Nano Progress

Research Article

Synthesis, Electrical, Magnetic and LPG Sensing Behavior of Polypyrrole/In₂O₃ Polymer Nanocomposite

Jakeer Husain,[a] Yesappa L.,*[b] Rehana Anjum,[c] Sweta M. Nayak,[d] Anjum Begum,[e] Jaisheel Sagar,[f] Bushara Anjum[g]

[a]Deptment of Engineering, Faculty of Engineering and Technology, KBNU Gulbarga - 585104, Karnataka, India.
[b]Department of Physics, University of Agricultural Sciences, Raichur - 584104, Karnataka, India.
[c]Department of Chemistry, Lords Institute of Engineering and Technology, Hyderabad, Telangana - 500008, India.
[d]Department of Physics, Gulbarga University Kalaburagi, Karnataka, India.
[e]Department of Chemistry, Lords Institute of Engineering and Technology, Hyderabad, India.
[f]Mechanical Engineering Department, Lords Institute of Engineering and Technology, Hyderabad, India.
[g]Nagambika B.Ed. College, Gulbarga - 585104, Karnataka, India.

*Corresponding author E-mail address: yesugs@gmail.com (Yesappa L.)

Abstract: Polypyrrole-In₂O₃ nanocomposites have been synthesized by using in-situ chemical reaction method. The Polypyrrole nanocomposite were characterized by Fourier transform infrared spectroscopy (FTIR), X-ray diffractometer (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), differential scanning calorimetry (DSC) techniques and the conductivity measurement were carried out at different temperature and frequency using two probe methods. The FTIR results confirmed the formation of chemical complexity of Polypyrrole and Polypyrrole/In₂O₃ nanocomposite and the structural phase change in the Polypyrrole nanocomposite was observed in XRD studies. The DSC results reveal enhanced thermal stability with respect to increased In₂O₃ nano concentration. The SEM image shows a substantial change in morphology after incorporating nano In₂O₃ and the presence of nanoparticle in composites was noticed in TEM images. The dielectric parameters are found enhanced with temperature and nano concentration. The AC and DC electrical conductivity increases with increasing nano concentration in polymer nanocomposites and achieved maximum conductivity for 50wt%. The magnetic properties of Polypyrrole/In₂O₃ nanocomposite are larger at 50wt% and decreases with decreasing the concentration of In₂O₃ nanoparticles in PPy composite. The observed results are suggesting that Polypyrrole–In₂O₃ nanocomposite material is a prominent candidate for LPG sensing and potential applications.

Keywords: Polypyrrole; nanocomposite; electrical conductivity; LPG sensing.

1. Introduction

The combination of the nanomaterial with polymer is very attractive not only to reinforce polymer but also to introduce new electronic properties based on the morphological modification or electronic interaction between the two components. Depending on the nature of the components used and the method of preparation, significant differences in composite properties may be obtained. Conducting polymer composite have several advantages over their pure metal counterparts including lower cost, ease of manufacture, high flexibility, reduced weight, mechanical shock absorption ability, corrosion resistance and conductivity control.[1,2] In recent years, intrinsic conducting polymers with conjugated double bonds have been attracted much attention as advanced materials. Among the conducting polymers, Polypyrrole (PPy) is specially promising for commercial applications because of its good environmental stability, facile synthesis and higher conductivity than many other conducting polymers. PPy can often be used as biosensors, gas sensors,[3,4] wires,

micro actuators, anti-electrostatic coatings, solid electrolytic capacitor, electrochromic windows and displays, and packaging, polymeric batteries, electronic devices and functional membranes, etc. PPy coatings have an excellent thermal stability and are good candidate for use in carbon composites. Furthermore, the electrochemical process parameters affecting the properties of the PPy coatings are also investigated. PPy can be easily prepared by either an oxidative chemical or electrochemical polymerization. However synthetically conductive PPy is insoluble and infusible which restricts it's processing and applications in other fields.[5-10] The innovative observed that the appearance of nanoparticle and high electrical conductivity for the polymer nanocomposites. On doping these conjugated polymers show very high conductivity similar to metals. Therefore sometimes they are also called synthetic metals. They combine the electrical properties of metals with the advantage of polymers such as smaller weight, greater workability, resistance to corrosion and lower cost. Recent developed sensors in research and industries, particularly those joined with nano-scale composites, give

