Available online at www.joac.info

ISSN: 2278-1862

Journal of Applicable Chemistry

2018, 7 (1): 219-223

(International Peer Reviewed Journal)

Electrical and Optical Properties of Semiconducting Nano-Composites

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Accepted on 20th January 2018, Published online on 27th January 2018

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-VI 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, Conducting polymers, FTIR, UV-VIS Spectroscopy, Nano-composites, Gas sensors, Solar cell etc.

INTRODUCTION

Production of semi conducting materials at nanoscale is a challenging task since long. We know that producing automatically flat surfaces in single crystalline materials is possible by manipulating 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. Conducting polymers provide tremendous scope for turning of their electrical conductivity from semiconducting materials to metallic regime [1-3]. 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 form their electrical properties are altered from those of basic materials. It has been shown that the conductivity of these heterogeneous systems depends upon number of factors such as the concentrations of the conducting fillers, their shape, orientation and interaction between filler molecules [4]. Polymer Nano-composites are polymer matrix composites in which the filler is less than 100 nm in atleast in one dimension [5]. 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 composite 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. 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 material 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 cost-effective devices.

Now a 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 decreases, the band gap changes and the colour of particles changes [6-8]. 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., [3] & [9]. Therefore, a synthesis of ZnS nanoparticles with polymer to form composites with conducting poly-aniline (PANI) 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 optical modulator, optical coating, hetero junction solar cells and photoconductor etc.

MATERIALS AND METHODS

Number of methods have been reported for the preparation of nanoparticles. ZnS has unique physical properties such as high refractive index, low optical absorption in visible and Infra-red 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. ZnS nano-particles is one of the II-VI semiconductor compound 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. This synthesized nano composite with different weight percentage (5%, 10%) is characterized using FTIR and UV-VIS spectroscopy.

Synthesis of ZnS Nanoparticles and ZnS-PANI Nano Composites: In order to synthesize semi conducting nano-composites of ZnS-PANI, 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 min. Then to above mixture 100 mL Na_2S solution was added drop wise with constant stirring. The stirring was continued for 1.5 h. 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].

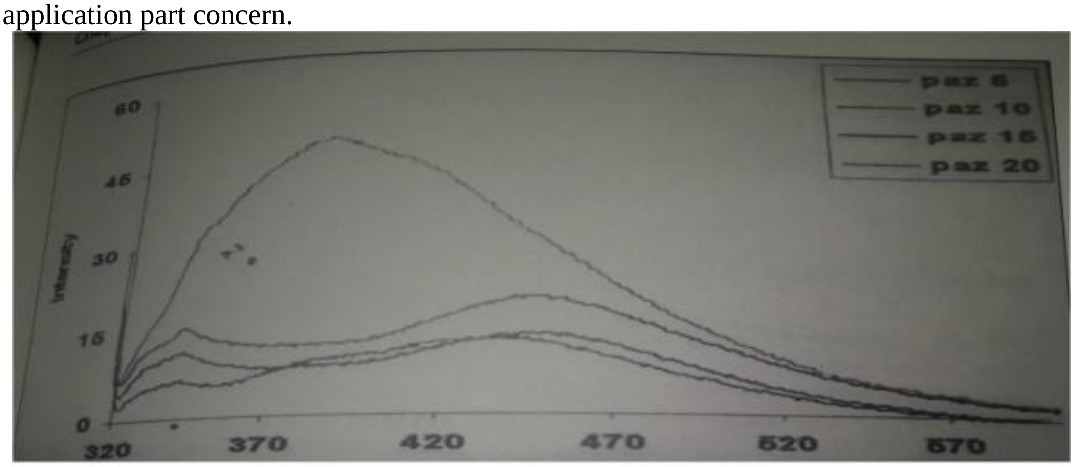
Characterization: The synthesized PANI-ZnS nano- composites are characterized by using UV-VIS and FTIR spectroscopy at different weight percentage. The measured values are plotted respectively and noted the characteristics as-

UV-VIS Spectroscopy: A study of UV-VIS spectra of PANI and PANI – ZnS is given in Figure 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 polaronic bands is observed in the nano-composites indicating the interaction of ZnS with PANI chain. By increasing the weight percentage of ZnS nanofiller, the peak centered at PANI spectra becomes substantially broadened and shifts towards higher wavelength.

