

Structural, Morphological and Tensile Study of CdS/Polystyrene (PS) Nanocomposite

Vishal Mathur^{a,*} and Kananbala Sharma^b

^aDepartment of Engineering Physics, Kautilya Institute of Technology & Engineering, ISI-16, Riico Institutional Area Sitapura, Jaipur-302004, India

^{a,b}Semiconductor and Polymer Science Laboratory, 5-6, Vigyan Bhawan, University of Rajasthan, Jaipur-302004, India

Abstract: Thick film of CdS/Polystyrene (PS) nanocomposite was synthesized by dispersing nanofiller particles of CdS in PS matrix. The nanostructure of the CdS particles has been ascertained through X-ray Diffraction (XRD) and Transmission Electron Microscopy (TEM). Small angle x-ray scattering analysis has been performed in order to ascertain nanocomposite character of the PS/CdS sample. Scanning Electron Microscopy (SEM) analyses of these samples have been carried out to establish the surface morphology. The Tensile studies of prepared samples have been ascertained through Dynamic Mechanical Analyzer (DMA). This study reveals that the young's modulus and the toughness of the material are greatly influenced by the existence of interfacial energetic interaction between dispersed CdS nanofiller particles and matrix of PS.

Keywords: Nanocomposite, SAXS analysis, mechanical properties, tensile properties.

INTRODUCTION

The use of thermoplastic polymers as engineering materials has become state-of-the-art [1]. Polymer nanocomposites are of great industrial and scientific interest, since they offer the potential for tailoring at a new scale. Nanometer-size semiconductor nanoparticles/organic polymer composites have attracted considerable interest due to their size-dependent properties and great potential for many applications such as nonlinear optics, photo electrochemical cells, heterogeneous photo catalysis, optical switching, and single electron transistors [2]. Dispersion of semiconductor nanoparticles into polymer matrixes offers a pathway for preparation of composite structures with tunable physical properties [3, 4].

Generally, a polymer is chosen as a host to the nanoparticles because it allows better utilization of their size dependent properties. Polymer shows good long term stability and processibility and it can be processed, in most of the cases, into a product of size and shape demanded by the application. However, it was shown that the polymer matrix can also be used to control the size, shape and degree of dispersion of the nanoparticles in which they are embedded [5-7].

Here in the present paper, we demonstrate the simplest chemical method for the preparation of PS-CdS semiconducting nanocomposite. The

morphological characterizations and evaluation of tensile performance of prepared nanocomposite specimen have been ascertained. This study reveals that PS-CdS nanocomposite show excellent film formability, good transparency and interesting mechanical properties.

EXPERIMENTAL

Material Preparation

CdS Nanoparticle Preparation

In order to prepare Polymer / nanocomposite samples, firstly CdS nano-particles have been prepared by simple chemical method using CdCl₂ and H₂S gas produced from thiourea [8]. The nanostructure of the CdS particles has been ascertained through X-ray Diffraction (XRD) and Transmission Electron Microscopy (TEM). The wide angle X-ray diffraction pattern has been recorded using a Philips 1840. The nanocrystallites powder was pressed inside the sample holder and, and the X-ray diffraction data was collected in the step scan mode. Transmission Electron Microscopy (TEM) on the nanocrystallite sample was carried out on JEOL-3010 electron microscope.

Figure 1 shows the XRD pattern of CdS nanoparticle. The presence of broad peaks confirms the nano size of the prepared nanoparticles. The average particle size obtained from Debye Scherrerr formula [9] is 3 nm, which is also verified with TEM results as shown in Figure 2.

*Address correspondence to this author at the Department of Engineering Physics, Kautilya Institute of Technology & Engineering, ISI-16, Riico Institutional Area Sitapura, Jaipur-302004, India; Tel: 91-141-2770364; Fax: 91-141-2770199; E-mail: wishalmathur@gmail.com, wishalmathur@yahoo.co.in

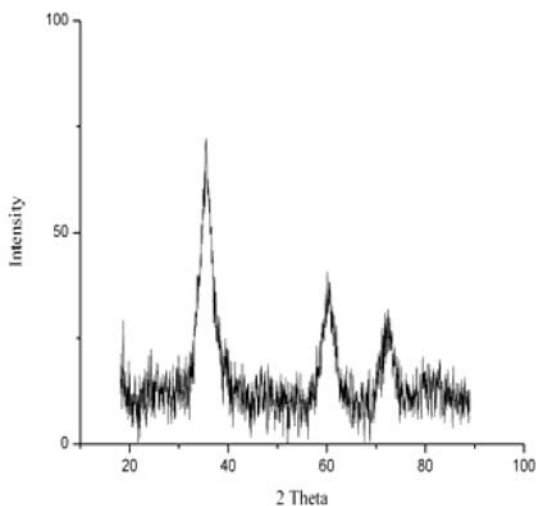


Figure 1: The XRD pattern of CdS nanoparticles.

