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Study of electrical properties of semiconducting nanocomposites

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ABSTRACT

Semiconducting nano-composites are the hybrid materials which are the combination of one or more semiconducting nano-particles with a conducting polymer. These materials have unique properties which can be used for wider applications. We have prepared a nano-composite of II-IV semiconducting nano-material and a conducting polymer by precipitation method at room temperature. The synthesized nano-composites with different weight percentage (5%, 10%) of semiconducting nano-particles were characterized by FTIR and UV-Vis spectroscopy. The measured electrical parameters of theses composites are compared with certain values available with other studies. The activation energy and electrical parameters of these nano-composites have been calculated from the plots between conductivity and temperature. It is concluded that the measured values are in better agreement with the available experimental values. This study also reveals that the electrical conduction behaviour of these composites is the intermediate behaviour of conducting polymer and pure semiconducting nano-crystals. Thus, we can conclude that nano-composites can be more useful with designed optical band gap energy which can be obtained by controlling size and shape of the semiconducting materials. Certain technological applications in nano-electronic devices, gas sensors, solar cells etc. have been suggested.

Keywords: Semi-conducting crystals, nano-particles, FTIR, UV Vis-spectroscopy, composites etc.

INTRODUCTION

During last few years, a lot of emphasis is on production of semi conducting materials at nanoscale. We know that producing automatically flat surfaces in single crystalline materials is possible by manipulateing atoms, whereas, this is meaningless, in case of glassy systems. The structure of amorphous materials is disordered at the atomic level. Therefore, these nano materials can easily be tailored and may yield a great variety than that of crystalline nanostructures. It is well known that the selenium and tellurium rich semi conducting materials exhibit the phenomena of electrical switching. Two types of electrical switching namely, reversible (threshold) and irreversible (memory) switching are observed in semi conducting materials glasses. Studies on semi conducting materials glasses are of great interest due to their application in electronic switches and memories. Recently there are many reports on semi conducting materials available in the literature. Since, semi conducting materials are much cheaper and exhibit more than one type of memory switching; the switching and memory devices based on semi conducting materials are expected to provide more efficient and costeffective devices. Conducting polymers provide tremendous scope for turning of their electrical conductivity from semiconducting materials to metallic regime [1,2]. The conductivity of the conducting polymer as can be tuned by polymers and by the nature of dopant, by the degree of doping, and by making composites with inorganic materials. When conducting polymers are taken in the composite from their electrical properties are altered from those of basic materials. It has been shown that the conduc-tivity of these heterogeneous systems depends upon number of factors such as the concentrations of the conducting fillers, their shape, orientation and inter-action between filler molecules [3]. Polymer Nano-composites are polymer matrix composites in which the filler is less than 100 nm in at least in one dimen-sion [4]. These composites exhibit extraordinary interesting properties. A feature of polymer Nano-composites is that the small size of the filler leads to a dramatic increase in the interfacial area creates a significant volume fraction of interfacial polymer with properties different from the bulk polymer even at low loadings. Experimental work has generally shown that all types and classes of nano composite materials lead to new and improved properties when compared to their nano composites counterparts. Therefore nano-composites promise new applications in many fields such as mechanically reinforced lightweight components, non-linear optics, nano wires, sensors and other systems. Now days fillers have emerged, providing an opportunity for the development of high performance multifunctional nano-composites. The recent resurgence of interest in conducting polymer nano-composites has emerged for several reasons. For example, as the size of silicon nano-particles decree-ses, the band gap changes and the colour of particles changes [5,6]. Number of II-VI semiconducting materials have been investigated in which ZnS have considerable interest due to its vast applications like solar cell, fluorescent material and photonic receiver etc. [7] Therefore, a synthesis of ZnS nanoparticles with polymer to form composites with conducting polyaniline is proposed. Zinc sulphide (ZnS) has unique physical properties, such as high refractive index, low optical absorption in the visible and infrared light range and wide optical gap, such film is widely used in many optical and electronic areas. In the area of optics, Zns can be used as reflectors and dielectric filters because of its high refractive index and high transmittance in visible range. ZnS can be used for fabrication of optoelectronic devices such as blue emitting diodes, electroluminescent devices, electro optic modulator, optical coating, heterojunc-tion solar cells and photoconductor.

METHODOLOGY

Numbers of methods have been reported for the preparation of nanoparticles. ZnS has unique physical properties such high refractive index, low optical absorption in visible and infra red light range and wide optical gap. This film is widely used in many optical and electronic areas. ZnS can also be used for fabrication of optoelectronic devices such as LED, Solar cells etc. Synthesis of ZnS nano-particles is one of the II-VI semiconductor compounds which have wide ranging applications in solar cells, infrared window materials, photo-diode and cathode ray tube, electroluminescent devices and multiplayer dielectric filters. Keeping in mind, we have prepared nano composites of ZnS with conducting polymer at room temperature using precipitation method.

