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Synthesis and Characterization of CdS/ZnS Core-shell Nanoparticles and their Possible Application as Electronics Filter

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Abstract—*Core-shell nanoparticles where shells are thin coatings deposited on core particles of different material have gained considerable attention. These core-shell materials show novel properties which are different from their single-component quantum dots. The properties of these materials depend on the core to shell ratio. By simply tuning the core to shell ratio, the properties can be altered.*

Our works involves loading of CdS-ZnS core-shell nanoparticles by dispersing them in a polyvinyl alcohol. This nano composite solution acts as a dielectric for a parallel plate polymer capacitor. As-synthesised nanoparticles are characterized by UV-vis, PL, XRD, SEM and TEM. From the TEM and SEM pictures we have found that the particles are in the nanometer range. Different test samples have been prepared and by making thin films of the nanosolutions, we have fabricated a few devices to study the capacitance and inductance as well as filter properties of the as-fabricated devices.

1. INTRODUCTION

Nanotechnology, which is one of the new technologies, refers to the development of devices, structures, and systems whose size varies from 1 to 100 nanometers (nm). Nanoshell particles constitute a special class of nanocomposite materials. They consist of concentric particles, in which particles of one material are coated with a thin layer of another material using specialized procedures. Nanoshell particles are highly functional materials with fascinating properties, which are quite different than either of the core or of the shell material.In this paper, we describe chemical and quenching method to produce CdS and CdS–ZnS nanocrystals using poly-vinyl alcohol (PVOH) as the capping agent. The structural and optical properties of the nanoparticles samples are investigated precisely.

2. SYNTHESIS

We have used chemical method to prepare the samples and poly-vinyl alcohol (PVOH) is used as the matrix or capping agent. Cadmium acetate ($(CH_3COO)_2Cd.2H_2O$), zinc acetate ($(CH_3COO)_2Zn.2H_2O$), sodium sulphide (Na_2S) and distilled water is used for preparing the samples.

3. CHARACTERIZATION

We have used liquid samples of core and core-shell for UV-Vis, PL and HRTEM characterization. For XRD characterization we have used powder form of the samples and for SEM characterization we have prepared thin films from the samples. From the optical absorption spectra (Fig. 1), band gaps of the as-synthesized samples are estimated using Tauc method and found to be higher than the bulk band gap. From the photoluminescence spectra (fig.2), it is clear that the luminescence intensity of the core-shell samples is lower than that of the core samples.

4. RESULTS

4.1 Results obtained from uv-visible

The uv-vis absorption spectra of samples CdS1 core,CdS1-ZnS core-shell and ZnS1-CdS core-shell are shown in Fig. 3.8. Quantum confinement effect is evident in these graphs.

