that the noble-metal contact improves the energetics of the semiconductor-assisted photocatalysis. Two blank experiments were run as given below.

1) 100 mL 20 ppm Rh B + 0.1 gm ZnO \( \rightarrow \) dark no degradation is observed (Table 5.5).

2) 100 mL 20 ppm Rh B \( \rightarrow \) Sunlight no degradation is observed (Fig. Table 5.6).

**Table 5.5:** Study of absorption changes in set 2 from 1 hr to 5 hrs irradiation

<table>
<thead>
<tr>
<th>No.</th>
<th>Time (hr)</th>
<th>Absorbance (a.u)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1.22</td>
</tr>
<tr>
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<td>1.21</td>
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<tr>
<td>3</td>
<td>3</td>
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</tr>
<tr>
<td>4</td>
<td>4</td>
<td>1.22</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>1.22</td>
</tr>
</tbody>
</table>
Table 5.6: Study of absorption changes in set 3 from 1 hr to 5 hrs irradiation

<table>
<thead>
<tr>
<th>No.</th>
<th>Time (hr)</th>
<th>Absorbance (a.u)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1.26</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>3</td>
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<td>4</td>
<td>1.25</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>1.26</td>
</tr>
</tbody>
</table>

Fig. 5.11b represents plot of % degradation against time. From fig.5.11b it is clear that about 90 % degradation of Rh B took place after 5 hrs irradiation of sunlight. Fig.5.11c is a plot of C/C₀ and time, where C is the concentration of Rh B remains after irradiation and C₀ is the initial concentration of Rh B. This graph indicates the decrease in concentration after 1 hr. From Table 5.5 and 5.6 it is clear that the degradation was not due to adsorption or photodegradation, but it was due to our silver loaded zinc oxide photocatalyst. The synergetic effect was observed on the photocatalytic activity of Rh B because of loading of silver nanoparticles on zinc oxide. For ZnO catalyst 80 % degradation takes place within 8 hrs using 0.2 g, but for silver loaded zinc oxide catalyst about 90 % degradation will takes place to within 5 hrs using 0.1 g catalyst.
Fig. 5.11b Percentage degradation of Rh B with respect to time

Fig. 5.11c Plot of $C/C_0$ with respect to time
Chapter 5

5.4 Conclusions

In this study, Ag loaded ZnO nanoparticles were successfully synthesized using reduction of silver ion on zinc oxide using Ocimum tenuiflorum leaf extract. The synthesized silver loaded nanoparticles was characterized by different techniques like XRD, diffuse reflectance UV-visible, PL, FE-SEM, FT-IR, TEM, PSD, Zeta potential etc. Zeta potential confirms surface modification of zinc oxide with silver nanoparticle. The antibacterial activity of silver loaded zinc oxide nanoparticles was studied for three representative classes of bacteria observed in hospital environment. From diffuse reflectance UV-visible the silver loaded zinc oxide nanoparticles shows absorption from 275 nm to 400 nm indicating that these nanoparticles are better for UV-blocking. The photocatalytic degradation of Rhodamine B was studied for silver loaded zinc oxide nanocomposite under sunlight irradiation. It serves as a very efficient photocatalyst for Rh B. The synergetic effect was observed on antibacterial activity and photocatalytic activity due to loading of silver nanoparticles on zinc oxide. The loading of silver nanoparticles on zinc oxide leads to the surface modification which is responsible for enhancement of antibacterial properties and photocatalytic activity due to separation efficiency of photogenerated electrons and holes in ZnO.
Chapter 5

References