

Synthesis and Characterization of Zinc Oxide Nanoparticles

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(Received October 28, 2022, revised March 27, 2023, Accepted March 31, 2023)

Abstract: Precipitation method was used to effectively create zinc oxide (ZnO) nanoparticles, and its structural characteristics were investigated. UV-vis and Raman spectroscopy were used to analyse the prepared nanoparticles. The Raman Spectroscopy reveals the phonon frequency in these nanoparticles, and it was discovered that the Raman modes of zinc oxide nanoparticles move to the lower wave number side. Additionally, the UV-vis Spectroscopy reveals that ZnO's highest wavelength is close to 200 nm, which is in the UV region and has an absorbance of 0.78.

Keywords: Synthesis, Characterization, Nanoparticles, Zinc Oxide, Precipitation Method.

1. Introduction

Nanotechnologies and nanomaterials are attracting academic interest. The physical properties and technologies in sample preparation as well as device fabrication evoke on accounts of the development of Nano science. Moreover, physical and chemical properties of a given material are derived from its crystalline structure. Zinc Oxide (ZnO) nanoparticle has a direct and wide band-gap of the II-VI semiconductor group¹. Mostly, it is an n-type semiconductor which possesses a band gap of about 3.37eV (at room temperature) and 3.44eV (at low temperature)^{2,3}. The optical absorption coefficient value of ZnO thin films was relatively high (upto $5 \times 10^4 \text{ cm}^{-1}$). Zinc oxide crystallizes in two forms- hexagonal wurtzite and cubic zinc blende⁴. This semiconductor has several favourable properties: good transparency, high electron mobility, wide band-gap and strong room-temperature luminescence, etc. and have been used in different fields of catalysis, sensors, electronic devices, solar cells, etc. Optical properties of zinc oxide can be investigated by using UV-vis absorption and photoluminescence (PL) Spectroscopy².

In recent years, considerable efforts have been made in the synthesis of ZnO nanostructures. Today, when the world is surmounting on the roof of technology and electronics, mostly dominated by compatible electronic equipment's and thereby creating the need for materials possessing versatile properties. But, the world now demands a larger band gap, higher electron mobility as well as higher breakdown field strength. So, on making investigation about such a material the name of compound comes out is "Zinc Oxide (ZnO)". ZnO has been commonly used in its polycrystalline form over hundred years in a wide range of applications. Since its discovery in 1950, ZnO research has been gaining momentum. Numerous studies on its electrical and optical properties have been published⁵⁻⁷, and some significant metal oxide nanoparticles are used in antibacterial and wastewater applications⁸.

2. Synthesis of Zinc Oxide Nanoparticles

Zinc Oxide (ZnO) nanoparticles were synthesized by Precipitation Method. Two chemicals viz. Zinc Nitrate Hexahydrate and Sodium Carbonate are used as precursors. 0.1 M solution of zinc nitrate is prepared by dissolving 30g of zinc nitrate hexahydrate in 200 ml of distilled water and 0.12 M solution of sodium carbonate is prepared by dissolving 10g of sodium carbonate in 250 ml of distilled water. Then, in the next step, burette is filled with 0.12M solution of sodium carbonate in order to add it drop wise into 0.1 M solution of Zinc nitrate under vigorous stirring for 1 hour which then result in the formation of white precipitate solution. Besides, after overall adding, the white precipitate solution is further stirred for at least 3 hours. White precipitate is then collected by filtration and washed two times with distilled water in order to remove the unreacted soluble reactants. The solid white mass is then washed with ethanol three times to remove organic impurities, if present, and then dried at the temperature range 80°C-100°C for 6 hours in oven.

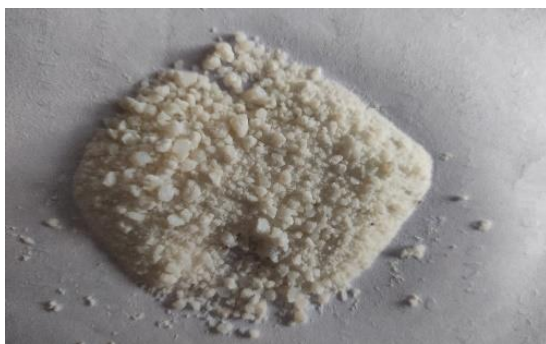


Figure 1 : Synthesized ZnO nanoparticles

Finally, ZnO nanoparticles are obtained by annealing this solid white mass at 120°C to improve the crystallinity of ZnO particles (Figure 1).

3. Characterization

Synthesized ZnO nanoparticles have been characterized by Raman Spectroscopy and UV-vis Spectroscopy. The phonon spectrum of ZnO has been studied with Raman spectroscopy and the corresponding Raman spectra shows that frequency of the phonon in these nanoparticles was initially high, which later decreases with the crystalline size, while its line width increases. Besides, UV-vis spectroscopy was employed to determine the characteristic absorption of UV radiation by the ZnO nanoparticles. Under the study of this spectroscopy, it shows UV-vis spectra with a sharp peak. This peak indicates the Nano scale particle.

4. Raman Spectroscopy of ZnO Particles

For finding out how crystalline a material is, Raman spectroscopy is essential. The foundation of this spectroscopy method is the inelastic scattering that results from the contact of the sample with a monochromatic light source, typically a laser (Figure 2).