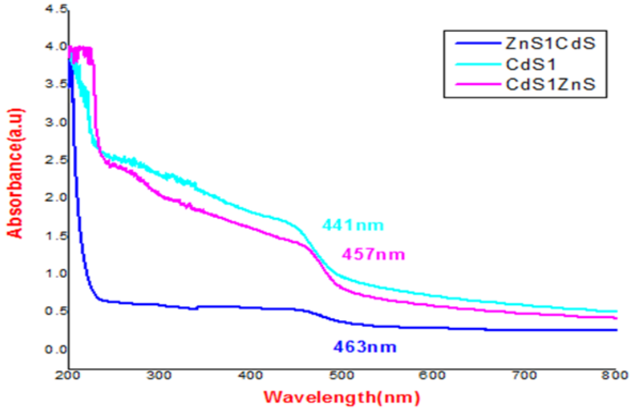
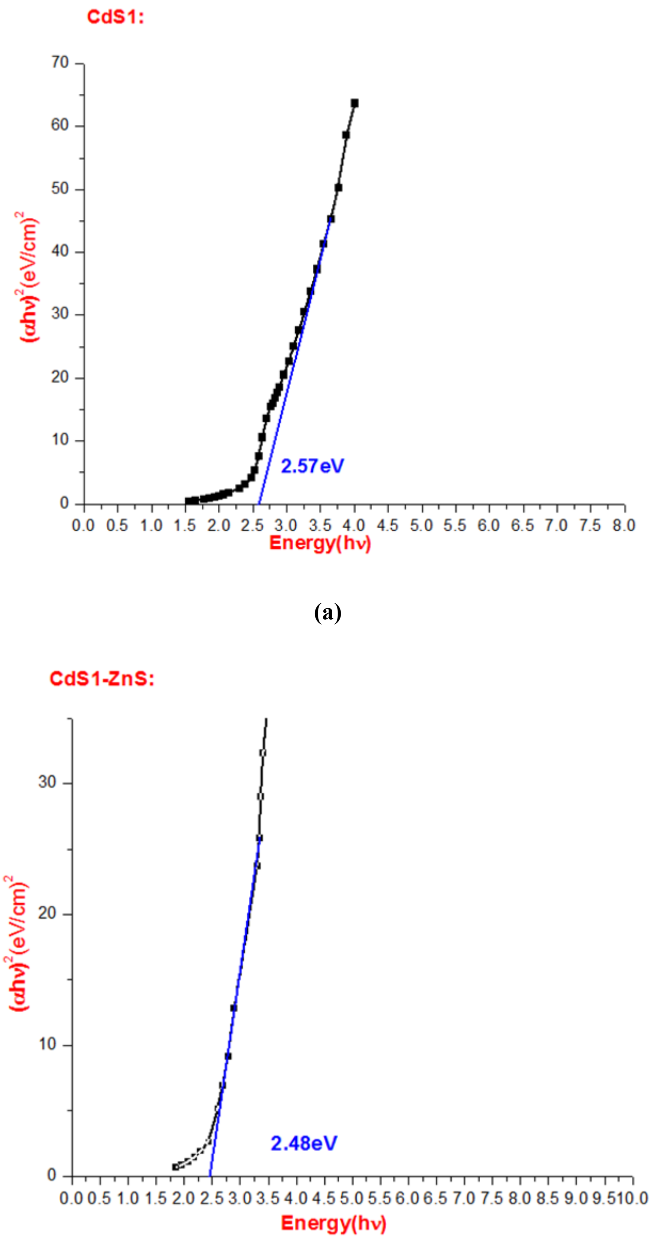


Fig. 1: uv-vis absorption spectra of CdS1 core, CdS1-ZnS core-shell and ZnS1-CdS core-shell samples

The absorption edge of CdS1-ZnS shifts to lower wavelengths from that of CdS1 alone. So, shell formation was confirmed by the observation of a blue shift in the UV–vis absorption spectra.

From the tauc equation we can measure the band gap of the materials. Fig. 2 shows the tauc plot of the samples.



(a)

(b)

Fig. 2 (a), (b): tauc plot of CdS1 core, CdS1-ZnS core-shell samples.

4.2 Results obtained from PL:

Fig. 3 shows the PL spectra of the samples CdS1 core, CdS1-ZnS core-shell and ZnS1-CdS core-shell. It can be seen that there is a strong emission peak at desired wavelength.

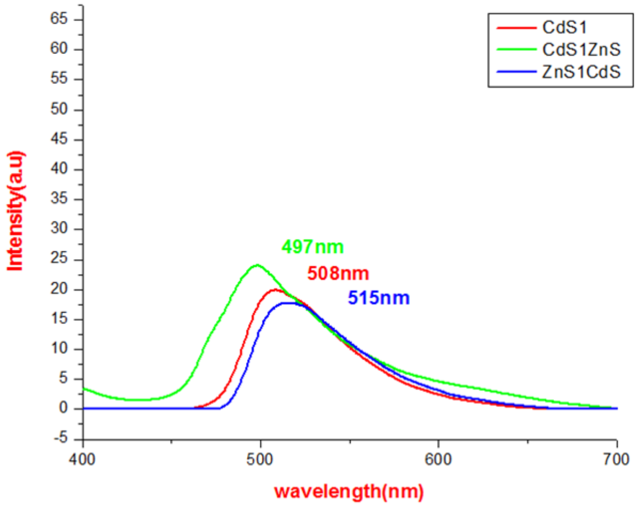


Fig. 3: PL spectra of CdS1 core, CdS1-ZnS core-shell and ZnS1-CdS core- shell samples.

4.3 Results obtained from XRD:

Fig. 4(a) and 4(b) shows the XRD patterns of the as-prepared CdS core, CdS-ZnS core shell nanoparticles at the room temperature.