FTIR Spectroscopy: The IR-spectra of PANI are shown in adjacent Figure 2 representing the absorption of radiation by high frequency phonon vibrations. These spectra show the characteristic vibration bands. All these bands are well matches with the earlier reported values of polyaniline. 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 composites of PANI –ZnS enhanced polaronic and bipolaronic bands for the 5%, 10% composites. The blue shift in absorption maxima and increased band gap of the synthesized ZnS confirms the formation of nano sized inorganic semiconductor ZnS.

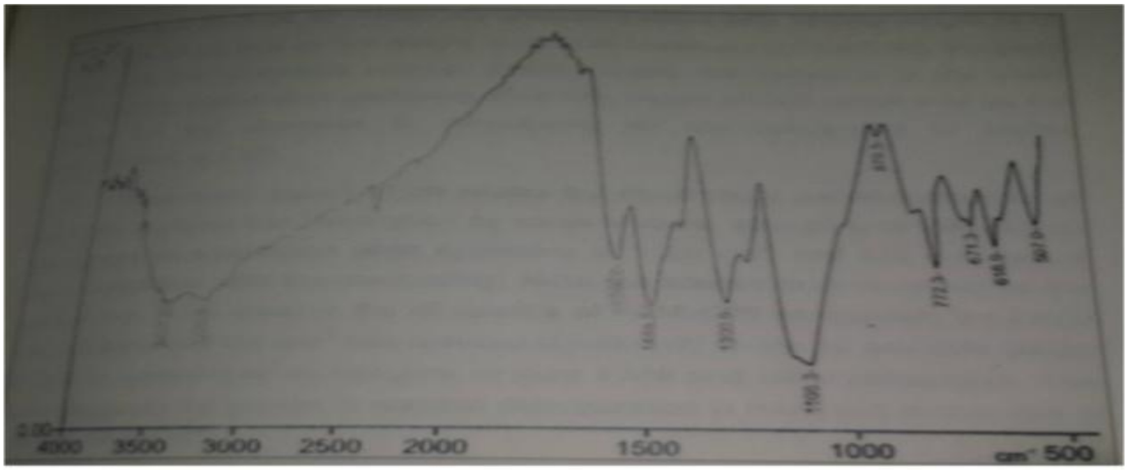
RESULTS AND DISCUSSION

The nano composites of PANI-ZNS are characterized by using FTIR and UV -VIS spectrograph and measured the parameters at room temperature and plotted respectively. On the basis of above measurements, it is observed that inorganic semiconducting nanoparticles of ZnS have been synthesized successfully by chemical precipitation method showing different behaviour in comparison of semiconducting nano composites at different weight percentage of ZnS. Thus, we successfully synthesized the nano-materials 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 [9-11] as far as their application part concern.



Fluorescent spectra of PANI-ZnS

Figure 1



FTIR Spectra of PANI ZnS Nano-composites

Figure 2

APPLICATIONS

The main applications of conducting polymers are in electrical energy storage systems, gas sensors, bio-sensors. These materials are useful for corrosion protection, antistatic coatings for immobilization of bio-molecules or as selective filters, preparation of pH or reference electrodes, development of individual electronic devices and integrated circuits. Transparent conducting polymer can be used in solar cell electrode, transparent coating in cell phone and compact disc technology with different weight percentage. Such materials can also be used in optoelectronic devices.

CONCLUSIONS

The computed values of activation energy and electrical parameters of these nano composites reveals that 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 nano-composites can be synthesized with desired thermal stability, optical band gap energy and tenable 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 nano-composites can be used in the tuned circuits, optical devices, gas sensors and nanoelectronic devices. Transparent conducting polymer can be used in 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.

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