Figure2 : Raman Spectrometer (XploRA ONE 785nm)

After wards the frequency of the particles in the monochromatic light changes. The Raman Effect is a phenomenon that occurs when a sample absorbs photons and then releases them with a frequency that is shifted up or down in comparison to the initial frequency. Information about rotation, vibration, and other low frequency changes in molecules is provided by this shift. Raman spectroscopy can analyse samples of gases, liquids, and solids. Some phonons or vibration modes may become constrained as the size of the

crystalline particle shrinks as a result of the particle's tiny volume. This can manifest in a number of ways, such as shifting vibrations to different frequencies, changes in the symmetry of the vibrational peak shapes, and even the augmentation or disappearance of peak shapes. Thus, simply analysing the spectra (Figure 3) one can provide information about the object being studied.

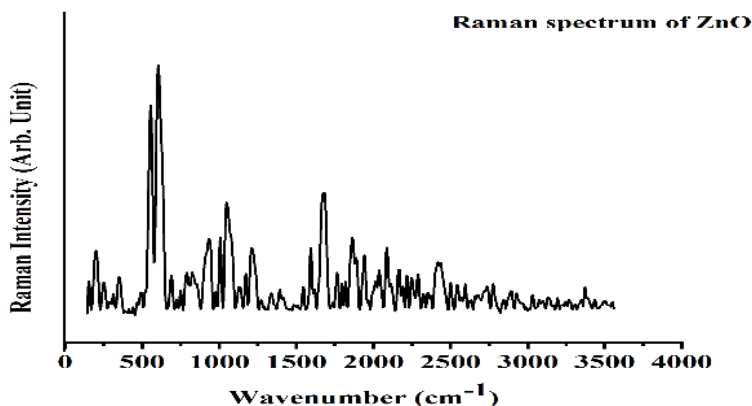


Figure 3: Raman Spectrum

5. UV Spectroscopy of Zinc Oxide Nanoparticles

UV-Vis spectroscopy is very popular analytical techniques as it is very competent and can detect almost every molecule. With UV-Vis spectroscopy, the UV light is passed by a sample and the transmittance of light by a sample is measured. From the transmittance (T), the absorbance is calculated by formula, $A = -\log(T)$. An absorbance spectrum is obtained that shows the absorbance of a compound at different wavelengths. The amount of absorbance at any wavelength is caused by the molecule's chemical structure. The UV extends from 100 to 400 nm and the visible spectrum from 400-700 nm. The 100-200 nm range is called the deep UV. Typical UV-vis spectrometers (Figure 4) use a deuterium lamp for the UV that produces light from 170-375 nm and a filament lamp made of tungsten for visible, which produces light from 350-2500 nm. When a photon hits a molecule and is absorbed, then the molecule tends to transit into a more excited energetic state. UV-visible light has enough energy to promote electrons to a higher electronic state, from the Highest Occupied Molecular Orbital (HOMO) to the Lowest Unoccupied Molecular Orbital (LUMO). The energy gap between the HOMO and the LUMO is called the band gap. Typically, these orbitals are called bonding and anti-bonding. The photon energy must be same as the

band gap for the photon to be absorbed. Thus, molecules with different chemical structures have different energy band gaps and different absorption spectra.



Figure 4 : UV Spectrophotometer (HITACHI U-3900)

6. Conclusion

Precipitation method was used to effectively create zinc oxide (ZnO) nanoparticles, and Raman and UV-vis spectroscopy were used for characterization. The phonon spectrum of ZnO nanoparticles has been studied with the help of Raman spectroscopy, and the corresponding Raman spectra (Fig.3) indicate that the Raman modes were observed at nearly 590 cm^{-1} , 1100 cm^{-1} , and 1600 cm^{-1} with some weak intensity modes. Additionally, it was found that the Raman modes of zinc oxide nanoparticles shifted towards the side with smaller wave number due to phonon confinement.

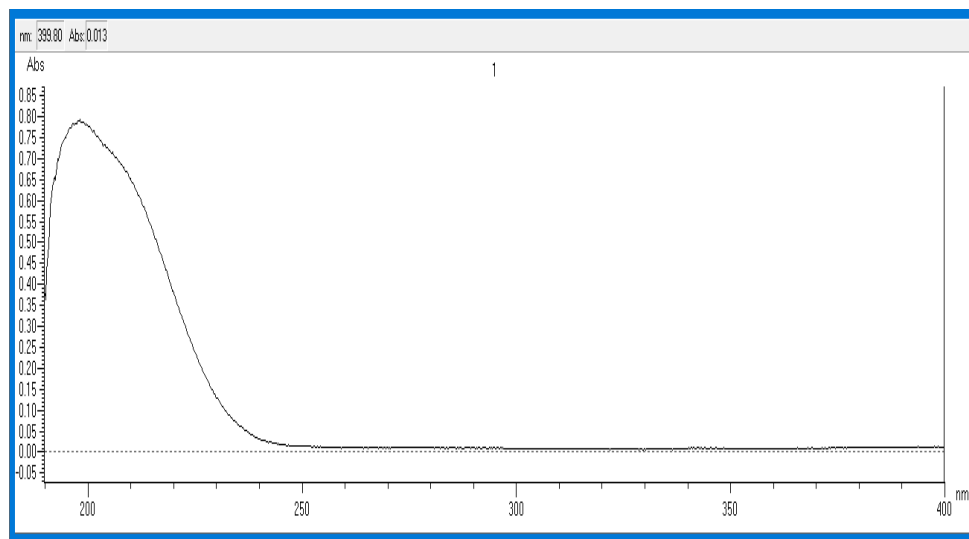


Figure 5 : UV Spectra

Using UV-vis spectroscopy, it has been observed that ZnO has a maximal wavelength close to 200 nm, which is in the UV region as well as has an absorbance of 0.78 (Figure 5). The most common use of ZnO nanoparticle is in sunscreen due to its ability to absorb the UV light effectively. It play vital role in manufacture of rubber and cigarette filters, calamine lotion and creams. Also it is used as a coating agent in various plants.

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