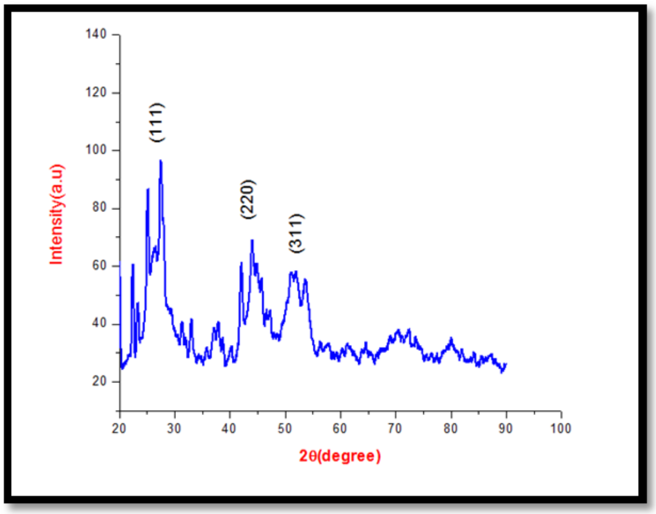


Fig. 4(a): XRD pattern of CdS1 core nanoparticles

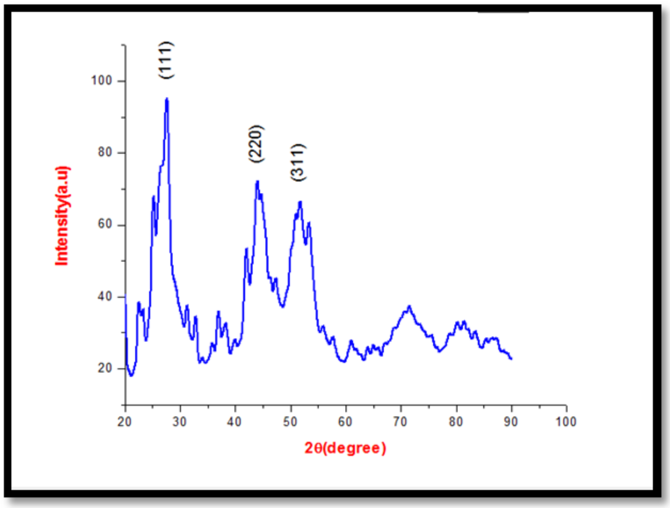


Fig. 4(b): XRD patterns of CdS1-ZnS core-shell nanoparticles

The crystallite size of the samples was calculated using the Debye–Scherrer formula

$D = k\lambda/\beta \cos\theta$

Where k is the Scherrer constant, λ is the X-ray wavelength, β is the Full Width at Half Maximum and θ is the Bragg diffraction angle. The interplaner distance (d-spacing) is calculated using Bragg's law

$n\lambda = 2\,d \sin\theta$

and we find average crystallite size 2.27nm and 2.8nm for core and core-shell nanoparticles and average d-spacing 0.234nm and 0.235nm respectively for core and core-shell samples.

