Journal of Material Science and Mechanical Engineering (JMSME)
p-ISSN: 2393-9095; e-ISSN: 2393-9109; Volume 4, Issue 5; October-December, 2017, pp. 261-267

http://www.krishisanskriti.org/Publication.html

A Study on Potential Applicability of Polymer/ Semiconductor Nanocomposites as Nanoelectronics Frequency Filter Circuits

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Abstract—*Over the past decade, polymer/semiconductors nanocomposites have drawn a great deal of attention due to their extensive application in organic flexible devices. Today, the necessities of introducing nanocomposites act as an important role in the nanoelectronics is well understood from Moor's law and have become an integral part in the present day technology. The wide spread success from microelectronics to concept of nanoelectronics led to the development of newer nanomaterials with better physical and electrical properties. In this paper, an attempt has been made to review various existing synthesis and characterization techniques employed all over the world for the development of industrially important nanocomposites and extent of particle size reduction achieved through the different polymer embedded colloidal sulfide II-IV group compound semiconductor nanocomposites in terms of their performance, advantages, disadvantages and analysis of quantum inductance and capacitance. The approach being followed by the classical frequency filter characteristics of optimization with gain, phase shift and cut-off frequency. These investigations three parameters are found to be different for doped undoped and corresponding core to shell ratio; each other based on their dielectrics, crystal structures, sizes and band gape is presented.*

1. INTRODUCTION

Polymer/semiconductor nanocomposites have been processed via an in situ formation of semiconductor nanoparticles in the polymer matrix from suitable Colloidal sulfide II–VI groups inorganic compound semiconductor precursors [1-3] and received increasing interest recently in view of potential applications in various fields of science and technology including dielectrics, charge-storage capacitor, optoelectronics, nanoelectronics, electroactive materials and pH sensors [4-8]. The presence of the protective polymer can prevent the agglomeration and limit the size of the nanoparticles [9-10]. The past few years have witnessed an exponential growth in the potential use of polymer capped based nanocomposites. Among different polymers, polyvinyl alcohol (PVA) is the most promising because of its unique properties. PVA is highly soluble in water and biologically friendly. Its easy processability and high transmittance [11] make it a good matrix of polymer films. It acts both as a reducing agent and as a stabiliser. It is non-corrosive in nature, and hence suitable for electronic and optoelectronic application [12-13]. In other hand, 3-Mercaptopropionic acid (3-MPA) is a clear, near water-white liquid with strong odor used as used as an intermediate for the synthesis of organic compounds [14] and also useful as ion exchange catalysts, coupling agents, and in UV-curable formulations [15]. The Styrene Butadane Rubber (SBR) latex is a carboxylated styrene butadiene copolymer latex admixture that is designed as an integral adhesive for cement bond coats, mortars and concrete to improve bond strength and chemical resistance [16], which acts as matrix, plays the key role in controlling the size and shape of quantum dots [17] during single and Core@shell sample fabrication. Apart from single component counterparts or nanoparticles, Core@shell particles constitute a special class of Nanocomposites materials which have modified and improved physical [18] and chemical properties [19]. Core@shell nanoparticles are formed when two dissimilar materials [20] are placed into contact with each other. The core@shell structural quantum dots have excellent fluorescence properties [21], such as improved brightness, narrow and symmetric emission spectrum, resistance against photobleaching, and multicolor light emission [22]. As the lattice constant, energy gaps, doping concentrations [23] and affinity of core and shell material differences, the properties of core@shell material are modified [24]. The small lattice mismatch of 7.3 % between CdS and ZnS make it possible for epitaxial growth of CdS@ZnS or ZnS@CdS core@shell nanoparticles [25]. These type I and II core@shell nanoparticles are widely used in light emitting diode (LED) [26], biological labeling [27] and solar cell [28] respectively.

