

Tensile study of PVC-CdS semiconducting nanocomposite

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Thick film of CdS/Polyvinyl chloride (PVC) semiconducting nanocomposite was synthesized by dispersing nanofiller particles of CdS in PVC matrix. The nanostructure of the CdS particles has been ascertained through X-ray Diffraction (XRD). The tensile study of prepared samples has been done through a Dynamic Mechanical Analyzer device. 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 PVC. As a result elastic modulus, toughness and fracture energy are significantly improved in the semiconducting nanocomposite sample.

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1. Introduction

Polymer nanotechnology is a favored research area, in terms of funding and correspondingly increasing numbers of scientific publications. The risk for overexploitation is obvious. The term “nano” has strongly positive value, but can be used in contexts where it is not motivated. Such an example is clay nanocomposite studies where the clay particles are still at the scale of tens of micrometers. Although the polymer matrix may penetrate into the particle, properties are not controlled at the nanoscale.

Polymer nanocomposites are of great industrial and scientific interest, since they offer the potential for tailoring at a new scale. Greatly improved properties are reported at very small reinforcement contents. Different mechanisms contribute to this effect. One is conventional composite mechanics effects from a stiff phase in a soft or liquid matrix phase. Another suggested mechanism emphasizes the formation of regions of lowered polymer matrix mobility. Recently, it was suggested that nanoscale reinforcement may interact with the matrix so that entropic effects become increased. The physical or chemical molecular network of the molten or rubbery matrix phases becomes extended by interaction with the reinforcement.

The use of thermoplastic polymers as engineering materials has become state-of-the-art. To incorporate micron-size inorganic particles into a polymer matrix is a well-known method for improving the modulus of such composites. However, a reduction in the ductility of the material may take place. Furthermore, either by diminishing the particle size or by enhancing the particle volume fraction, the flexural strength and even the tensile strength can be enhanced. On the other hand, the fracture toughness and modulus remain fairly independent of the particle size [1], even when going down to the nanoscale

[2–4]. Recently, researchers demonstrated that inorganic nanoparticles could be of benefit for an increased tensile elongation [5, 6]. In our previous paper we have reported an increase of the glass transition temperature of PMMA by the dispersion of CdS nanoparticles, which may be due to a good bonding between the nanoparticles and the polymers, thus restricting the motion of the polymer chains [7].

The objective of the present study is to discuss tensile properties of PVC-CdS semiconducting nanocomposite. This study reveals that prepared nanocomposite show excellent film formability, good transparency and interesting tensile properties.

2. Experimental

2.1. Material preparation

2.1.1 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 nanocrystalline sample was carried out on JEOL-3010 electron microscope.

Fig. 1 shows the XRD pattern of a CdS sample. The presence of broad peaks confirms the nano size of the

prepared nanoparticles. The average particle size obtained from Debye Scherrer formula [9] is 3 nm, which is also verified with TEM results as shown in Fig. 2.

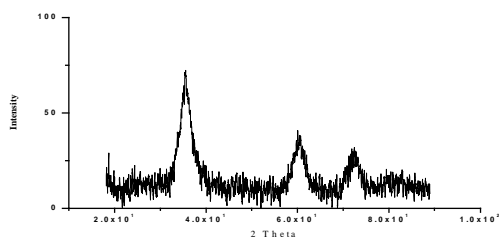


Fig. 1. The XRD pattern of CdS nanoparticle.

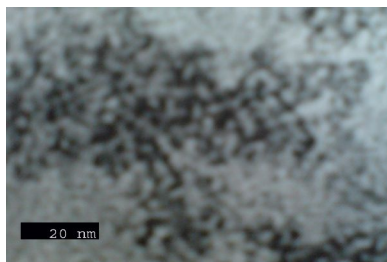


Fig. 2. TEM image of CdS nanoparticle.

2.1.2 PVC-CdS semiconducting Nanocomposite preparation

Now for the preparation of CdS-PVC composite, PVC of laboratory grade was dissolved in Tetrahydrofuran (THF) solvent and 10 % of PVC chalcogenide CdS nanoparticles were dispersed in this PVC solution. This solution was then stirred with the help of magnetic stirrer and then poured into flat-bottomed petri dishes to form film with a thickness of ~ 0.05 mm. The solvent is allowed to evaporate slowly over a period of 24 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].