4.5 Results obtained from SEM and TEM characterization

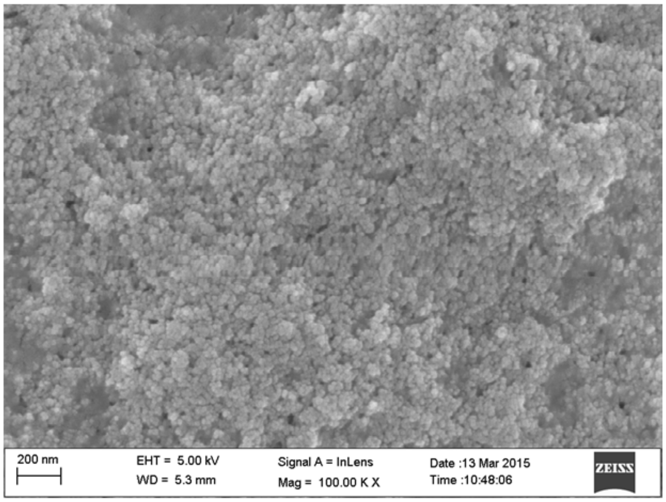
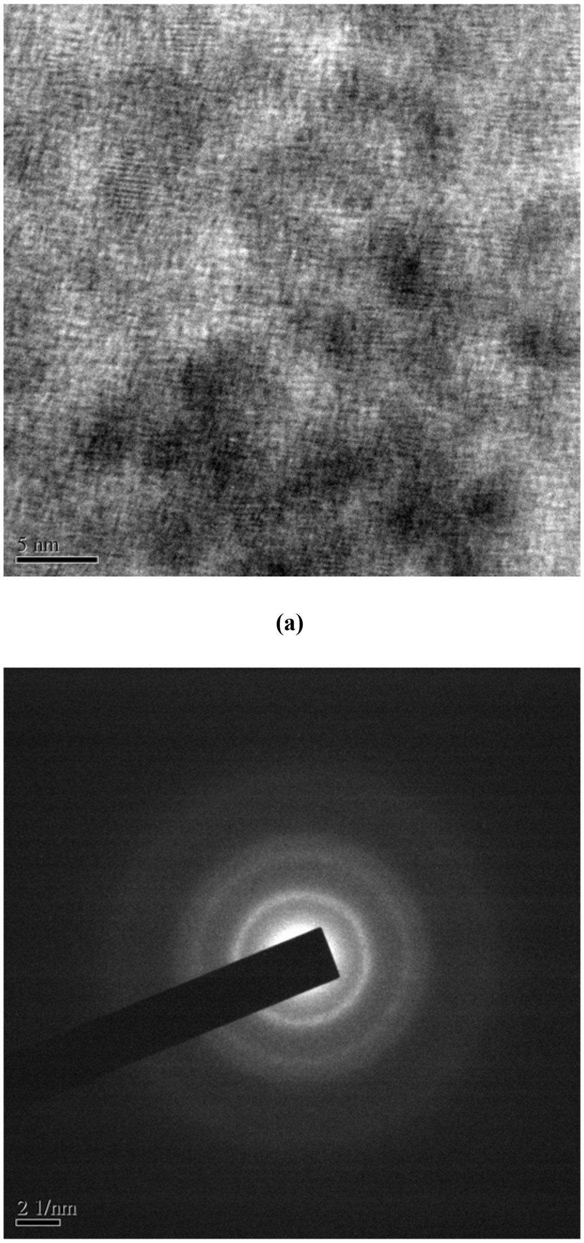


Fig. 5.1: SEM image of CdS1-ZnS core-shell nanoparticles



(a)

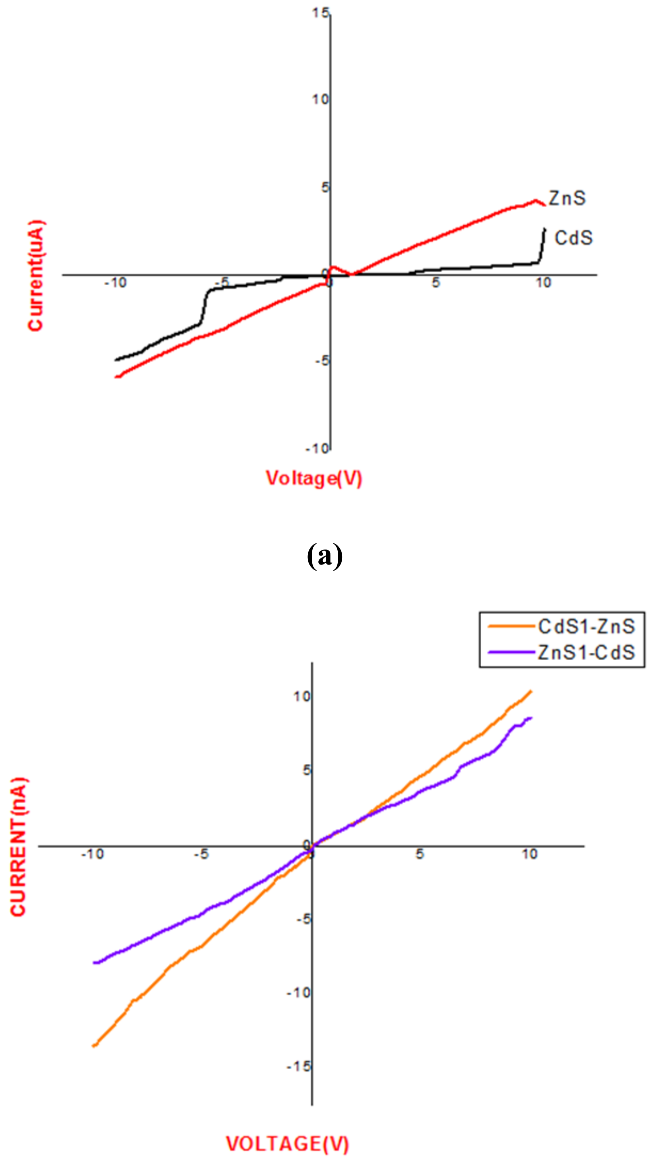
(b)

Fig. 5.2: (a) HRTEM image for CdS1 –ZnS core-shell , (b) SAED image

From the above Fig. of TEM images we see that nanoparticles are seen to have nearly spherical shape with clear lattice fringes indicating formation of well crystallized particles.