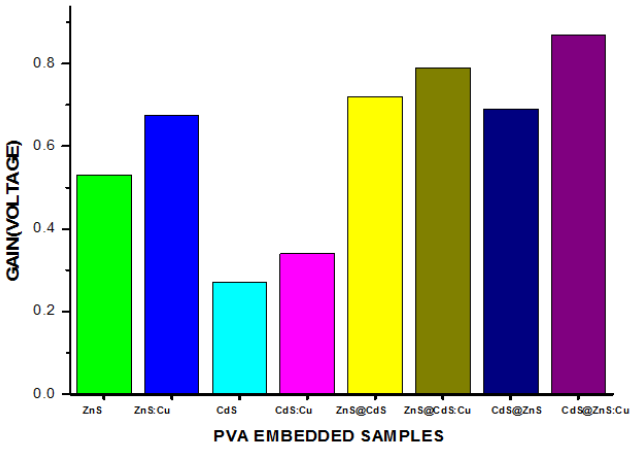

Figure: 1: Maximum Gain of PVA embedded different samples [29-33].

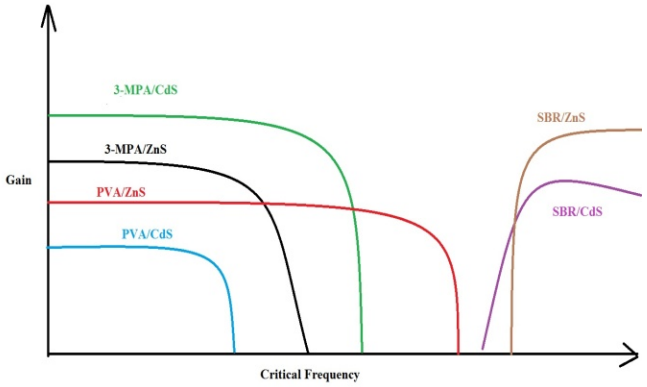

Figure 2: Schematic picture of investigated Gain Vs critical frequency curves [29-33].

Explanation works in support of the inductive and capacitive behaviour of quantum dots are very few. S.S. Nath and his group [29] in 2008 reported that individually ZnS and CdS quantum dots embedded in SBR Latex can act as a High pass filter and an electronic tuned circuit in the frequency range of 20-23 MHz respectively. Some preliminary works done by Kakati J. et al. [30] in 2012 on chemically synthesised CdS (undoped and doped:Cu^{2+}) quantum dots embedded in PVA as low-pass filter are reported. Simultaneously, T. Das et al. [31] in 2012 has prepared copper doped ZnS Quantum dots embedded in polyvinyl alcohol (PVA) samples with frequency response of the low pass filter Characteristics shows higher gain as compared to the undoped samples.

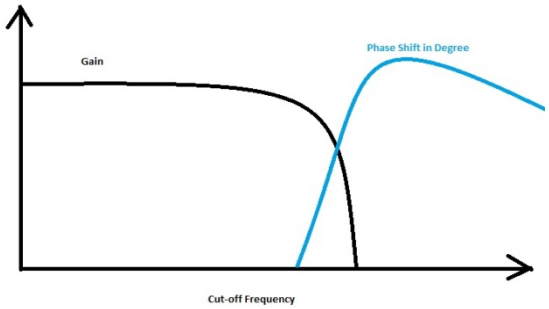

Figure 3: Schematic picture of investigated Gain & phase shift Vs cut-off frequency curves for low pass filter [29-33].

Phase of the output relative to the input as a function of frequency is also recorded to have some insight into the observed low-pass filter characteristics of the as-fabricated CdS and CdS:Cu^{2+} quantum dot devices, following MPA capped synthesis have been demonstrated by H. Das et al. [32] in 2015. Capacitance values of the order 10^{-6} F and inductance approximately in the range of 1.232 H to 0.02788 H of CdS@ZnS core@shell nanocomposites as a function of frequency shows Low pass filter characteristics reported very recently by R. L. Deka et al. [33] in 2016.

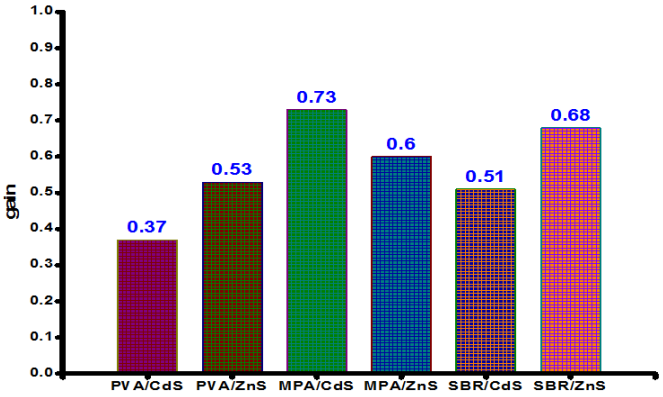

Figure 4: Maximum Gain of different polymer embedded samples [29-33].