promising execution with the tall affect commitment to an advancement of precision, unwavering quality and financial effectiveness. In any case, within the genuine condition of viable situations, there still stay challenges to be unravelled for upgrading the sensor proficiency and reaction characteristics. The aforementioned literature review showed that researchers have done a lot regarding synthesis of PPy/nanocomposites by different methods. They have also added different oxides to improve the sensor and electrical properties recently, gas sensing, as a typical application in intelligent systems, is receiving increasing attention in both industry and academia. Gas sensing technology has become more significant because of its widespread and common applications in the following areas: (1) industrial production (e.g., methane detection in mines (2) automotive industry (e.g., detection of polluting gases from vehicles (3) medical applications (e.g., electronic noses simulating the human factory system) (4) indoor air quality supervision (e.g., detection of carbon monoxide) (5) environmental studies (e.g., greenhouse gas monitoring). During the last fifty years, different studies have established various branches of gas sensing technology. Among them, the three major areas that receive the most attention are investigation of different kinds of sensors, research about sensing principles, and fabrication techniques.[11-16] In the present investigation, the synthesis of Polypyrrole/In_2O_3 nanocomposite using in-situ method and characterized them to know the chemical interaction, structural phase, thermal, morphology and micro structural properties. And temperature dependence electrical conductivity, ac conductivity and LPG sensing were also studied. Therefore, a research study in these areas may help to fabricate compact size and high-performance for sensor application.

2. Experimental Section

2.1. Synthesis of Polypyrrole

Polypyrrole (PPy) was synthesized by chemical oxidative polymerization technique using monomer pyrrole. Analytical grade ammonium per-sulphate (APS) was used as an oxidizing agent. The chemical polymerization was carried out in a beaker by mixing 0.1 M aqueous solution of pyrrole and 0.1 M of APS in 1:1 ratio. The polymerization was carried out for a period of three hours. After termination of polymerization process, the precipitate obtained was filtered. The product was washed successively by methanol followed by distilled water.

2.2. Synthesis of Polypyrrole

A known quantity of Pyrrole solution dissolved in HCl is taken in a beaker and stirred for 5 minutes and 0.5g (10wt %) of In_2O_3 nanoparticles were added and stirred with magnetic stirrer for 15 minutes then ammonium per sulphate was added drop by drop. Even after complete addition of ammonium per sulphate stirring was continued for another 10 minutes and allowed the precipitate for about 30-40 minutes to settle down. Now precipitate was filtered and washed with distilled water several times to remove the impurities. Finally washed with acetone and precipitate was dried on its own at room temperature and was grinded for fine powder with
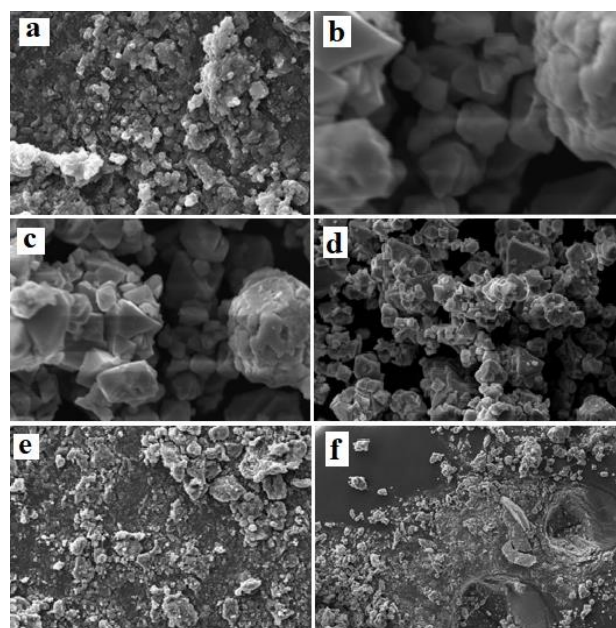

Fig. 1. The SEM images of Polypyrrole/In_2O_3 nanocomposites a) PPy b) PPy/ In_2O_3 10wt%, c) PPy/ In_2O_3 20wt%, d) PPy/ In_2O_3 30wt%, e) PPy/ In_2O_3 40wt% and f) PPy/ In_2O_3 50wt%.

agate and mortar. Now the resultant sample is the Polypyrrole/In_2O_3 nanocomposite with 10wt% of In_2O_3. The same process was repeated for Polypyrrole/In_2O_3 nanocomposites with 20wt%, 30wt%, 40wt% and 50wt% of In_2O_3 are synthesized.