5. APPLICATION AS FILTER

To test the conductivity of the as-synthesised samples, I-V characteristics are done as follows



(a)

(b)

Fig. 6.1(a),(b:) I-V characteristics of CdS, ZnS core and CdS-ZnS ZnS-CdS core-shell samples.

5.1 Capacitance and inductance:

The capacitance vs frequency and inductance vs frequency curves are recorded using LCR meter(GWINSTEK LCR-821).

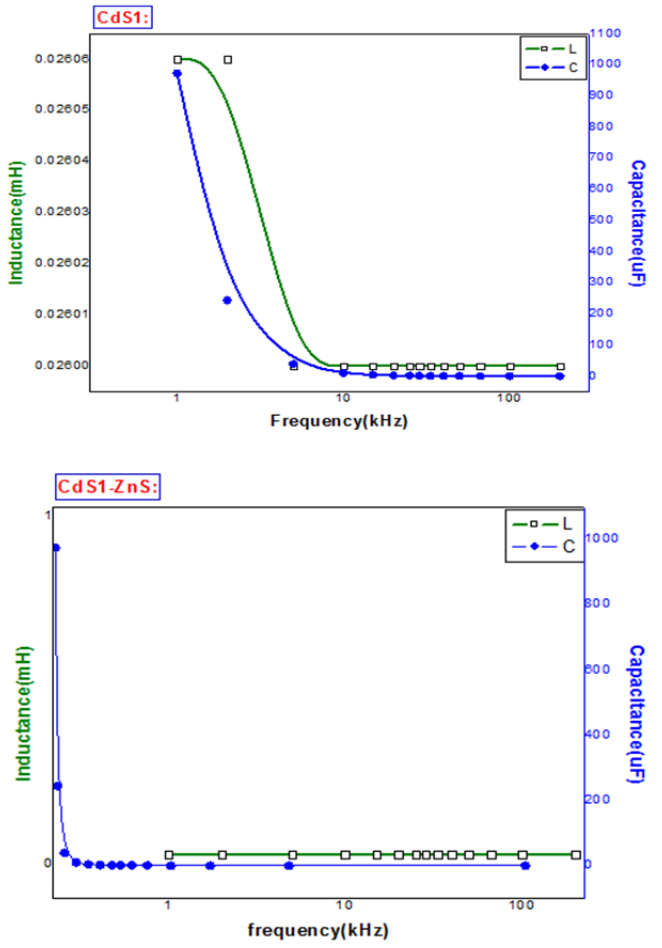
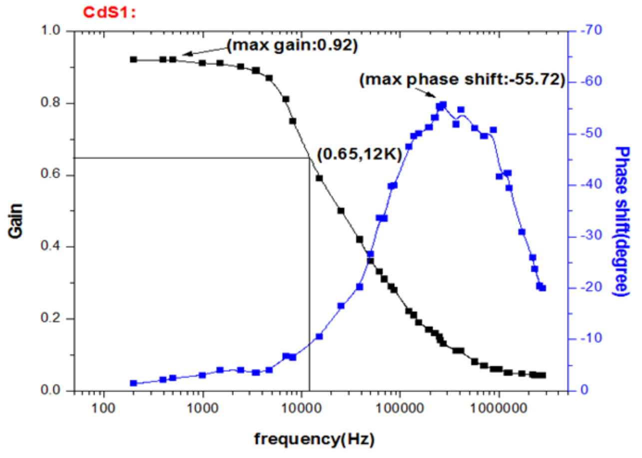