In this paper, a systematic investigation of frequency response of PVA, 3-MPA and SBR latex capped CdS (doped:Cu^{2+} and undoped), ZnS (doped:Cu^{2+} and undoped), CdS@ZnS (doped:Cu^{2+} and undoped) and ZnS@CdS (doped:Cu^{2+} and undoped) quantum dot devices, following by chemical route synthesis technique of semiconductor quantum dots, characterization and their useable applications of the frontier research areas at present [29-33].

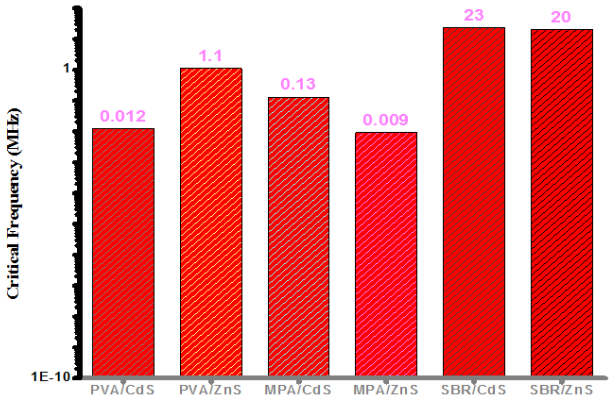

Figure 5: Variations of Critical frequency (MHz) with different polymer embedded samples [29-33].

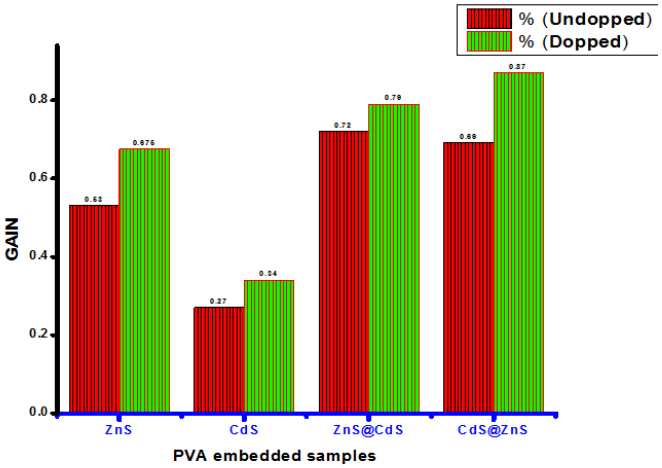

Figure 6: Variation of voltage gain with PVA embedded different samples [doped:Cu^{2+} & undoped]

2. PREPARATION STRATEGIES

In this strategy almost all are reported to control the size by chemically arrested precipitation technique [1-20]. The basic trick has been to synthesis and studies the nanomaterial in situ i.e. in the same liquid medium avoiding the physical changes and aggregation of tiny crystallites [15-27]. Thermal coagulation and Oswald ripening were controlled by double layer repulsion of crystallites using non-aqueous solvents at lower temperatures for synthesis [21-35].

Table 1: Physical properties of the SBR latex matrix material [29-33].

Physical Properties	Value
Glass transition temperature	211
Melting temperature (K)	273
Refractive index	1.53
Specific gravity	0.93
Specific heat (J/gm.K)	1.89
Thermal conductivity (W/m.K)	1.34
Dielectric constant	3.1

3. CHARACTERISATIONS STRATEGIES AND RESULTS

The liquid samples of doped undoped and corresponding core@shell solutions used for UV-Vis and HRTEM characterization. From the optical absorption spectra (29-33), band gaps of the as-synthesized samples are estimated using Tauc method [34-37] and found to be higher than the bulk band gap.

