Plant Based Synthesis of ZnO Nanoparticles and Characterization by UV-Vis Spectroscopy

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Abstract

In the modern fast changing world, as the green and environment friendly methods are much required and preferred over conventional toxic methods, plant based nano synthesis has a brilliant scope in future developments of nanotechnology. In the present work, the synthesis and characterization of Zinc Oxide nanoparticles has been discussed by using the green synthesis method which utilizes the leaves of Ocimum Tenuiflorum as reducing agent for Zn salt. ZnO NPs prepared by such a technique exhibit superior antibacterial efficacy against a range of bacteria compared to ZnO NPs produced through chemical methods, without developing resistance to antibiotics. The characterization of ZnO NPs has been done by UV-Vis spectroscopy technique and the Tauc Plot method has been used for calculation of bandgap.

Keywords: Green synthesis, UV-vis Spectroscopy, Ocimum Tenuiflorum, ZnO nanoparticles.

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Introduction

In this modern and fast changing world, nano technology plays a very crucial role. A major part of nano technology subject is the synthesis of nano sized particles or structures. Nano materials excel in various regions like electrical conductivity, magnetic properties, thermal properties, as compared to bulk materials [1]. The various electronic and optical properties of ZnO such as high optical transparency due to wide band gap and luminescence in the near ultra violet and the visible regions makes it an important material for the fabrication of solar cells (anti-reflecting coating and transparent conducting materials), gas sensors, liquid crystal displays, heat mirrors, surface acoustic wave devices etc [2-5]. ZnO NPs can be prepared by various physical and chemical methods but the physical techniques involve a number of draw backs such as requirement of high energy, lack in accuracy, irregular size distribution, high cost, tremendous amount of secondary waste, and uncontrolled environmental pollution [6-10]. Thus the use environmental friendly synthesis techniques will be capable to make ZnO NPs the material of optimum use. One of such method is plant-based synthesis. Plants and their extracts are simple to get, and the sole requirement for the procedure is a zinc salt solution to act as a precursor metal which is then reacted with plant extract. Extracts obtained from plants may act as a reducing, stabilising and capping agent [11-15].

Recently, it has been studied gold, copper and ZnO nano particles can be prepared frpm Ocimum tenuiflorum, commonly known as Holy Basil, Tulsi [16-17]. It is an aromatic perennial plant native to the Indian subcontinent from the family of Lamiaceae and its phytochemical constituents are oleanolic acid, ursolic acid, rosemarinic acid, eugenol, carvacrol, linalool and β- caryophyllene (about 8%) [18]. In this present task, ocimum tenuiflorum leaves extract has been used to make ZnO nanoparticles and the particles obtained have been characterized by using an UV-Vis spectrometer.

Laboratorial Procedure

Material

The chemicals used in this process such as Zinc Nitrate (96%), distilled water, ethanol (99%), were purchased from Friends Chemicals & laboratories, Bikaner, Rajasthan, India. Instruments like Magnetic Stirrer- Heater, Beakers, Flasks and other basic laboratory tools were used and the experiment was performed at research laboratory of Physics Dept., Engineering College Bikaner.

Methodology

Leaves extract preparation of ocimum tenuiflorum

(i)Fresh leaves of Tulsi (Ocimum Tenuiflorum)

were collected from plant nursery at Sri Jagannath Ji Temple, Bikaner. (Figure 1)

(ii) The leaves were washed and cleaned with distilled water and kept in bright sunlight to dry for 3 days.

(iii) 10-12 gm dried leaves were boiled in 100 mL of distilled water until the water turned deep reddish in colour. (12-15 mins)

(iv) After letting the mixture cool down at room temperature, the extract was filtered by filter paper in a glass container.

(v) The extract was ready and was stored in refrigerator for later use. (Figure. 2)

Figure 1: Ocimum Tenuiflorum Plant

Figure 2: Aqueous Leave extract of Ocimum Tenuiflorum Plant

Fabrication of ZnO NPs from extract of ocimum tenuiflorum

(i) 50 mL of the leave extract was heated by magnetic stirrer heater until the temperature reached 70-80 °C.