2.2 Measurement technique

Dynamic Mechanical Analyzer (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. In this instrument, a force is applied to a sample and the amplitude and phase of the resultant displacement are measured. DMA employs a linear actuator where the applied force /stress to the sample are calculated from the knowledge of the input signal to the electromagnet coils of the driver [12]. The sinusoidal stress that is applied to the sample generates a sinusoidal strain or displacement. This applied stress/force is taken to be small, so as not to alter the shape and size of the material being analyzed. By measuring both the amplitude of the deformation at the

peak of sine wave and the lag between the stress and strain sine waves, quantities like the modulus, viscosity and the damping can be calculated. When the response of the material to the applied wave is perfectly elastic, the input response is in-phase with that of output i.e. phase lag (δ) = 0° , while a viscous response gives an out of phase, i.e. $\delta = 90^\circ$. Viscoelastic materials fall in between these two extremes i.e. $0^\circ < \delta < 90^\circ$ [13]. This technique separates the dynamic response of materials in to two distinct parts: an elastic part (E') and a viscous component (E'').

$$E^* = E' + iE'' \quad (1)$$

where, complex modulus E^* is defined as the instantaneous ratio of the in-phase or elastic response E' (which is proportional to the recoverable or, stored energy) and viscous response E'' (which is proportional to the irrecoverable or, dissipated energy).

Mechanical loss factor ($\tan \delta$) is another useful parameter, which can be very useful in order to compare viscoelastic responses of different materials

$$\tan \delta = E'' / E' \quad (2)$$

where $\tan \delta$ (damping factor) is the ratio of energy dissipated/ energy stored. The technique has gained a great amount of popularity due to its speed and high accuracy and ability of scanning the materials over a wide range of temperature and frequency.

Film samples were cut to be between 4-6mm in width and 10mm in length for DMA measurements. After mounting the sample in tension mode, the furnace was sealed off, scanned over a temperature range from 30°C to +150 °C at fixed frequency 1 Hz. The heating/ ramp rate was 2°C/min and strain amplitude 0.01mm within the linear viscoelastic region for all temperature scan tests. The mechanical loss factor ($\tan \delta$) has been determined during the test as a function of increasing temperature [14].

3. Results

Fig. 3 shows the stress strain curves for samples S_1 and S_2 . It is observed that stress strain curve consist of small linear region followed by nonlinear region for both the samples under study. For sample S_1 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 stress-strain variation of sample S_2 suggests that PVC-CdS nanocomposite is more ductile material at room temperature. The area of the stress strain plot represents fracture energy of the specimen. Here fracture energy improves for PVC-CdS nanocomposite sample. Calculated

values of Young modulus, tensile strength and fracture energy of both the samples are tabulated in Table 1.

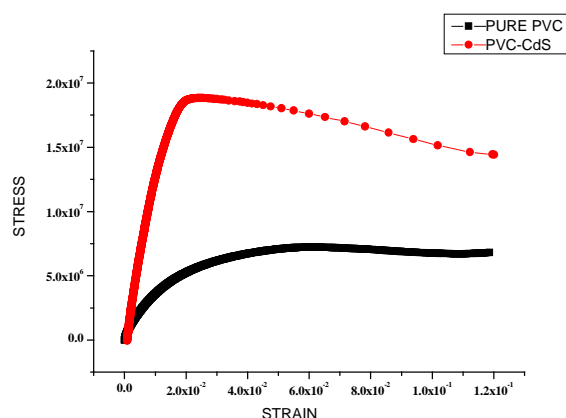


Fig. 3. Stress-Strain plots of pure PVC & PVC-CdS samples.

Table 1. The results of mechanical characterization of Pure PVC & PVC-CdS samples.

S.N.	Sample	Pure Pvc (S ₁)	Pvc-Cds (S ₂)
1.	Young Modulus (GPa)	0.279	1.15
2.	Tensile Strength (MPa)	6.8	18.51
3.	Ultimate Strength (MPa)	7.18	14.11
4.	Fracture Energy (kJ)	727.34	1900.77
5.	Fracture Strain (%)	11.85	11.89

4. Discussion

This study has demonstrated that in PVC-CdS nanocomposite fracture energy, Young's modulus and tensile strength are significantly improved. During tensile study, on applying the external stress through DMA device to the sample S₁ and sample S₂, the CdS nanoparticles of sample S₂ act as stress concentrators and the induced stress pervade over the entire specimen. These dispersed CdS nanoparticles serve as restriction sites to retard the mobility of molecular chain of polymer matrix and reduces flexibility of chains at surface. In this way increase in toughness & fracture energy of basic PVC polymer matrix in the presence of dispersed CdS nanoparticles and an increment in values of Young's modulus and tensile strength of sample S₂ is observed in results. Thus the rupture of the nanocomposite specimen would not take place quickly after the application of external stress.

5. Conclusions

In the light of findings reported in this work, some fundamental conclusions can be reached.

1. An improvement in the tensile strength is suggestive of the fact CdS nanoparticles act as stress concentrator and change fracture mechanism of basic PVC from crazing to yielding.

2. The improve values of young's modulus, tensile strength, fracture energy and ductility of PVC-CdS nanocomposite places them in advantageous position and make them attractive for advanced engineering and technology.

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