2.3. Preparation of In_2O_3 Nanocomposite film

The synthesized Polypyrrole/In_2O_3 nanocomposites powder was dissolved in PVA solution and it was sonicated for 15-20 min. The sonicated solution was stirred for ½ hour and then the PVA/ Polypyrrole/In_2O_3 nanocomposites paste was formed. Then known volume of viscous PVA/ Polypyrrole/In_2O_3 nanocomposites solution was poured onto a levelled clean glass plate and left to dry at room temperature for about 48 h. The dried films were peeled off from the glass plate and cut into suitable pieces for characterization and applications.

3. Characterization Techniques

To explore the formation of crystal structure, bonds, vibrational modes, microstructure; X-ray diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), Scanning electron microscope (SEM) and Transmission electron microscopy (TEM) studies were employed. Polypyrrole/In_2O_3 nanocomposites were characterized through XRD, Which is carried out using CuK alpha radiation and diffractogram 2theta is run from 10° - 80° under a step size of 0.02^o. The FTIR spectra of all the samples are recorded on Perkin Elmer (model 783) FTIR spectrometer in KBr medium at room temperature in the region 4600-400 cm^{-1}. For recording FTIR spectra, powders are mixed with KBr in the ratio 1:25 by weight to ensure uniform dispersion in KBr pellets. The mixed powders are pressed in a cylindrical dye to obtain clean discs of approximately 1 mm thickness. The morphology of the polymer nanocomposites in the form of powder was investigated
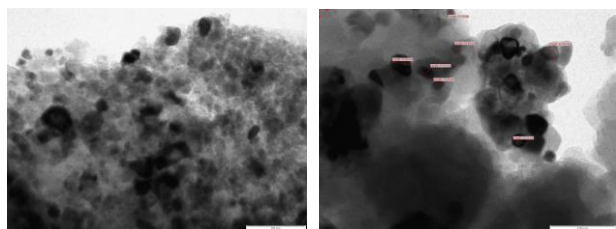
Fig. 2. The TEM image of the as synthesized Polypyrrole and Polypyrrole/In₂O₃ nanocomposite.

using scanning electron microscope (SEM - Model-EVO-18 Special Edison, Zeiss, Germany) and transmission electron microscope (TEM - model JEOL, JEM-2100). Thermal studies were investigated by differential scanning calorimetry (DSC - Q20 V24.10 Build 122). The conductivity of these nanocomposites are studied by using Keithley 6514 electrometer, To understand the sensing properties of the nanocomposites are coated with silver for good ohmic contact the sensing studies was done by using sensing chamber with programmable computer and digital multimeter.

4. Results and Discussions

4.1. Scanning Electron Micrographs (SEM)

In order to inspect the surface morphology of both Polypyrrole and Polypyrrole/In₂O₃ nanocomposites, the samples were examined by SEM as represented in Fig. 1. All the nanocomposites reveal flaky shaped structure, in which the size of flakes reduces as percentage of In₂O₃ nanoparticles increased into Polypyrrole. It can be seen that the size of final crystals of In₂O₃ covered by Polypyrrole reduced due to the possibility of agglomeration of In₂O₃ particles and PPy has declined. The SEM images help us draw a conclusion that the doping of In₂O₃ nanoparticles has a strong effect on the morphology of PPy, since PPy has various structures such as granules, nanofibers, nanotubes, nanospheres, microspheres and flakes. It is observed from the SEM images that, the distribution of metal oxide particles are agglomerated due to the formation of matrix mixing or close complexation.[17] Most of the particles are in spherical shape and are complexed with polymer forms by matrix mixing, which enhances the crystalline nature of the PPy.[18] These nanocomposites gives the opportunity to obtain improved capacitance due to surface effects. Nanocomposite present in different sizes and shapes compared to the bare In₂O₃ nanoparticles where the layers are wrapped on the surface of nickel oxide nanoparticles appearing as small aggregated globules.