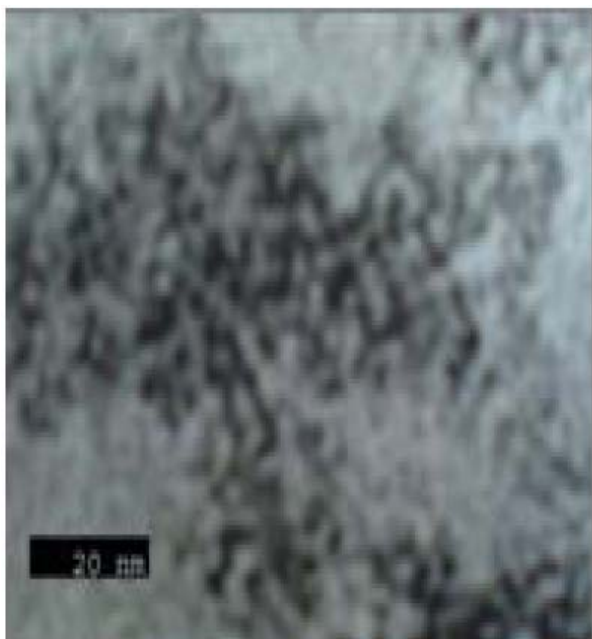


Figure 2: TEM image of CdS nanoparticles.

CdS-PS Nanocomposite Preparation

Now for the preparation of CdS-PS composite, PS of laboratory grade was dissolved in Tetra hydrofurane (THF) solvent and 10 % of PS chalcogenide CdS nanoparticles was dispersed in this PS film with a thickness of ~ 0.05 mm. The solvent is allowed to evaporate slowly over a period of 24 hours. This solution was then stirred with the help of magnetic stirrer and then poured into flat-bottomed petri dishes to form hours in dry atmosphere. The so obtained film was then peeled off and dried in vacuum at 50 °C, well below the boiling point of solvent to avoid bubbling, for 24 hours in order to ensure the removal of the solvent [10,11].

Dynamic Mechanical Analyzer

Dynamic Mechanical Analyzer (TRITEC-2000 DMA) is a sensitive technique that characterizes the mechanical response of materials by monitoring property change with respect to the temperature and frequency of applied sinusoidal stress. DMA film samples were cut to be between 4-6mm in width and 10mm in length. The average thickness of each sample is of 100-micrometer order. After adjusting DMA device in tension mode, the furnace was sealed off, sample scanned over a temperature range from room temperature to 140 °C. The sample was held at that temperature for 5 minutes. The heating/ ramp rate was 2 °C/min for all temperature scan tests. Frequency of oscillations was fixed at 1Hz and strain amplitude 0.01mm within the linear visco-elastic region [12,13].

RESULTS AND DISCUSSION

Small Angle X-Ray Scattering Analysis

SAXS measurements were performed on an X'Pert Pro MPD system to investigate the size of the CdS-nanoparticles within nanocomposite sample. Figure 3 show the scattering intensity as a function of angle (2θ) for PS and its CdS nanocomposite respectively. It is observed that SAXS pattern of PS/CdS embedded polymer nanocomposites show higher scattering intensity as compared to without CdS dispersed samples. The nano-crystals of CdS act as independent scattering centers in the respective polymer matrices and add to the total scattering intensity in the respective SAXS pattern. SAXS patterns are used for elucidating the shape and size of CdS nano-crystals by subtracting the background scattering intensity (without CdS embedded polymeric phase) from scattering intensity of CdS embedded polymeric/nanocomposite phase with the help of EasySAXS software. Figure 4 shows the particle size distribution curves for the PS/CdS nanocomposite. The particle size distribution report of this nanocomposite suggests that the distribution is well approximated by a Gaussian. The minor oscillations in the distribution curve around zero toward larger particle radii may be regarded as insignificant. It is observed that particle size distribution curve is approximately centered at $R = 1.5$ nm and it means that the most frequent radius (R) of CdS nanofillers is 1.5 nm and major volume fraction of these CdS nanoparticles is exhibiting radius within 0.7 nm to 2.4 nm.

