OPTICAL PROPERTIES OF STABLE, STRONGLY CONFINED CdS NANOSTRUCTURES PREPARED BY MICROWAVE ASSISTED SYNTHESIS

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Abstract

Strongly confined CdS nanostructures are formed by a microwave-assisted chemical route of synthesis. The mean particle size is found to be around 1 nm. The nanostructures are obtained in the form of either powders or suspensions in appropriate solvents by different chemical treatments. The nanostructures are found to be quite stable. Optical absorption spectra exhibit clear and large blue-shifts from the bulk spectrum depending on the particle size. The experimental data are analysed by fitting them to theoretical models. Room temperature absorption spectra show structures attributed to exciton transitions. The corresponding excitation spectra reveal exciton transitions. Results on the nonlinear optical response using the z scan technique suggest large optical nonlinearity in the nanostructures.

Introduction

The optical properties of semiconductor nanoparticles are greatly influenced by quantum confinement of charge carriers. Several interesting results have been obtained on the confinement effect on the linear and nonlinear optical properties of semiconductor nanoparticles [1-3]. These materials are also being investigated as candidate materials for various photonics device applications [4].

Different methods have been developed for the synthesis of nanoparticles, for e.g. using stabilizers such as thiols, selenols, phosphates and phosphine oxides and by using matrices such as zeolites, glasses, polymers, reverse micelles, vesicles, LB films and silica. Microwave assisted synthesis is one of the novel methods for preparing semiconductor nanoparticles[5]. In microwave irradiation, the interaction of the dipole moment of polar molecules or molecular ionic aggregates with alternate electric and magnetic fields causes molecular level heating which leads to homogeneous and quick thermal reactions.

Experimental section

1mM of cadmium acetate was dissolved in 50 ml DMF. 52mM of thioacetamide dissolved in 2ml of DMF was added dropwise into this solution while vigorously stirring it. This solution was stirred for 30 minutes. Initially colorless,, the solution now turns transparent yellow due to the formation of colloidal CdS nanoparticles. This solution was microwave irradiated for different scheduled times. The optical absorption spectra were recorded on Hitachi U 3400

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recording spectrophotometer. Nonliner optical studies are done with a Spectra Physics Ti:Saphire amplifier.

Results and discussion

Optical absorption spectra of the samples microwave-irradiated for 10 seconds, 20 seconds, 35 seconds, 40 seconds and 45 seconds respectively (fig 1) exhibit clear and large blue shifts from the bulk spectrum depending on the particle size. Mean CdS particle sizes were determined from the absorbance spectra using Henglein's model [6,7].

The data on the long wavelength side of the optical absorption spectrum are fitted to two Gaussian bands (Fig 2). The broad shoulder in the absorption spectrum in these samples appears to arise out of more than one optical transition. Effective mass approximation (EMA) and tight binding models(TB) models are known to be in good agreement with experimental results in case of larger clusters whereas both the models tend to overestimate the confinement energy for the quantum dots of smaller diameters. Both EMA and TB calculations use parameters relating to the bulk material as numerical inputs which may be one of the reasons for the discrepancy between experimental and theoretical predictions.