(ii) When the temperature reached 70 °C then 5 gm Zinc Nitrate was added and stirred for 30-40 seconds.

(iii) The solution was then boiled at 100-110 °C until deep reddish paste was obtained. (It took 40-45 minutes. The water slowly evaporated and after around 40 minutes, only a deep reddish wet paste was left)

(iv)The paste was then heated at 140-150 °C. after few minutes of heating, Brown coloured fumes were seen and the wet paste started turning into dry yellow powder.

(v) Soon all the remaining water evaporated in form of Brown fumes and a yellow powder was left behind. (It took around 10 minutes for the wet paste to get completely dry)

(vi) The yellow powder was cooled down at room temperature and then was crushed in ceramic mortar pestle.

The ZnO NPs were obtained in form this yellow powder (weight = 1.43 gm) and were stored in glass container in dark place for further characterisation. Figure 3 pictorially shows the entire process.

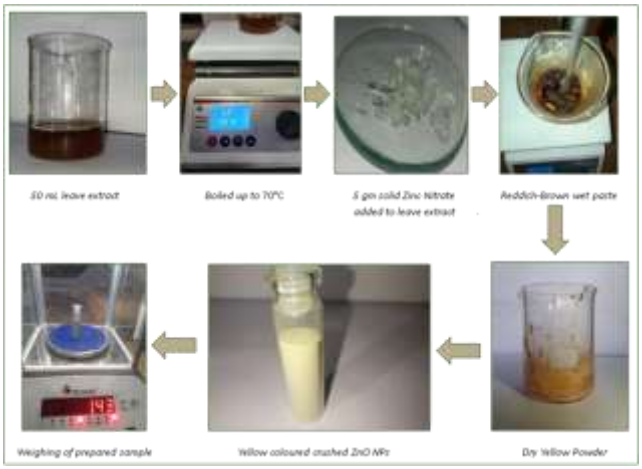

Figure 3: The process of making ZnO NPs from Ocimum Tenuiflorum leave extract

Discussion of Results

UV-Visible Spectroscopy

To confirm the biogenic synthesis of ZnO and to characterize the optical absorption properties of ZnO, the UV-Visible Spectroscopy was done on the obtained sample. A Shimadzu UV 3600 UV-Vis-NIR spectrometer (Engineering College Bikaner) using Ethanol (99%) as reference has been used and the UV-Vis absorption spectra of the samples were recorded in the wavelength range of 300 to 800 nm at room temperature. Tauc's method was used to study the obtained data. The obtained absorption spectrum is shown in Figure 4.

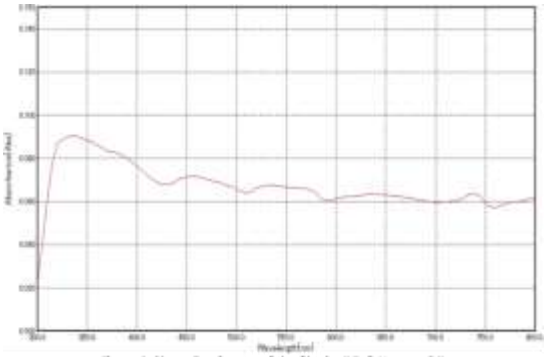

Figure 4: Absorption Spectra of the Obtained ZnO Nanoparticles

A peak of absorption spectra specific to ZnO nanoparticles was visible at 335 nm. The absorbance peak is reported to occur between 310 nm and 360 nm of wavelength for ZnO

nanoparticles [19]. The peak absorbance was 0.091 Abs. On comparing the absorption spectra and its details with the existing literature about ZnO NPs (both greenly and chemically synthesised), it is confirmed that the prepared sample does contain Zinc Oxide nanoparticles [20-22].