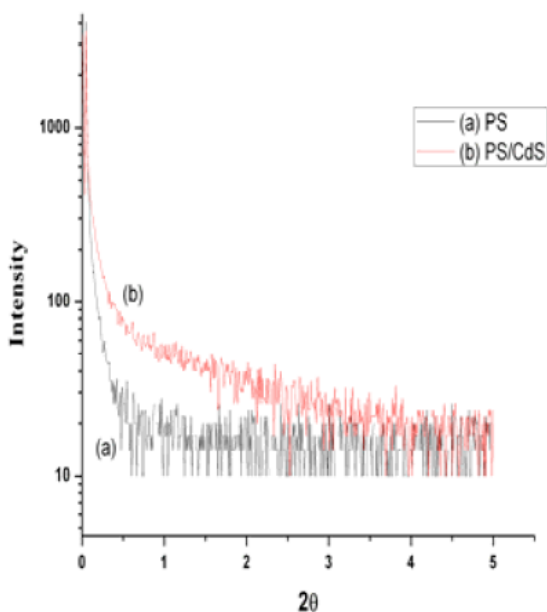


Figure 3: SAXS pattern of PS & PS-CdS.

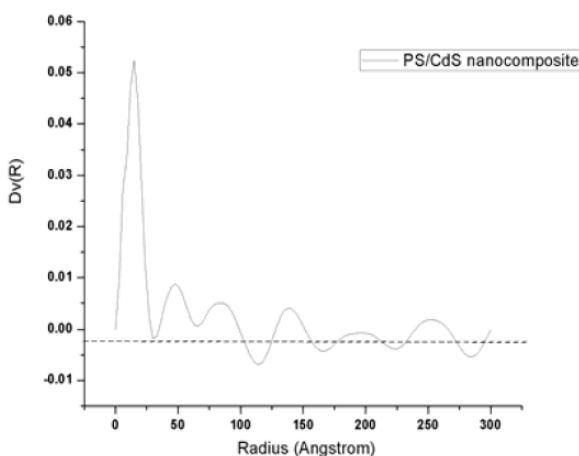


Figure 4: Particle size distribution curve for PS-CdS nanocomposite sample.

Morphological Characterization

The surface morphology of the samples has been characterized by Scanning Electron Microscopy (SEM) using a SEM (Quanta Fe-200 model). Figure 5a shows the micrographs of pure PS whereas Figures 5b-c show SEM micrographs at three different magnifications to have clear insight of morphological effect of dispersion of CdS nanoparticles into PS matrix. From the figures it is observed that in sem micrographs of PS/CdS, the concentration of CdS nanoparticles on the exterior surfaces of PS phase makes possible large number of contacts and nanophase separation is observed in this nanocomposite sample. In this way sem images of PS/CdS showed some level of flocculation of CdS nanoparticles, but of varying sizes which alters the morphology of the pure PS matrix.

Tensile Study

Figure 6 shows the Stress-Strain curves for samples S₁ and S₂. It is observed that stress strain curve consist of small linear region followed by nonlinear region for both the samples under study. For sample S₁ stress strain study shows that stress is proportional to strain and on increasing stress beyond a certain limit fracture of polymer matrix is mainly caused due to crazing. However the dispersed nanofiller particles promote or alter the fracture mechanism of the polymer matrix, depending on the intrinsic brittleness of the matrix.

The area of the stress strain plot represents fracture energy of the specimen. Here PS-CdS nanocomposite sample have to scarifify the fracture energy and tensile