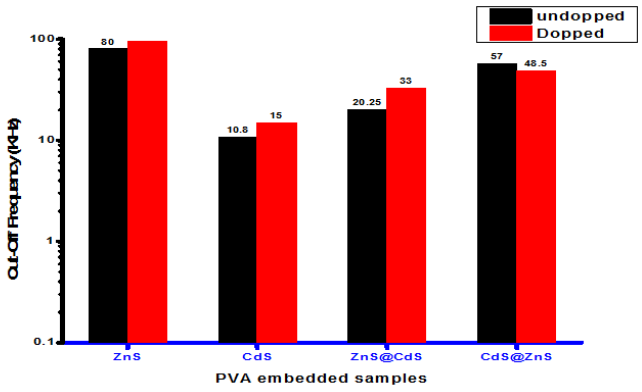

Figure 7: Variation of cut off frequency with PVA embedded different samples [doped:Cu^{2+} & undoped]

3.1 Results obtained from UV-Visible and TEM characterization

Absorption spectroscopy of the all investigated samples shows a strong blue shift in the absorption edge in comparison to that of bulk specimen [29-33]. From the blue shifted absorption edge, particle size has been assessed by using the hyperbolic band model [29].

$$R = \sqrt{\frac{2n^2h^2E_{gb}^2}{m^*(E_{gb}^2 - E_{gb}^2)}} \qquad \ldots\ldots..1$$

Where:

R is quantum dot radius (2R is the diameter and hence the particle size)

E_{gb} is the bulk band gap

E_{gn} is quantum dot band gap (calculated from the strong absorption edge which is 375 nm for SBR/CdS and 200 nm for SBR/ZnS as shown in Table 2)

h is Planck's constant

m* is effective mass of specimen (1.82 x 10 kg for CdS and 3.64 x 10 Kg for ZnS).

Table 2: CdS and ZnS particle sizes estimated using high resolution TEM (HRTEM) and UV/VIS spectroscopy [29-30].

Samples	HRTEM	UV-Visible	Gain	Critical Frequency (Hz)
PVA/CdS	4.7nm	3.9 nm	0.37	12 K
PVA/ZnS	6 nm	8.3 nm	0.53	1.1 M
MPA/CdS	4nm	4.4 nm	0.73	130 K
MPA/ZnS	6.5nm	8.7 nm	0.60	**90 K**
SBR/CdS	9.8nm	7.6 nm	0.51	23 M
SBR/ZnS	8.2nm	9 nm	0.68	20 M

Thus, from Table 2; it is found that for the PVA/ZnS, MPA/ZnS and SBR/ZnS composites have maximum gain (0.53, 0.60 and 0.68 respectively) and PVA/ZnS, MPA/ZnS and SBR/ZnS nanocomposites have the highest Critical frequency (1.1MHz, 90KHz and 20MHzrespectively) which first two gives a good low pass filter and last one as a high pass filter characteristics curve.

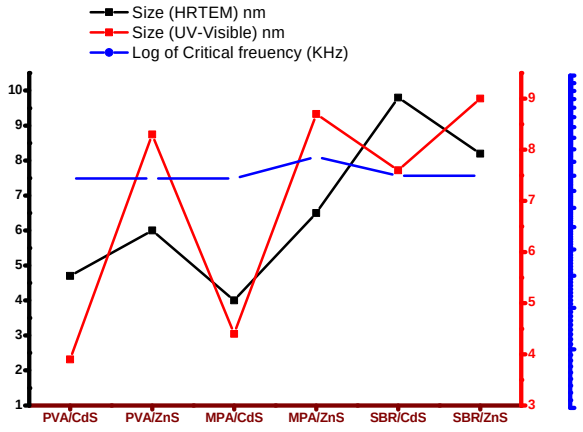

Figure 8. Variation of Critical frequency with size (nm) [undoped] [29-33].

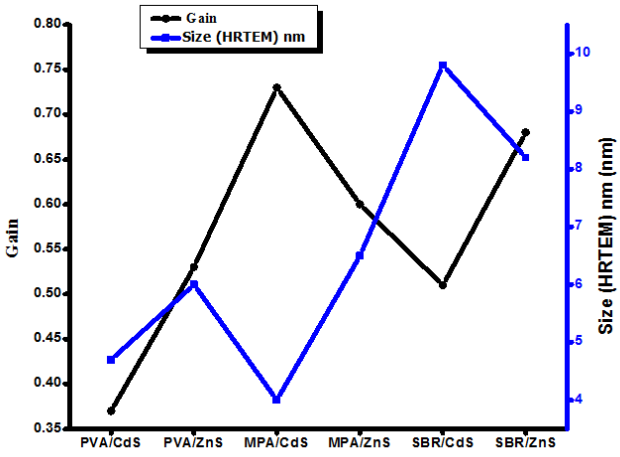

Figure 9. Variation of Gain with size (nm) [undoped] [29-33]