Synthesis of zinc sulphide (ZnS) nanoparticles

0.1M Zinc salt solution was made by dissolving Zinc Acetate in double distilled water and 0.1 M Na_2S solution was also made in double distilled water. From these stock solutions, 100ml of solution of Zinc acetate solution was mixed with 100 ml of DMF and stirred for 10 minutes. Then to above mixture 100 ml Na_2S solution was added drop wise with constant stirring. The stirring was continued for 1 hour. This results in milky white solution. The solution was kept overnight. The same procedure was repeated for the washing of resultant solution. Dry white powder of ZnS so obtained by this process and by precipitation method a composite of ZnS-PANI is prepared for experimental purpose [8].

RESULTS AND DISCUSSION

The nano composites of PANI-ZNS are characterized by using FTIR and UV VIS spectrography and measured the parameters at room temperature. On the basis of above measurements, it is concluded that inorganic semiconducting nanoparticles of ZnS have been synthesized successfully by chemical precipitation method. Polyaniline and its nano-composites with ZnS under investigation have been synthesized by chemical oxidation polymerization method. The powdered form of the synthesized material was used for the further study. The synthesized materials were characterized by UV –Vis, fluorescence spectroscopy at other weight percentage of ZnS. Thus, we successfully synthesized the nanomaterials by simple precipitation method and conducting polymer and composites by chemical oxidation polymerization at room temperature. A comparison of these data infers that the measured values of electrical parameters are in better agreement with other available results [8,9,10].

Characterization

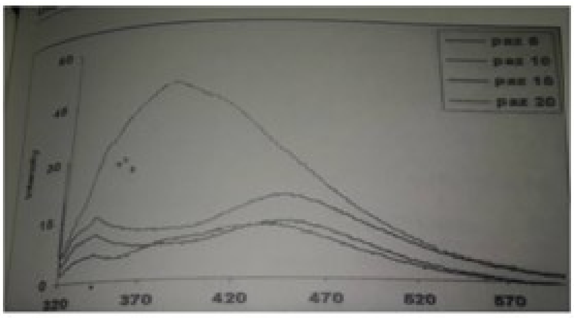
The synthesized PANI-ZnS is characterized by using UV-Vis and FTIR spectroscopy.

UV-Vis spectroscopy:

A study of UV-Vis spectra of PANI and PANI – ZnS is given in fig.-1. It is observed that there is a shift in the absorption maxima. The shift in the absorption bands due to addition of ZnS which changes the delocalisation in the polymer chain. The increase in intensities of the excitonic and poloronic bands is observed in the nanocomposites indicating the interaction of ZnS with PANI chain. By increasing the weight percentage of ZnS nanofiller the peak centred at in PANI becomes substantially broadened and shifts towards higher wavelength.

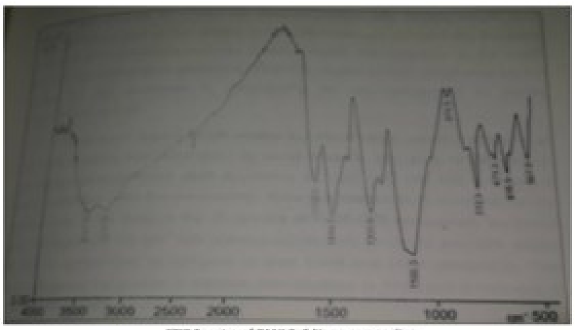
FTIR spectroscopy:

Fig.-2 representing the absorption of radiation by high frequency phonon vibrations. The IR-spectra of PANI are shown in adjacent fig. These spectra shows the characteristic vibration bands. All these bands are well matches with the earlier reported values polyanniline. The IR spectra of pure PANI – ZnS shows that the composites of PANI-ZnS are built up of repeating units as that of pure PANI indicating the formation of conducting polymer nanocomposites. IR study also reveals that peak intensities and conductivity variation in the polymer sample are in tight interaction with each other. It is also observed that of PANI –ZnS enhanced poloronic and bipoloronic bands for the 5%, 10% composites.



Fluorescent spectra of PANI-ZnS

Fig.1



FTIR Spectra of PANI ZnS Nano-composites

Fig.2

The blue shift in absorption maxima and increased band gap of the synthesized ZnS confirms the formation of nanosized inorganic semiconductor ZnS.

CONCLUSION

The conductivity increases only for the composites containing 5% and 10% **ZnS**. For higher concentrations the conductivity decreases. From the above discussion we conclude that there is a change in the corresponding frequencies of pure PANI and its composites as well as the new polymer nanocomposites can be synthesized with desired thermal stability, optical band gap energy and tunable electrical conductivity. It is also observed that peak intensities in IR spectra and conductivity variation in the polymers are in better interaction with each other. The desired electrical band gap could be synthesized by controlling the size, shape and amount of nanofiller in the polymer matrix. Such nanocomposites can be used in the tuned circuits, optical devices, gas sensors and nanoelectronic devices. Transparent conducting polymer/solar cell electrode, transparent coating in cell phone and compact disc technology. Also nano-particles are being considered for enhancing matrix properties of traditional composites to increase out of plane properties and add conductivity and sensing capabilities.

Conflicts of interest: The authors stated that no conflicts of interest.

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