4.2. Transmission Electron Microscopy

Fig. 2(a, b) shows the typical bright filed TEM images of the synthesized Polypyrrole and Polypyrrole/In₂O₃ nanocomposite. It was seen from the image that, the oxide particle is well dispersed and forms well dispersed polymer matrix. Varied particle sizes are observed and most of them are spherical and hexagonal in shape and are in the nano range. According to the TEM micrographs in PPy and Polypyrrole/In₂O₃ have formed a nanocomposite in which the nanoparticles are embedded in the polymer matrix. It is obvious that In₂O₃ nanoparticles were uniformly distributed in PPy. In addition to
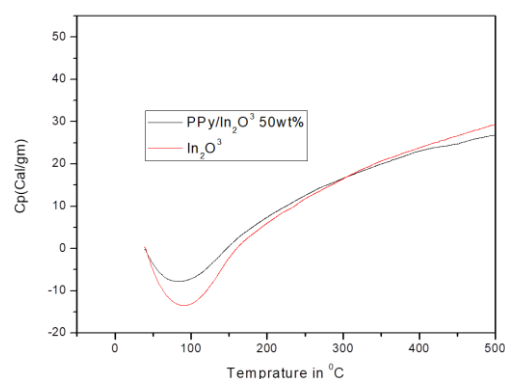

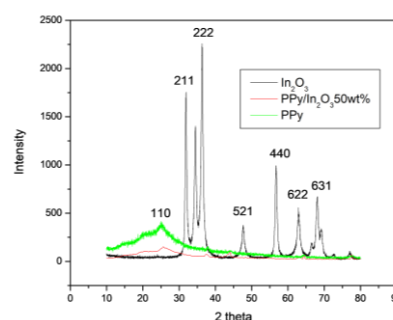**Fig. 3.** The DSC curve of the as synthesized Polypyrrole/In₂O₃ nanocomposite

Fig. 4. The XRD spectra of the as synthesized Polypyrrole/In₂O₃ nanocomposite

increasing the rigidity of the polymer matrix, the particles are added to modify rheological property. The conformational energy map of PPY matrix macromolecules displays a very rigid and extended structure. This may be attributed to the formation of intra residue hydrogen bonds between the molecules, resulting in a spherical and hexagonal shaped structure.

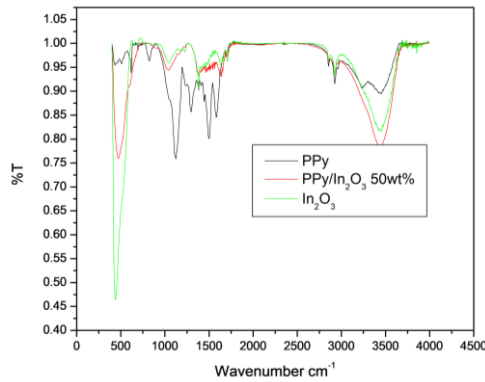### 4.3. Differential Scanning Calorimetry (DSC)

Substituting for the heat flow by the DSC then the heat capacitance C_p can be estimated against temperature. Fig. 3 represents the temperature dependence of the heat capacitance of In₂O₃ & Polypyrrole/In₂O₃ nanocomposite. According to Fig. 3, the heat capacitance of Polypyrrole/In₂O₃ nanocomposite is close to that of In₂O₃ nanoparticles at room temperature. However as the temperature increase the divergence between Polypyrrole/In₂O₃ and In₂O₃ increase. As the temperature increase the heat capacitance of In₂O₃ and Polypyrrole/In₂O₃ continuously increase. Such trend indicates the domination of In₂O₃ on the internal energy of the composite.

4.4. XRD Analysis

XRD pattern of the samples are shown in Fig. 4. It is analytical method used to identification and quantitative analysis of various crystalline forms from figure it is clearly observed that for Pure Polypyrrole the peak observed at 2theta=25° confirms the formation of pure PPY it is also shows the partially crystallinity. It is clear that all diffraction peaks became much stronger and sharper for pure indium oxide which is due to high degree of crystallization and could be well

Table 1: The estimated nanoparticle size and strain of In$_2$O$_3$ nano powder and nanocomposite.

Sample	Nanocrystallite size (nm)		Micro strain (x 10^{-4})
	Scherer's formula	W-H plot	
Pure In$_2$O$_3$	28	36	8.14
PPy–In$_2$O$_3$ 50wt%	106	110	16.50

Fig. 5. The FTIR spectra of the as synthesized Polypyrrole/In$_2$O$_3$ nanocomposite.