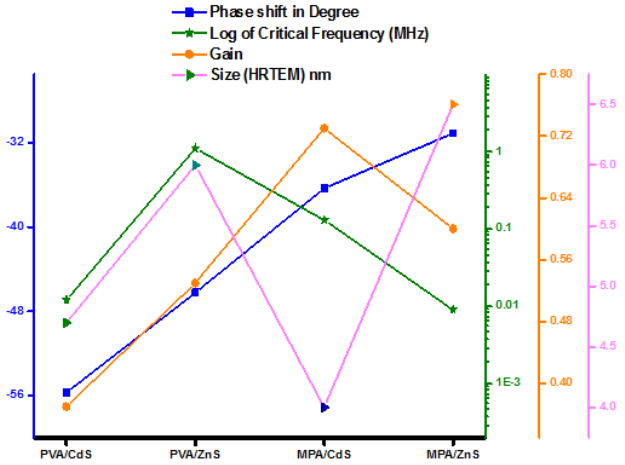

Figure 10: Maximum Phase Shift, Critical Frequency (MHz), Gain, particle size (HRTEM) of CdS & ZnS with different polymer embedded samples [29-33].

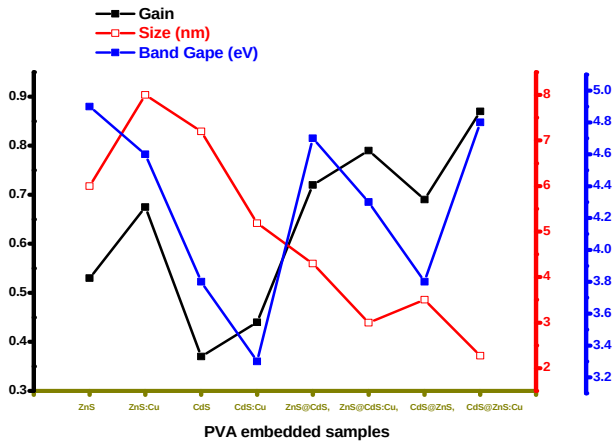

Figure 11. Maximum Gain, particle size (HRTEM) in nm and Band Gape Vs PVA embedded different samples [29-33].

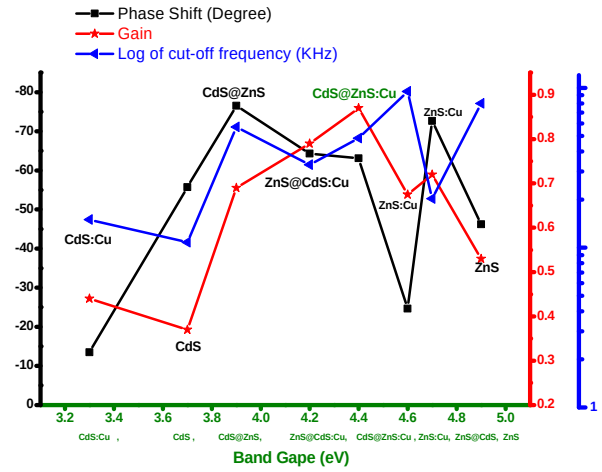

Figure 12. Maximum phase shift, band gape and cut-off frequency Vs PVA embedded different samples [29-33].

There are so many figures [8, 9, 10, 11 and 12 respectively] reveal the different polymer embedded colloidal sulfide II-IV group compound semiconductor nanocomposites in terms of their performance, advantages, disadvantages and analysis of quantum inductance and capacitance has never been focused in any earlier report. The findings of the present work call for further theoretical works as well as simulated viewpoint on the problem.

