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Non linear optical investigations of silver nanoparticles synthesised by curcumin reduction

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ABSTRACT

Metal nanoparticles have considerable applications in assorted fields like medicine, biology, photonics, metallurgy etc. Optical applications of Silver nanoparticles are of significant interest among researchers nowadays. In this paper, we report a single step chemical reduction of silver nanoparticles with Curcumin both as a reducing and stabilising agent at room temperature. Structural, plasmonic and non linear optical properties of the prepared nanoparticles are explored using Scanning Electron Microscope, Transmission Electron Microscope, UV absorption spectrometry, Spectroflurometry and Z scan. UV–Vis absorption studies affirm the Surface Plasmon Resonance (SPR) absorption and spectroflurometric studies announce the emission spectrum of the prepared silvernanoparticles at 520 nm. SEM and TEM images uphold the existence of uniform sized, spherical silvernanoparticles. Nonlinear optical studies are accomplished with the open aperture z scan technique in the nanosecond regime. The nonlinearity is in virtue of saturable absorption, two-photon absorption and excited state absorption. The marked nonlinearity and optical limiting of the Curcumin reduced silvernanoparticles enhances its photonic applications.

1. Introduction

Sustainable, commercially viable synthesis of nanoparticles in a faster way is an active area of research nowadays. Nanoparticles have high surface to volume ratio which gives them additional properties than their macro counter parts. Their optical, chemical, photochemical and electronic properties receive greater attention among researchers. Metal nano particles, especially the noble metals, have been studied because of their strong optical absorption in the violet-blue region caused by excitation of free-electron gas [1,2].

Silver nanoparticles (AgNPs) have many applications in non linear optics, catalytic action in chemical reduction, high energy absorption, and dentistry, clothing, photography and food industry [2]. As it is a potential candidate for many applications several preparation methods also have been developed for synthesis of AgNPs [3–16]. Here we report a fast, single pot wet chemical synthesis of AgNPs using Curcumin in alkaline pH without the use of any additive protection of nanoparticles from aggregating, template shaping nanoparticles or accelerants [12]. Here Curcumin act both as a reducing and stabilising agent.

The intense monochromatic radiation from a laser can induce profound changes in the optical properties of a material. Non linear absorption refers to the change in transmittance of a material as a function of intensity or fluence [17]. Open aperture Z-scan method is an effective and sensitive method to study the nonlinear optical properties of materials [19]. At sufficiently high intensities, the probability of a material absorbing more than one photon before relaxing to the ground state can greatly be enhanced.

2. Materials and methods

Curcumin and Silver nitrate were used as such without further purification. NaOH was used to make the alkaline pH for Curcumin. Glass wares used were clean enough.

2.1. Synthesis of AgNPs

0.1 g of $AgNO_3$ dissolved in 20 ml of distilled water. 0.1 g of Curcumin is mixed with 5 M NaOH to get Curcumin oxide solution. 0.75 ml of Curcumin oxide solution was added drop by drop to the $AgNO_3$ solution taken in a round bottom flask and stirred well for 2 h. The colour change of the solution from yellow to brown is an

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indication of formation of AgNPs. After 2 h continuous stirring, the reduction is over and solution is centrifuged at the rate 4000 rpm for 30 min, the supernatant is decanted, precipitate was washed 3 to 4 times to remove the impurities. The solution after washing with DI water is filtered using cellulose membrane filter paper and was dried under vacuum to get pure AgNPs.

2.2. Characterisation methods

UV–Visible spectrometry studies were done in PerkinElmer LAMDA 35 spectrophotometer in the wavelength range 300–800 nm. Emission spectrum characterisation was done using Horiba Fluromax-4 in the wavelength range 400–700 nm Scanning Electron Microscope (SEM) imaging with ZEISS FE -SEM was used to get the topographic image of the prepared silver nanoparticles. Transmission electron microscopy studies were carried out using TECNAI T 12 G2 Spirit Bio-TWIN instrument. Colloidal suspension in ethanol was used for all the characterisation procedures.

2.3. Non linear optical study using open aperture Z scan

Nonlinear optical absorption studies of the AgNPs in the ns excitation time scale was carried out using the open aperture Z-scan technique (Fig. 1), employing linearly polarized Gaussian pulses of 5ns duration at 532 nm obtained from a Q-switched frequency doubled Nd; Yag laser, operating in the single-shot mode. The laser beam was focused using a converging lens of focal length 10.75 cm. Beam propagation direction is taken as the z axis, and the focal point is taken as $z = 0$. For non linear transmission measurements, the AgNPs uniformly dispersed in ethanol was taken in a 1 mm path length cuvette. The concentration of the solution is adjusted to have a linear transmittance 84%. The cuvette was mounted on a stepper motor controlled linear translational stage and was translated from $-z$ to $+z$ through the focal point in successive steps, and the transmitted energy was measured at each step using a pyro-electric energy detector (Laser Probe, RjP-735).