Fig. 6. The variation of dc conductivity as a function of temperature for Polypyrrole**.**

Fig. 7. The DC conductivity of the Polypyrrole/In$_2$O$_3$ nanocomposite.

indexed to cubic structure they show a broad peak which has a sharp and well defined peak indicates the good crystallinity. The intensity of diffraction peaks for Polypyrrole/In$_2$O$_3$ nanocomposite is found to be lower than that of In$_2$O$_3$. The broad XRD peaks are indicating that the particles are in nanometre size range (JCPDS. No.060416). The amorphous background hump comes from the PPy and the crystallite sizes of the samples were decreased with the increase of PPy content.[19] The average particle size calculated by using the Scherrer equation is given D=Kλβcosθ, where K is the shape factor for the average crystallite, λ is the X-rays wavelength, β is full width at half maximum of the diffraction peak and θ is Braggs angle. It is found that the particle size of In$_2$O$_3$ is 28nm and that of Polypyrrole/In$_2$O$_3$ nanocomposite is 106 nm and the calculated parameters were tabulated in table 1.

4.5. FT-IR Analysis of Polypyrrole/In$_2$O$_3$ Nanocomposite

Fig. 5 shows the FTIR spectra of pure In$_2$O$_3$ and it has predominant peaks at the wave number of 3465 cm^{-1} which is due to the O-H bond vibration and it formed at higher frequency due to splitting of water molecules on the surface of oxide nanoparticles. The peak at 1112 cm^{-1} is assigned to C-H plane bending mode and the peaks at 414 cm^{-1} to 590 cm^{-1} are corresponds to metallic stretch may be assigned to In$_2$O$_3$ groups. The spectra of Polypyrrole nanocomposite where the large broad bands appears from 3903 to 3437 cm^{-1} were due to the O-H bond stretching because of absorption of water molecule. The peak at 2852 cm^{-1} is corresponds to C-H bond stretch due to the composite formation and the other peaks at 2372cm^{-1} & 2330 cm^{-1} is due to the unsaturated amine, 1458 cm^{-1} is due to C=O aromatic stretch, 1106 cm^{-1} is due to C-O ester stretch, 1559 cm^{-1} is due to N-H bending. The peaks from 887 to 612 cm^{-1} are due to C-H bending and the peaks from 575 to 447 cm^{-1} is due to the metallic stretch.[20] The change id peak positions and peak shifting confirms that there is a formation of complexation between the polymer and nanoparticles.
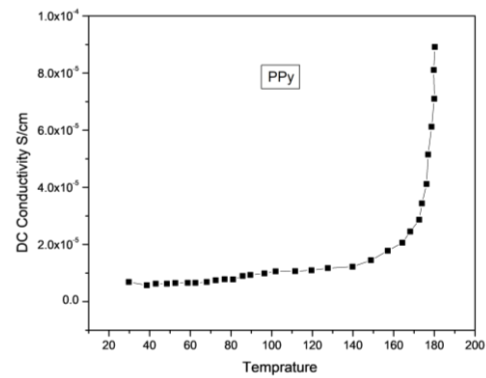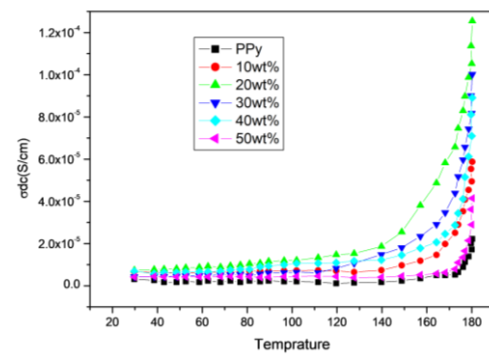
4.6. Electrical Conductivity

Fig. 6 shows the variation of dc conductivity as a function of temperature for Polypyrrole. It is observed that the value of dc conductivity increases with temperature. In the temperature range 30 – 100^{0}C, the conductivity values are almost constant and increases exponentially in the temperature range 100 – 180^{0}C. Which is due the polarons possess sufficient energy to hop between various favourable localized states. The conductivity behavior is the characteristic of amorphous materials.[21-22]