4. SUMMARY

The concept of nanoscale frequency filters characteristics has been reviewed from the viewpoints of molecular device fabrication and the building blocks used. It is shown that nanoscale devices in the field of communications should be sub-10 nm scale, addressable, durable, low-cost, highly integrated, and compatible with bioelectronics and/or nanoelectronics. Also shown that all the polymer/semiconductor composites of a sample fabricated are not identical; hence, the composite array may show the interplay between intrinsic effect of individual dots and properties of the composite ensemble. However, the general nature of the average behaviour is found not to deviate much from the single composite behaviour. It seems quite possible to achieve applicable nanofilter devices using crossed polymer/semiconductor or polymer/metal composite approaches in combination with the techniques of nanoparticle assembly and nanoelectronics. Currently, it is still too early to conclude which approaches and building units will be ultimately used in the 'coming' commercial nanoscale communication devices. In the meantime, the current approaches can be used as test-beds to investigate various building blocks from aspects of molecular synthesis, self-assembly, and effects of molecule interfaces, chemical structure, functional groups and/or local environment on the device performance. As one of the most critical steps, more effort should be made to figure out some simple but applicable methods for fabrication of nanoscale devices. Moreover, we may ask what is next after the generation of nanodevice? How will it affect our daily life? One answer might be semi-intellectual communication systems with some characteristics of the human brain, which may be achieved someday using the novel technologies, equipments, materials, and theories developed on the basis of molecular electronics, nanoelectronics and bioelectronics.

5. ACKNOWLEDGEMENTS

The authors are thankful to Dr. L. Robindro Singh, HOD, Department of Nanotechnology, NEHU, Shillong Campus, for valuable suggestions and encouragement towards this work.

REFERENCES

[1] Khannaa, P.K. Gokhale R.R. Subbarao, V.V. Singh, V.S. Narendra Jun, K.-W. Dasa, B.K. "Synthesis and optical properties of CdS/PVA nanocomposites", MCP, 94 (2005), 454–459

[2] Seoudi, R. El- Bailly, A. B. Eisa, W. Shabaka, A. A. Soliman, S.I. Abd El Hamid, R. K. Ramadan, R. A. "Synthesis, Optical and Dielectric Properties of (PVA/ CdS) Nanocomposites" JASR, 8(2): 658-667, 2012, ISSN 1819-544X

[3] Carley Corrado, Yu Jiang,§ Fadekemi Oba, Mike Kozina, Frank Bridges and Jin Z. Zhang "Synthesis, Structural, and Optical Properties of Stable ZnS:Cu, Cl Nanocrystals" J. Phys. Chem. A 2009, 113, 3830–3839

[4] Hong Van Bui, Hoang Nam Nguyen, Nam Nhat Hoang, Thanh Trung Truong, and Van Ben Pham "Optical and Magnetic Properties of Mn-Doped ZnS Nanoparticles Synthesized by a Hydrothermal Method" IEEE TRANSACTIONS ON MAGNETICS, VOL. 50, NO. 6, JUNE 2014

[5] Wei Chen, Zhanguo Wang, Zhaojun Lin, and Lanying Lin "Absorption and luminescence of the surfacestates in ZnS nanoparticles", Journal of Applied Physics · September 1997, DOI: 10.1063/1.366152,

[6] KARUPPASAMY KANDASAMY, HARKESH B SINGHand SHAILENDRA K KULSHRESHTHAb "Synthesis and characterization of CdS and CdSe nanoparticles prepared from novel intramolecularly stabilized single-source precursors" J. Chem. Sci., Vol. 121, No. 3, May 2009, pp. 293–296. © Indian Academy of Sciences.

[7] A. VADIVEL MURUGAN "Photoluminescence properties of nanocrystalline ZnS on nanoporous silicon", A NOVEL METHOD OF ADVANCED MATERIALS PROCESSING, J MATER SCI (2006) 1459–1464, DOI: 10.1007/s10853-006-7461-3

[8] Rožnov pod Radhoštěm, Česká Republika "SYNTHESIS AND MODIFICATION OF QUANTUM DOTS FOR MEDICAL APPLICATIONS", 20. - 22. 10. 2009,

[9] Vikas Nandwana et al."Supporting Information Direct Patterning of Quantum Dot Nanostructures via Electron Beam Lithography", ESI for JMC © The Royal Society of Chemistry 2011

[10] Juh Tzeng Lue "Physical Propertie of Nanomaterials"

[11] Sakshi Sahare et al. "Fabrication of ZnS:Cu/PVA nanocomposite electroluminescence devices for flat panel displays" Research Article Adv. Mat. Lett. 2013, 4(2), 169-173, Adv. Mat. Lett. 2013, 4(2), 169-173, DOI: 10.5185/amlett.2012.6374