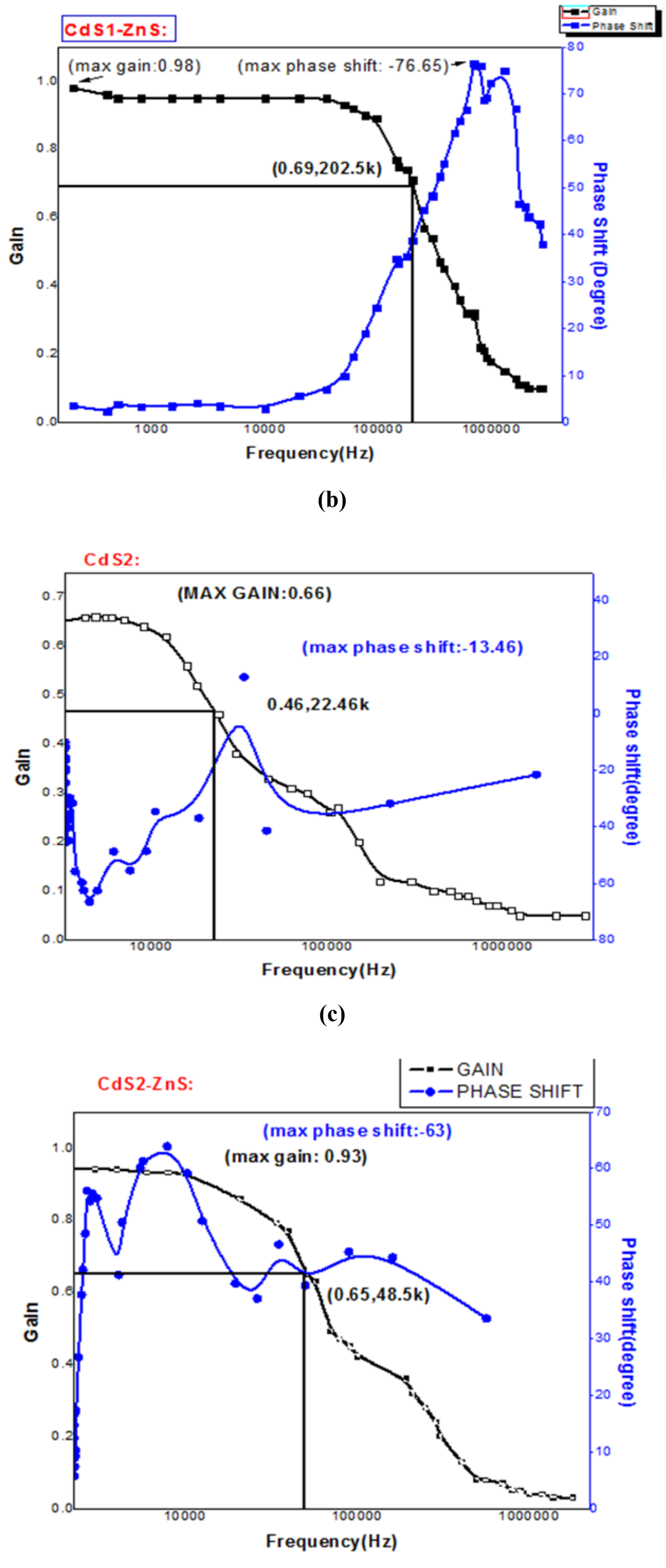
Fig. 6.2: Capacitance and Inductance of core and core-shell samples.

Gain- Frequency characteristics:

The gain vs frequency and phase shift vs frequency characteristics of the samples of undoped CdS core and CdS ZnS core-shell are shown in Fig. 6.3



(a)



(b)

(c)

(d)

Fig. 6.3 : Frequency response of CdS core and CdS-ZnS core-shell samples

Table 1 depicts gain, maximum phase shift and cut -off frequencies estimated from Fig. 6.3(a), (b),(c) and (d)

Table 1: Gain, cut-off frequencies and maximum phase shift for the as prepared samples

Sample Code	Gain	Cut off freq in KHz	Max phase shift(O)
CdS1 Core	0.65	12	-55.72
CdS1-ZnS Core-Shell	0.69	202.5	-76.65
CdS2 Core	0.46	22.46	-13.46
CdS2-ZnS Core-Shell	0.65	48.5	-63

Thus, from table 1, it is found that for the CdS1 core and CdS1-ZnS core-shell have maximum gain(0.65 and 0.69 respectively) and CdS1-ZnS core-shell have the highest cut-off frequency (202.5kHz) which gives a good low pass filter characteristics.

6. CONCLUSION

We have successfully fabricated CdS core and CdS-ZnS core-shell nanoparticles.An attempt is made to study the capacitance and the inductance behaviour of the as-synthesised nanocomposites. Capacitance and inductance of the nanocomposites as a function of frequency are measured and are found to be frequency dependent having capacitance values of the order **10^{-6} F** and inductance approximately in the range of **1.232 H** to **0.02788 H**. As-synthesized nanocmposites shows fow pass filter characteristics.

7. ACKNOWLEDGEMENTS

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