Fig. 7 shows the variation of dc conductivity as a function of temperature for Polypyrrole/In$_2$O$_3$ nanocomposites. It is observed that the value of dc conductivity of these composites increases with temperature. In the temperature range 30 – 100 ^{0}C, the conductivity values are almost constant and increases in between temperature 150 – 160 ^{0}C and a linear increment in the conductivity values are observed. The initial increment in Polypyrrole/In$_2$O$_3$ nanocomposite may be due to the extended chain length of PPy in which the polarons possess sufficient energy to hop between various favourable localized states.[23] The amorphous polymers can exist in different states depending upon the temperature. At low temperatures, they are hard and glassy materials. At a temperature known as glass transition temperature T$_g$, they undergo transition to rubber like state. X-ray diffraction pattern and SEM micrograph of Polypyrrole/In$_2$O$_3$ nanocomposites composites employed in the present investigation show semi-crystalline behavior.

Under such conditions, a uniform crystallinity is surrounded by amorphous regions. The localized states form extended band like structures which may act in trapping the carriers from extended
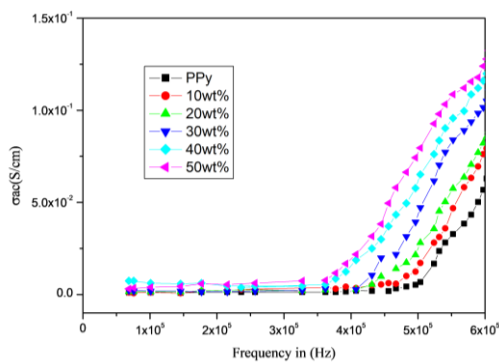
Fig. 8. The AC-electrical conductivity of PPy and Polypyrrole/In₂O₃ nanocomposite.

Fig. 9. The imaginary parts of the complex permeability of Polypyrrole/In₂O₃ nanocomposite.

states of crystalline region.[24-25] Polarization around a charge in localized state may be responsible for multiple phases of conductivity in Polypyrrole/In₂O₃ nanocomposites. The electrical properties in Polypyrrole/In₂O₃ nanocomposites can be explained on the basis of exchange of electrons between ions of the same element that are present in more than one valence state distributed randomly over equivalent crystallographic lattice sites. It is well known that the change in slope is attributed to the Curie temperature or to a change in the conduction mechanism at the Curie temperature and the samples transforms from an ordered state to a disordered paramagnetic state with a marked increase in conductivity.

4.7. AC Electrical Conductivity

In amorphous systems dc conductivity measurements are used to study the localization of electronic states, while ac conductivity measurements provide useful information concerning relaxation phenomenon related to the electrical polarization process. In high frequency measurements, the characteristic hopping lengths and hopping rates of carriers between localized states can be determined. The low frequency data are however, more sensitive to slower relaxation process like the reorientation of dipoles etc. In the latter case most relaxation process can be explained in the Debye theory of energy loss for dipole relaxations. The frequency and temperature dependences of AC-electrical conductivity of PPy and Polypyrrole/In₂O₃ nanocomposite are shown in Fig. 8. The AC-electrical conductivity of the Polypyrrole/In₂O₃ nanocomposite is higher than that of the pure PPy. The lower conductivity of the pure PPy could be ascribed to low level of protonation in the PPy chains.[26]

The improvement of AC conductivity for Polypyrrole/In₂O₃ nanocomposite comes from the effective dispersion of In₂O₃ nanoparticles in the PPy matrix, which favours better electronic transportation. It is evident that the AC-conductivity is both frequency and temperature dependent and enhanced with increase of both the frequency and the temperature. This indicates that there may be charge carriers which can be transported by hopping through the defect sites along the polymer chain. The frequency dependence of the AC-conductivity is considered to be a result of interface charge polarization (or Maxwell-Wagner-Sillars effect) and intrinsic electric dipole polarization. It is observed that all the composites show similar behaviour which is the characteristic of disordered materials; this is attributed to the variation in distribution of In₂O₃ particles in
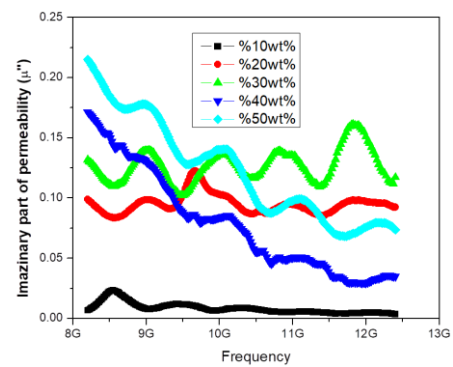
the polymer matrix. Lattice polarization around a charge in localized state may be responsible for variation of conductivity in PPY, Pure PPY is very light with poor compactness since micro particles are randomly oriented and the linkage among the polymer particles is very weak, resulting in relatively lower conductivity. But, the presence of In₂O₃ nanoparticles in the composites helps the formation of granular shaped particles, which leads to an increase in the compactness. As the weight percentage of In₂O₃ in the composites increases, the change in the compactness becomes more significant due to the encapsulation of polymer on the salt. This ultimately leads to an increase in conductivity of the composites.[27]