[12] Venkatesu, P. and Ravichandran, K. "Manganese doped cadmium sulphide (CdS: Mn) quantum particles: Topological, photoluminescence and magnetic studies", Adv. Mat. Lett. 2013, 4(3), 202-206, DOI: 10.5185/amlett.2012.7379

[13] Nada K.Abbas, Khalid T. Al- Rasoul and Zain J. Shanan "New Method of Preparation ZnS Nano size at low pH" Int. J. Electrochem. Sci., 8 (2013) 3049 – 3056

[14] Dhananjay Thakur, Shuang Deng, Thierno Baldt and Jessica O Winter "pH sensitive CdS–iron oxide fluorescent–magnetic nanocomposites", Nanotechnology 20 (2009) 485601 (9pp), doi:10.1088/0957-4484/20/48/485601

[15] Sakshi Sahare and Meera Ramrakhiani "Photoluminescence of ZnS:Cu nanoparticles in PVA matrix" IJLA,Volume 4(II), 04/04/2014, ISSN 2277 – 6362

[16] Sirait1, M. Gea, et al. "Effect of mixed nanoparticles ZnS and polyvinyl alcohol (PVA) against nanocomposite mechanical properties of PVA / ZnS" AJPC 2014; doi: 10.11648/j.ajpc.20140301.12

[17] MOHANTA, D. NATH, S. S. MISHRA, N C and CHOUDHURY A. "Irradiation induced grain growth and surface emission enhancement of chemically tailored ZnS:Mn/PVOH nanoparticles by Cl+9 ion impact" Bull. Mater. Sci., Vol. 26, No. 3, April 2003, pp. 289–294. © Indian Academy of Sciences.

[18] Sarkar, A. K. Das, H. and Datta, P. "Absorption Enhancement of CdS Nanoparticles using Poly Vinyl Alcohol (PVA)" Journal of Material Science and Mechanical Engineering (JMSME), p-ISSN: 2393-9095; e-ISSN: 2393-9109; Volume 3, Issue 8; October-December, 2016 pp. 526-528

[19] Ali, Z. Abd Salam, I. F. H. H. Saleh, Youssef, H. H. and Sokary, A. R. "Characterisation of semiconductor CdS/Poly(PVA) nanocomposites using ultraviolet/Visible Spectrophotometry", International Journal of Chemical, Material and Environmental Research ,ISSN 2410-5945,2015, Vol. 2, No. 3:pg. 17-29,

[20] Onwudiwe, Damian C. Krüger, Tjaart P.J. Oluwatobi, Oluwafemi S. and Strydom, Christien A. "Nanosecond laser irradiation synthesis of CdS nanoparticles in a PVA system" Applied Surface Science 290 (2014) 18– 26, Science Direct

[21] Kharazmil, A. Saion, E. Faraji, N. Soltani, N. and Dehzangi, A. "Optical Properties of CdS/PVA Nanocomposite Films Synthesized using the Gamma-Irradiation-Induced Method", CHIN. PHYS. LETT. Vol. 30, No. 5 (2013) 057803, PACS: 78.67.Sc, 81.07.Pr, 78.55.Et DOI: 10.1088/0256-307X/30/5/057803

[22] P.S. Khiew, S. Radiman, N.M. Huang, and Md. Soot Ahmad "Studies on the growth and characterization of CdS and PbS nanoparticles using sugar-ester nonionic water-in-oil microemulsion", Journal of Crystal Growth 254 (2003) 235–243, PACS: 79.60.Jv; 87.64.Bx; 81.10.Dn; 61.82.Rx; 61.82.Fk

[23] Fang, Xiaosheng Zhai, Tianyou Gautam, Ujja K. Li,Liang Wua, Limin Bando, Yoshio and Golberg, Dmitri "ZnS nanostructures: From synthesis to applications" Progress in Materials Science 56 (2011) 175–287

[24] Hirendra Das, P.K. Boruah , Pranayee Datta, "Microwave Assisted Synthesis of CdS & CdS/ZnS Core – Shell Nanoparticles and Their Characterization", (IJARPS) Volume 2, Issue 12, December 2015, PP 18-23, ISSN 2349-7874 (Print) & ISSN 2349-7882 (Online)