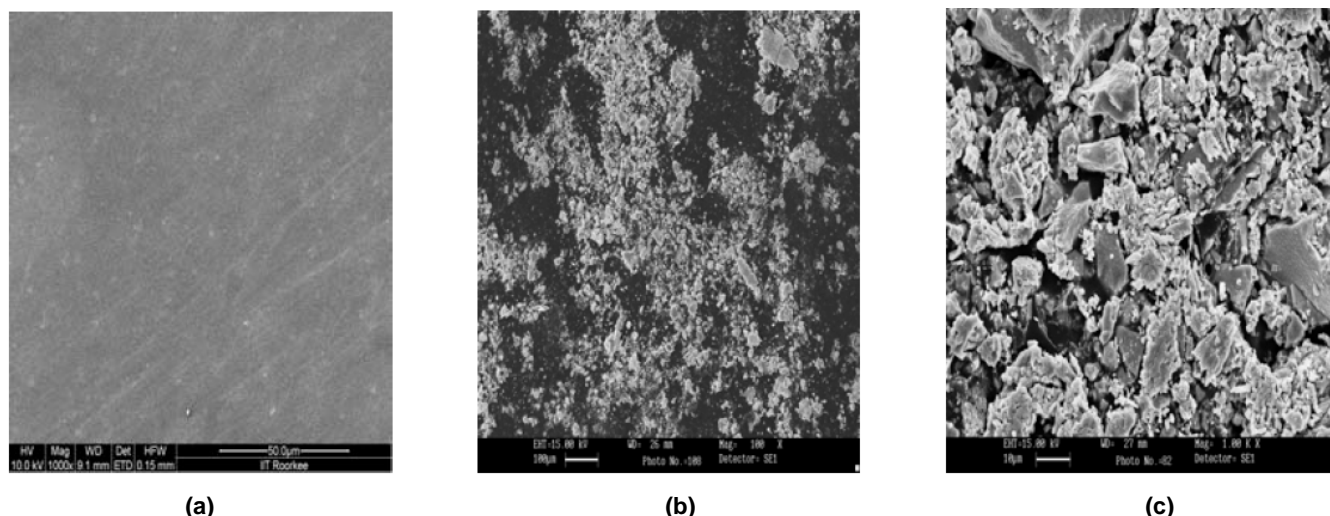


Figure 5: SEM micrographs of (a) pure PS (b-c) CdS-PS samples.

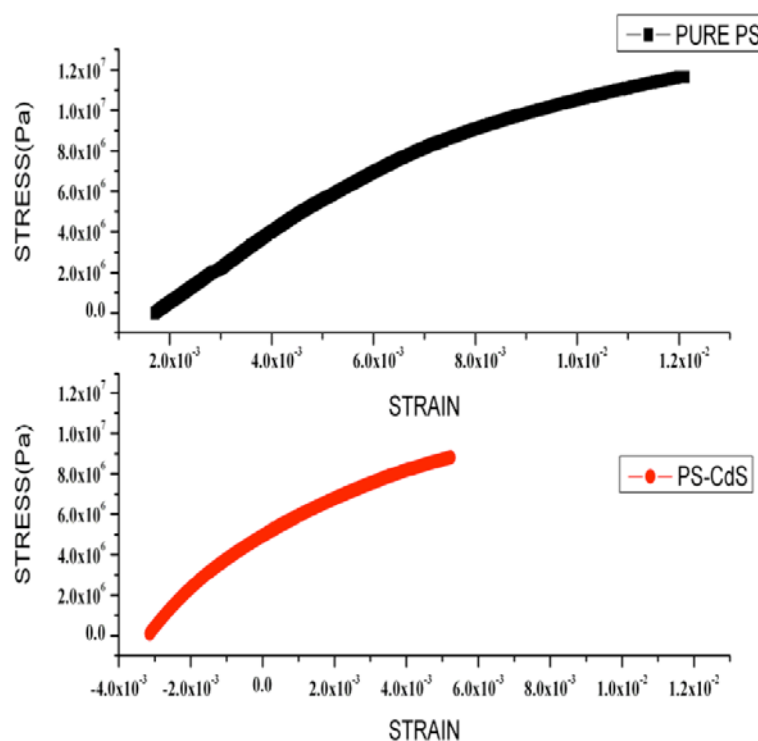


Figure 6: Stress-Strain plots of Pure PS & PS-CdS samples.

Table 1: The Results of Tensile Performance of Pure PS & PS-CdS Samples

S.N.	SAMPLE	PURE PS (S ₁)	PS-CdS (S ₂)
1.	Young's Modulus (GPa)	1.62	1.78
2.	Tensile Strength (MPa)	11.64	8.84
3.	Ultimate Strength (MPa)	11.64	8.84
4.	Fracture Energy (KJ)	69.98	44.48
5.	Fracture Strain (%)	1.20	0.51

strength. However young's modulus of the PS-CdS nanocomposite sample improves which is fruitful from in advance engineering and technology industries point of view. Calculated values of young's modulus, tensile strength and fracture energy of both the samples are as tabulated in Table 1.