4.8. Permeability studies

The imaginary parts of the complex permeability of PPy/In₂O₃ nanocomposite samples measured in the frequency range from 8 to 13 GHz are shown in Fig. 9. The imaginary part exhibits two resonance peaks at different frequencies.

The permeability comes from the cooperative effect of the domain wall resonance and spin rotational resonance of the nanoparticles. It was found that the value of the composites decreased with the increasing weight percentage of polymer. The decreased permeability of magnetic materials is frequently observed when they were coated or embedded by nonmagnetic material, which can be attributed to the reduction of saturation magnetization after combination with nonmagnetic materials.
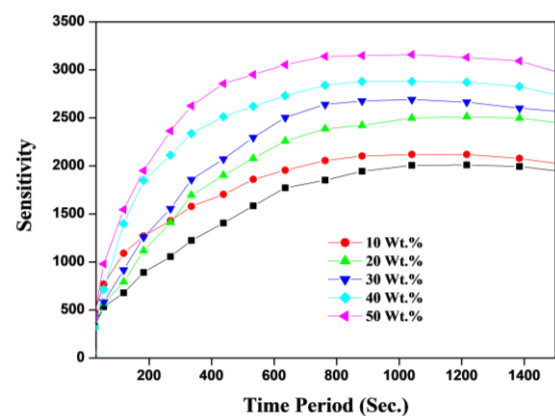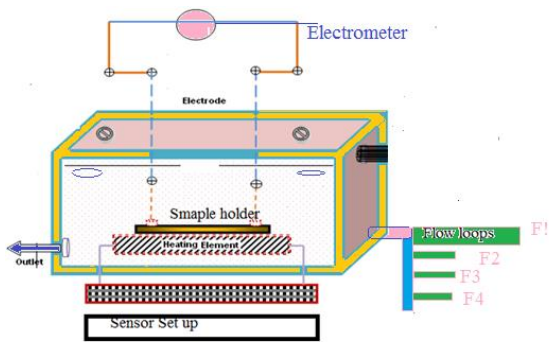

Fig. 10. The Sensitivity study of PPy and Polypyrrole/In₂O₃ nanocomposite.

Scheme 1. Schematic representation of design of gas sensor.

Table 2. The calculated saturation magnetization, remnant induction and coercive field of Polypyrrole/In_2O_3 nanocomposites at different wt% ratio.

Wt. %of Polypyrrole – In_2O_3	Ms. (emu/g)	Mr.(emu /g)	Hc. (Oe)
10wt%	07	02	22
20wt%	14	05	30
30wt%	26	14	63
40wt%	40	22	74
50w%	91	42	126

4.9. Sensor Application Studies

Fig. 10 shows the variation of sensitivity with time for PPy, Polypyrrole/In_2O_3 nanocomposites containing: 10wt%, 20wt%, 30wt%, 40wt% 50wt% In_2O_3 nanoparticles concentration. The sensitivity of the nanocomposites was measured at room temperature when exposed to LPG vapours. The sensitivity of all Polypyrrole/In_2O_3 nanocomposite samples increased with increasing the weight percentage of In_2O_3 nanoparticle and the reasons for the increase in sensitivity may be the increase in In_2O_3 adsorption capacity of the contact zone between the charged particles of PPy and In_2O_3 nanoparticles.