3. Results and discussions

3.1. Material characterisation

Silver nanoparticles exhibit a yellowish-brown colour due to excitation of surface Plasmon vibrations in the metal nanoparticles [13]. Graph 1 depicts the absorption spectra corresponding to the Curcumin reduced AgNPs at 464 nm. The Curcumin reduced AgNPs display excellent stability over time in solutions. Here AgNPs were prepared at room temperature. For irregular particles (non spherical), two or more Plasmon bands are expected depending on the symmetry of the particles. Here we obtained a single band of absorption at 464 nm which indicates the spherical shape as confirmed by SEM and TEM. SEM and TEM images (Figs. 2 and 3) also showed that the synthesised silver nanoparticles were of uniform size and shape of the order of 22 nm and spherical in shape.

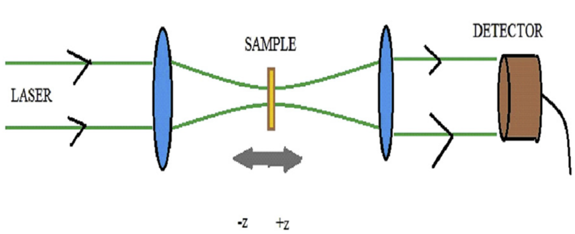


Fig. 1. Representative schematic of the open aperture Z-scan setup used for nonlinear optical measurements. A laser beam is focused using a converging lens. The light energy transmitted by the sample (taken in a 1 mm cuvette) at different positions is monitored as the sample is translated along the z-axis, through the focal point.

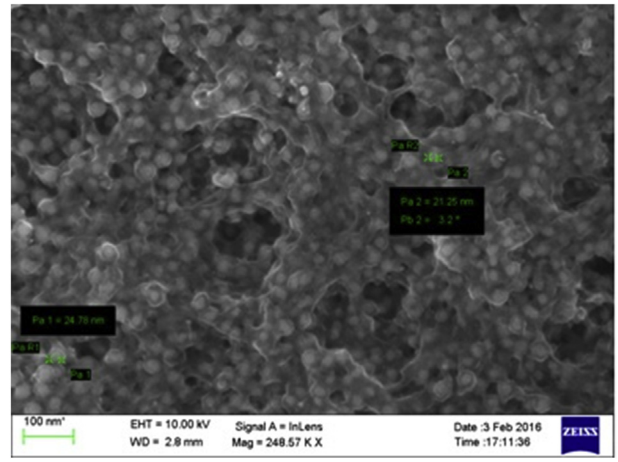


Fig. 2. SEM image of AgNPs.

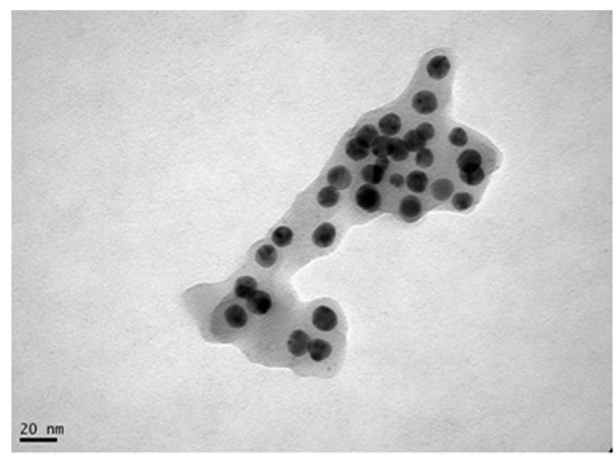
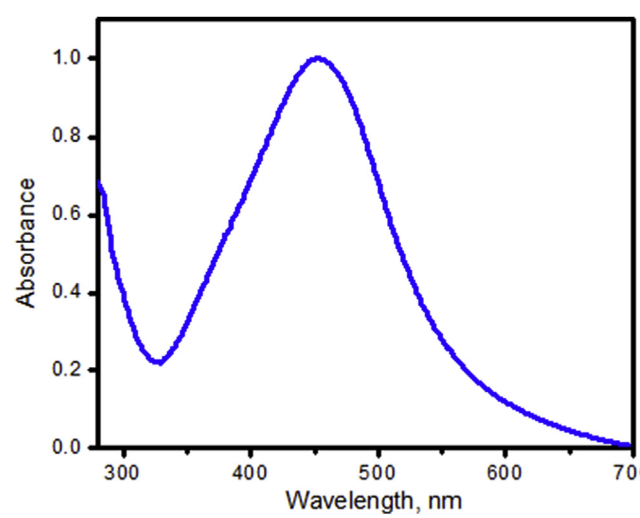


Fig. 3. TEM image of AgNPs.



Graph 1. UV–Vis spectrum of AgNPs at a sharp peak at 464 nm.