CONCLUSION

In the light of findings reported in this work, some fundamental conclusions can be reached. Surface morphological studies through SEM image of PS/CdS showed some level of flocculation of CdS nanoparticles, but of varying sizes. The improve values of young's modulus of PS-CdS is observed whereas this nanocomposite sample have suffer its other properties like tensile strength, fracture energy and ductility which help one to use this combination of

materials in advance engineering & technological point of view.

REFERENCES

- [1] Zhang Z, Yang JL, Friedrich K. Creep resistant polymeric nanocomposites. *Polymer* 2004; 45: 3481. <http://dx.doi.org/10.1016/j.polymer.2004.03.004>
- [2] Martin CR, Pauli MAD. Antistatic thermoplastic blend of polyaniline and polystyrene prepared in a double screw extruder. *Eur Polym J* 2005; 41: 2867.
- [3] Godovsky DYu. Device applications of polymer-nanocomposites. *Adv Polym Sci* 2000; 153: 163.
- [4] Caseri WM. Nanocomposites of polymers and metals or semiconductors: Historical background and optical properties. *Rapid Commun* 2000; 21: 705. [http://dx.doi.org/10.1002/1521-3927\(20000701\)21:11<705::AID-MARC705>3.0.CO;2-3](http://dx.doi.org/10.1002/1521-3927(20000701)21:11<705::AID-MARC705>3.0.CO;2-3)
- [5] Moffitt M, Eisenberg A. Size Control of Nanoparticles in Semiconductor-Polymer Composites. 1. Control via Multiplet Aggregation Numbers in Styrene-Based Random Ionomers. *Chem Mater* 1995; 7: 1178. <http://dx.doi.org/10.1021/cm00054a017>

- [6] Moffitt M, McMahon L, Pessel V, Eisenberg A. Size Control of Nanoparticles in Semiconductor-Polymer Composites. 2. Control *via* sizes of spherical Ionic microdomains in Styrene Based Diblock Ionomers. *Chem Mater* 1995; 7: 1185. <http://dx.doi.org/10.1021/cm00054a018>
- [7] Du H, Xu GQ, Chin WS, Huang L, Ji W. Synthesis, Characterization and Nonlinear Optical Properties of Hybridized CdS-polystyrene Nanocomposites. *Chem Mater* 2002; 4473. <http://dx.doi.org/10.1021/cm010622z>
- [8] Mathur V, Dixit M, Rathore KS, Saxena NS, Sharma KB. Tensile Study of PVC-CdS Semiconducting Nanocomposite. *Rap Commun J Optoelect Adv Mat* 2009; 7: 685.
- [9] Rathore KS, Patidar D, Janu Y, Saxena NS, Sharma KB, Sharma TP. Structural and Optical Characterization of Chemically Synthesized ZnS Nanoparticles. *Chalcogen Lett* 2008; 6: 105.
- [10] Favier V, Canova GR, Shrivastava SC, Cavaille JY. Mechanical percolation in cellulose whisker nanocomposites. *Polym Engg Sci* 1997; 37: 1732. <http://dx.doi.org/10.1002/pen.11821>
- [11] Chazeau L, Cavaille JY, Canova G, Dendievel R, Bouterin B. Viscoelastic properties of plasticized PVC reinforced with cellulose whiskers. *J Appl Polym Sci* 1999; 71: 1797. [http://dx.doi.org/10.1002/\(SICI\)1097-4628\(19990314\)71:11<1797::AID-APP9>3.0.CO;2-E](http://dx.doi.org/10.1002/(SICI)1097-4628(19990314)71:11<1797::AID-APP9>3.0.CO;2-E)
- [12] Mathur V, Dixit M, Saxena NS, Sharma KB. Morphological Effects on Mechanical properties of Polystyrene-Polyvinylchloride blends. *Phase Transitions* 2009; 11: 769. <http://dx.doi.org/10.1080/01411590903445089>
- [13] Menard K. *Dynamic Mechanical Analysis, A Practical Introduction*; LLC: CRC Press, 1999; pp. 61-64 and 94-100.
- [14] Ahmad Z, Awadi NAA, Sagheer FA. Morphology, thermal stability and visco-elastic properties of polystyrene-poly(vinyl chloride) blends. *Polym Degrad Stab* 2007; 92: 1025. <http://dx.doi.org/10.1016/j.polymdegradstab.2007.02.016>

Received on 28-05-2013

Accepted on 11-06-2013

Published on 26-06-2013

[DOI: http://dx.doi.org/10.6000/1929-5995.2013.02.02.3](http://dx.doi.org/10.6000/1929-5995.2013.02.02.3)