Calculation of Band Gap

The optical energy band gap (Eg) for the obtained NPs was calculated by Tauc's method. the absorption coefficient is given by, $\alpha = \ln(10) * A/t$, where A is the absorbance and t is the optical path length. The optical path followed by light is equal to the cuvette used in photo-spectrometer which was measured to be 1 cm. Thus, for Various values of absorbance (at various wavelength), the values of Absorption Coefficient can by calculated by

$$\alpha = \ln (10) *A \ (cm^{-1})$$

The photon energy for various wavelength can be calculated by

$$E = hv = hc/\lambda = 1240/\lambda \text{ eV-nm.}$$

Now the Tauc's relation states that

$$(\alpha hv)\ n = A*(hv-Eg)$$

where Eg is the band gap of the material. Since ZnO is a direct band gap material and for direct band gap material n=2, therefore

$$(\alpha hv)\ 2 = A*(hv-Eg)$$

In this equation if (αhv) becomes zero then

$$E = hv = Eg$$

which shows that if a graph is plotted between (αhv) 2 on Y-axis and (hv) on X-axis then at Y=0, the value of (hv) will give the value of Eg i.e. Energy band gap of the ZnO. The plot between (αhv) 2 and (hv) is known as Tauc's Plot. By taking values from the above absorption spectra, Tauc's plot for the prepared ZnO NPs was plotted which is shown in Figure 5.

On extrapolating the first linear region in the obtained plot, the value of Band gap came out to be 2.61 eV. This value is very close to the industrial standard values for ZnO NPs prepared by chemical methods. The standard value of band gap for ZnO NPs lies between 3.1 to 3.4. [23]

The red shift seen in the obtained bandgap can be attributed to surface oxidation. The surface oxidation led to formation of new energy states which disturbs the effective band gap. Also, the surface of particles might be covered by organic ions and compounds from the plant extract [24].

Another notable reason could be sample aging which could lead to agglomeration of nanoparticle by weak forces. This reduces the energy gap of material [26].

The energy gap of greenly synthesized nanoparticles often comes out to be slightly red or blue shifted due to the above-mentioned reasons [25-28].

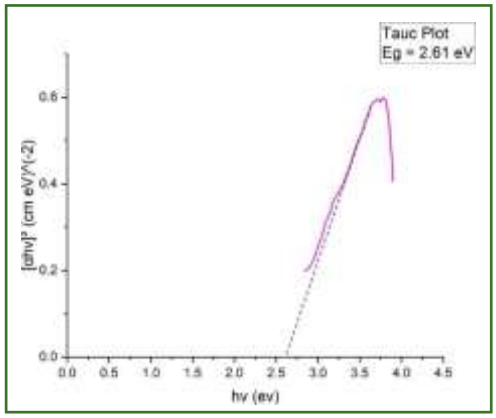

Figure 5: Tauc's plot for ZnO NPs

Conclusion

In this article, we have synthesized Zinc Oxide Nanoparticles by environment friendly plant based synthesis method. Leaves extract of Ocimum Tenuiflorum (TULSI) was used as stabilizing, reducing and capping agent. ZnO nanoparticles were obtained in form of yellow powder. By Tauc's method, their band gap came out to be 2.61 eV which was slightly red shifted from industrial standard value of ZnO NPs. This could be due to surface oxidation and sample aging. Since the band gap of plant-based nanoparticles often tends to be slightly red or blue shifted, this particular method can be used to make ZnO nanoparticles of a slightly narrow band gap. As such NPs show great antibacterial activity, they serve wide range of applications in medical textile like antibacterial bandages, masks gloves etc. They also serve applications in semiconductor devices, photoluminescent devices and harvesting piezoelectric energy. Narrow band gap ZnO NPs are specially required for degradation of organic dyes.

Overall, this turned out to be an convenient, economic and eco-friendly method to synthesize ZnO nanoparticles.

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