The increasing sensitivity at higher weight percentage may be due to high surface area with possible reaction sites of the nanocomposites due to adsorption of gas molecules. The gas sensing mechanism of nano based LPG sensor is a surface controlled phenomenon i.e., it is based on the surface area of the nanoparticles at which the LPG molecules adsorbs and reacts with pre-adsorbed oxygen molecules. It is found that the large specific area contributes to the oxygen and LPG adsorption on the surface of the materials, which is responsible for the increase insensitivity of the sensor. The gas sensing mechanism in Polypyrrole/In_2O_3 nanocomposites is expected mainly because of two reasons. First the trapping of LPG molecules in between the Polypyrrole/In_2O_3 nanocomposites islands by electrostatic forces and second is a surface controlled phenomenon i.e., it is based on the change in surface resistance of the nanocomposites at which the LPG adsorb and reacts with pre-adsorbed oxygen molecules.[15,16] The Polypyrrole/In_2O_3 nanocomposites pellet is more porous due to the distribution In_2O_3 particles in the mesoporous structure (as observed from SEM). Therefore, the oxygen chemisorptions centers viz., oxygen vacancies, localized donor and acceptor states and other defects are formed on the surface during synthesis. These centers are filled by adsorbing oxygen from atmospheric air. When the nanocomposites is placed inside the gas sensing setup, after some time equilibrium is established between oxygen adsorbed at the surface of sensing element and atmospheric oxygen through the chemisorptions at room temperature. The stabilized resistance at this state is known as resistance in the presence of air (R_a). The electron transfer from the conduction band to the chemisorbed oxygen results in the decrease of electron concentration at the surface of the sample. As a consequence, a decrease in the resistance of the pellet is observed. In LPG, the reducing hydrogen species are bound to carbon, therefore, LPG dissociates less easily into the reactive reducing components on the surface of the samples.[28-29]

4.10. Design of Gas sensor setup

The sensor setup was consists of rectangular glass box of dimension of 6 x 8 x 18 inches with a total volume of 14,158 cm^3 as shown in scheme 1. The flow loops F1, F2, F3 and F4 refer to flow meter used to introduce different test gases into the chamber through the gas balloon, where in test gases mixes. The chamber is provided with a heating element to increase the temperature of the sample but in the present study only room temperature measurement has been carried out. The change in electrical resistance was recorded by two probe method using Keithley–6514 electrometer.

4.10.1. Magnetic properties

In the present work, we have prepared Polypyrrole/In_2O_3 nanocomposite. By using In-situ polymerization method and these samples with the lowest crystallite size exhibited relatively high saturation magnetization, generally the magnitude of saturation magnetization of Polymer nanocomposites is dependent on various factors such as the preparation techniques, doping concentration and annealing temperature of the nanoparticles. The observed variation in coercivity is ascribed to the change in anisotropy. In memory storage devices, coercive field is important for the writing and overwriting of tap media, together with long-term thermal stability of materials. From magnetic hysteresis measurement in the range H = ± 10 kOe it is observed that pure In_2O_3 nanoparticles exhibit a saturation magnetization (Ms) at room temperature is found 80.34 emu/g, remnant induction Mr=76.23 emu/g and coercive field Hc=1285.95Oe. But in the case of Polypyrrole–In_2O_3 nanocomposite the values of (Ms, Mr, Hc) are shown in the table 2. It can be seen that the loosely packed particles as well as the particles do not show any resolvable coercivity, but on the other hand, these particles doped in a PPy matrix show a significant difference with an opening up of hysteresis with coercivity.[30]

5. Conclusions

Polypyrrole/In_2O_3 nanocomposites of various weight percentages were synthesized by solution casting method. X-ray diffraction studies show the retention of In_2O_3 in polymer matrix. Fourier transform infrared spectroscopy (FTIR) confirmed the formation of complexation between PPy-In_2O_3 nanocomposites and the SEM image revealed the presence of In_2O_3 particles which are uniformly distributed throughout the composite. The electrical conductivity was increased along with the nano concentration and the maximum

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conductivity was observed in 50wt% of In_2O_3 in PPy. The magnetic properties of Polypyrrole/In_2O_3 nanocomposite are larger at 50wt% and decreases with decreasing the concentration of In_2O_3 nanoparticles in PPy composite. The Sensitivity of Polypyrrole/In_2O_3 nanocomposite was increased gradually as the In_2O_3 content increases in PPy matrix. Hence the Polypyrrole/In_2O_3 nanocomposites are promising materials for storage and gas sensing devise applications.

Acknowledgements

Conflicts of Interest

The authors declare no conflict of interest.

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