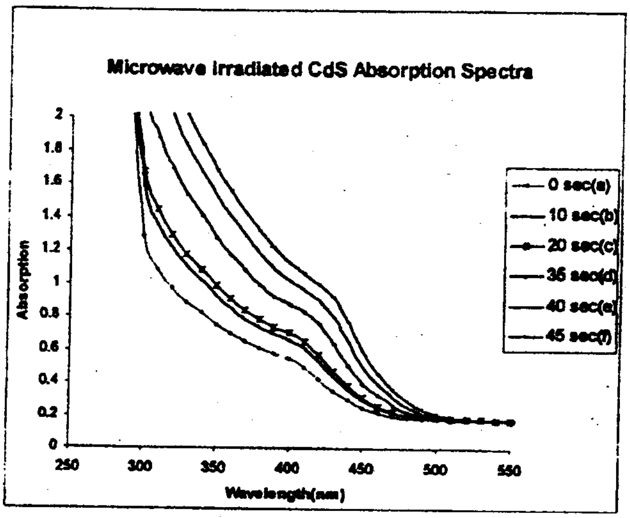

Fig-1

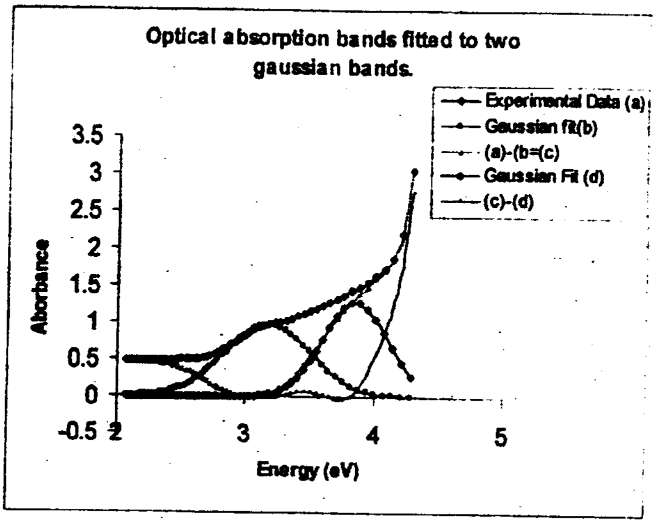

Fig-2

Therefore we have used in this work a non-interacting particle model [8], based on which a quantitative comparison can be made with experimental results in a way which is independent of bulk material parameters such as the effective masses and bandgap. The tow bands identified in the optical absorption spectra could be attributed to $1s_e$-$1s_h$ and $1p_e$-$1p_h$ transitions of the noninteracting particle model, on the basis of which we estimated the values of reduced masses and bandgap.

Nonlinear optical absorption studies of CdS nanoparticles have been done using open aperture z-scan studies. We have used a single beam z-scan technique[9] with chirped laser pulses of width 300 ps and wavelength 400 nm. The wavelength of 400 nm was chosen as it is near the absorption edge. Open aperture z scan was performed for two input energies, 4 μJ and 8 μJ. The nonlinear absorption studies were made on a microwave irradiated sample S1 and also on another similar sample S2 which was not irradiated with microwaves. We have chosen two samples (sample without microwave irradiation S1 and sample irradiated for maximum time S2) for nonlinear absorption studies and the former was found to show increased nonlinearity. The mechanism of nonlinearity observed in the present work appears to be two-photon absorption, as seen from an analysis with theoretical models. Two photon absorption coefficients are be obtained from the transmittance curves.

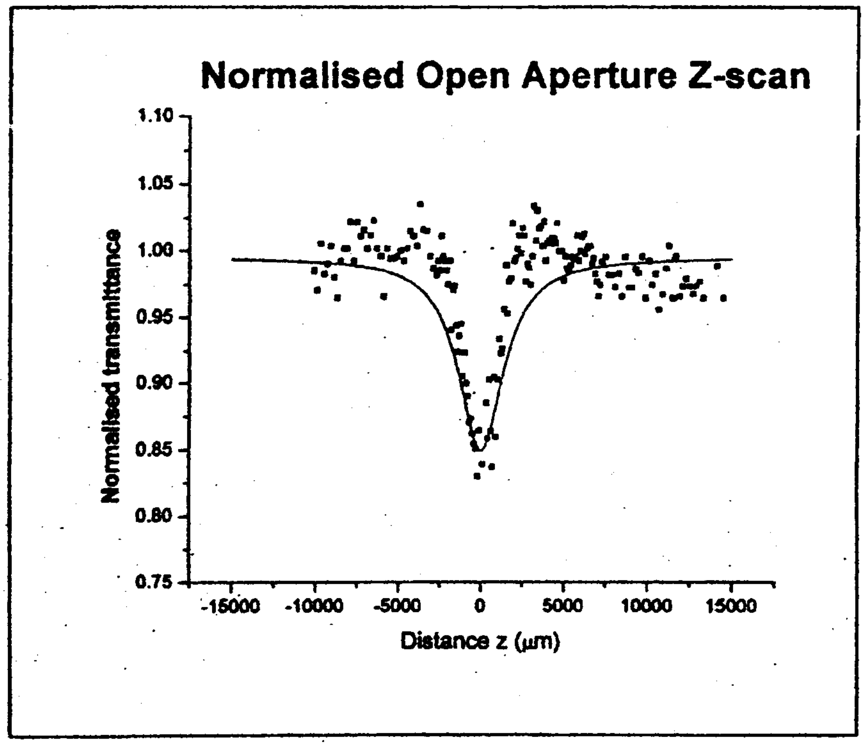

Fig-3 Normalised Z-scan transmittance of CdS(S1) nanoparticles measured using picosecond pulses at λ=400nm and input energy E=4μJ. The solid line is the theoretical curve. The fit gives the nonlinear absorption coefficient β=1.33e-11m/W

Conclusion

A microwave assisted method of synthesis is found to yield stable and strongly confined CdS nanoparticles. Optical absorption spectrum exhibited a large blueshift from the bulk cut-off wavelength, indicating strong quantum confinement. Nonlinear absorption in this material appears to be resulting from two-photon absorpton.

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