[25] SreeramCingarapu, Zhiqiang Yang, ChristopherM. Sorensen, and Kenneth J. Klabunde "Synthesis of CdSe/ZnS and CdTe/ZnS Quantum Dots: Refined Digestive Ripening", Journal of Nanomaterials, Volume 2012, Article ID 312087, 12 pages, doi:10.1155/2012/312087

[26] ATEFEH EMAMDOUST1, SABER FARJAMI SHAYESTEH1, and MAZIYAR MARANDI2 "Synthesis and characterization of aqueous MPA-capped CdS–ZnS core–shell quantum dots", PRAMANA _c Indian Academy of Sciences Vol. 80, No. 4, journal of April 2013, physics pp. 713–721

[27] Myriam Protie`re, and Liang Li "Core/Shell SemiconductorNanocrystals",DOI: 10.1002/smll. 200800841, 2009, 5, No. 2, 154–168 _ 2009 © 2012 by American Scientific Publishers, Science of Advanced Materials Vol. 4, pp. 771–779, 2012

[28] Vu Thi Kim Lien, Chu Viet Ha, Le Tien Ha and Nguyen Nhu Dat "Optical properties of CdS and CdS/ZnS quantum dots synthesized by reverse micelle method" APCTP–ASEAN (AMSN08), Journal of Physics: Conference Series 187 (2009) 012028 doi:10.1088/1742-6596/187/1/012028

[29] Nath, S.S. Chakdar, D. and Gope, G. "Characterization of CdS and ZnS Quantum Dots Prepared via a Chemical Method on SBR Latex", AZoNano, A journal of materials online, May 12 2008, DOI : 10.2240/azojono0128

[30] Kakati, J. Das, H. and Datta, P. "PVA/CdS and PVA/CdS:Cu quantum dots as low pass filter" Advanced Science Engineering and Medicine, American Scientific Publications, Vol.4, pp.1-7, 2012

[31] Das, H. Das, T. M. Rabha, S. Bhattachajee, S. and Datta, P. "Low-Pass Filter Characteristics Of Zns:Cu Quantum Dots Embedded In Polyvinyl Alcohol (PVA)" International Journal Of Innovative Research & Developement,Vol.1,Issue7,October 2012

[32] Das, H. and Datta, P. "Semiconductor quantum dots as nanoelectronic circuit components" JOURNAL OF

EXPERIMENTAL NANOSCIENCE, 2016, VOL. 11, NO. 11, 901_915, DOI.org/10.1080/17458080.2016.1178401

[33] Deka, R. L. Rabha, D. and Datta P. "Synthesis and Characterization of CdS/ZnS Core/shell Nanoparticles and their Possible Application as Electronics Filter" Advanced Research in Electrical and Electronic Engineering, p-ISSN: 2349-5804; e-ISSN: 2349-5812 Volume 3, Issue 1 January-March, 2016, pp. 32-36

[34] Seoudi, R. Shabaka, A. A. Kamal, M. Abdelrazek, E.M. and Eisa, W. "Dependence of spectroscopic and electrical properties on the size of cadmium sulfide nanoparticles", Physica E 45 (2012) 47–55, Sci Verse Science Direct.

[35] J.P. Borah and K.C. Sarma "Optical and Optoelectronic Properties of ZnS Nanostructured Thin Film" Vol. 114 (2008) ACTA PHYSICA POLONICA A No. 4

[36] Jyoti P. Borah, J.Barman and K.C.Sarma "STRUCTURAL AND OPTICAL PROPERTIES OF ZnS NANOPARTICLES" Chalcogenide Letters Vol. 5, No. 9, September 2008, p. 201- 208

[37] U. BAISHYA and D SARKAR "Structural and optical properties of zinc sulphide polyvinyl alcohol (ZnS–PVA) nanocomposite thin films: effect of Zn source concentration" Bull. Mater. Sci., Vol. 34, No. 7, December 2011, pp. 1285–1288. © Indian Academy of Sciences.1285

[38] Gregory A. Khitrov and Geoffrey F. Strouse "ZnS Nanomaterial Characterization by MALDI-TOF Mass Spectrometry", J. AM. CHEM. SOC. 2003, 125, 10465-1