HUMIDITY SENSOR USING POLYANILINE-METAL OXIDE COMPOSITES

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Abstract

This paper presents sensing characteristics of pure Polyaniline as well as Polyaniline-metal oxide nanocomposites. Polyaniline is an excellent polymer for making sensors as it can be easily synthesized and has long stability. Here Polyaniline is formed by oxidative polymerization of its monomer.Polyaniline is then mixed with different proportions of Al_2O_3 and Fe_2O_3. Pellets of organic-inorganic nanocomposites thus formed are found to detect change in humidity as they show variation in their electrical resistance with variation in relative humidity of the ambient-atmosphere. The results are presented here for a wide range of humidity variation. The resistance falls from GΩ to MΩ as %RH increases from 25 to 90%.The morphological and FTIR study of the composites has also been done. The FTIR spectra have been recorded in the region 4000-400 cm^{-1} showing characteristic polyaniline bands between 750–1800 cm^{-1}. The FTIR spectra show a shift in the bands as the metal oxide percentage is decreased in the composites (from 50 to 10%). The peaks for polyaniline with 50% Al_2O_3 were recorded in 400 cm^{-1} to 3400 cm^{-1} range whereas for composites with 10% Al_2O_3 were in 400 cm^{-1} to 2400 cm^{-1} range. SEM shows crystal like structure over a spongy base thereby increasing the surface area of the pellets. The increased surface area is useful for adsorption of gases and vapours for their detection.

***Keywords**: Polyaniline, FTIR, SEM, Humidity sensor*

1. Introduction

Technological developments in the recent decades have brought along with it several environmental problems and human safety issues to the fore. Humidity, the concentration of water molecules in air, affects various materials used in daily life and industrial processing of drugs, beverages, food, electronic goods etc. High and low humidity affects human beings adversely. Excessively high humidity causes corrosion in metallic components. Therefore, humidity is an important measure in the control of electronic goods production. Recently, there have been increased demands for humidity sensing elements for use in automatic humidity control systems. Conductivity of polyaniline can be varied over a broad range and hence, it has a wide use in making sensors [1]. It can be synthesized easily and has long stability.

2. Experimental

There are two major polymerization approaches to synthesize polyaniline: electro-polymerization and chemical polymerization. In the present work, the chemical polymerization technique has been employed. The synthesis of polyaniline was done by oxidative polymerization with ammonium peroxysulphate. Aniline hydrochloride and ammonium peroxysulphate solutions are first kept for 1 hour separately, then mixed and briefly stirred and left for polymerization for 24 hours. As a result green colored precipitate of polyaniline is formed which is then washed and dried. Fe_2O_3 and Al_2O_3 are added in the polyaniline during the polymerization stage in two different proportions i.e. 10% and 50% by weight. Thus, four samples have been prepared for study.

The pellets were prepared with the help of a Hydraulic Press Machine. The thickness and weight of each pellet was measured, which was found to be 0.62mm and 0.127gm respectively.

Morphology of pellet was investigated by scanning electron microscope. The FTIR spectra of the composites were recorded on Perkin-Elmer spectrometer in KBr medium.

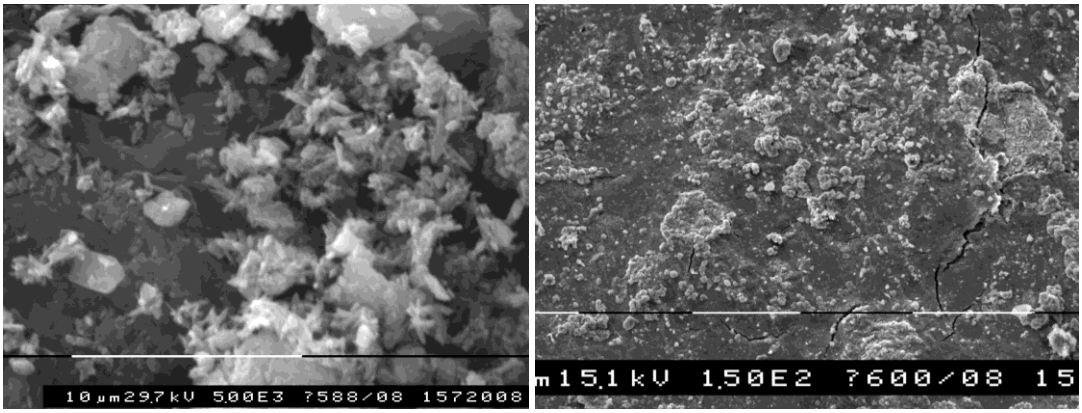
The resistance of the sensor was measured by controlling the humidity in a closed chamber. The humidity was first lowered by keeping $CaCl_2$ in the chamber. Then water vapours were introduced in the chamber with the help of air compressor which was already attached with a flask containing water for increasing humidity inside the chamber from 25 to 90% relative humidity.

3. Results and discussions

a) Characterization

The study of surface morphology of Polyaniline/Fe_2O_3 and Polyaniline/Al_2O_3 pellets has been carried out using SEM (Model No. 430, LEO Cambridge, England).

Scanning electron micrograph of Polyaniline/Fe_2O_3 composites(Figure1) shows homogeneous surface with powdery clusters evenly scattered, thereby, increasing the surface area of the pellet.

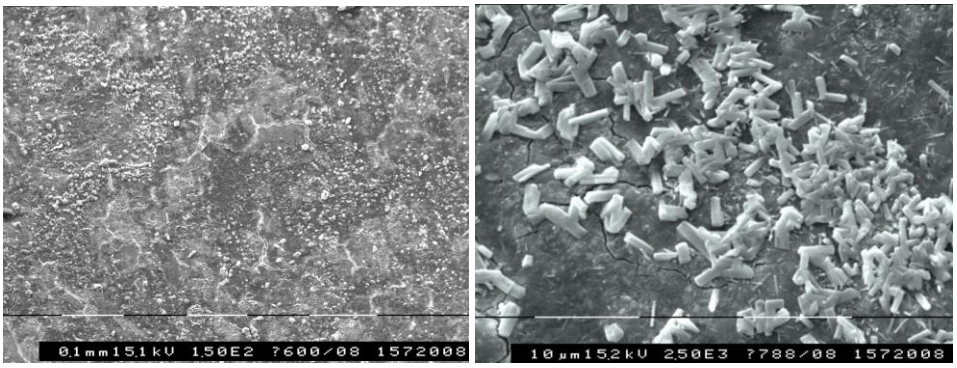


SEM of PANI+50%Fe_2O_3 **SEM of PANI+10%Fe_2O_3**

Figure 1

The scanning electron micrograph shows presence of small powdery clusters which is more significant in case of 50%Fe_2O_3 in comparison to 10%Fe_2O_3.

The Scanning electron micrograph of Polyaniline/Al_2O_3Figure2 shows rod like structure over a spongy base thereby increasing the surface area of the pellet. The increased surface area may be useful for adsorption of gases and vapours for their detection.



(a) (b)

Figure 2 SEM of polyaniline/Al2O3 (50% by wt.) at low magnification (a), at high magnification (b)

The FTIR Transmission spectrum was recorded in KBr medium in the range 450-4000cm^{-1}. The sample showed strong bands in the region 750-1800 cm^{-1} which is characteristic of polyaniline.

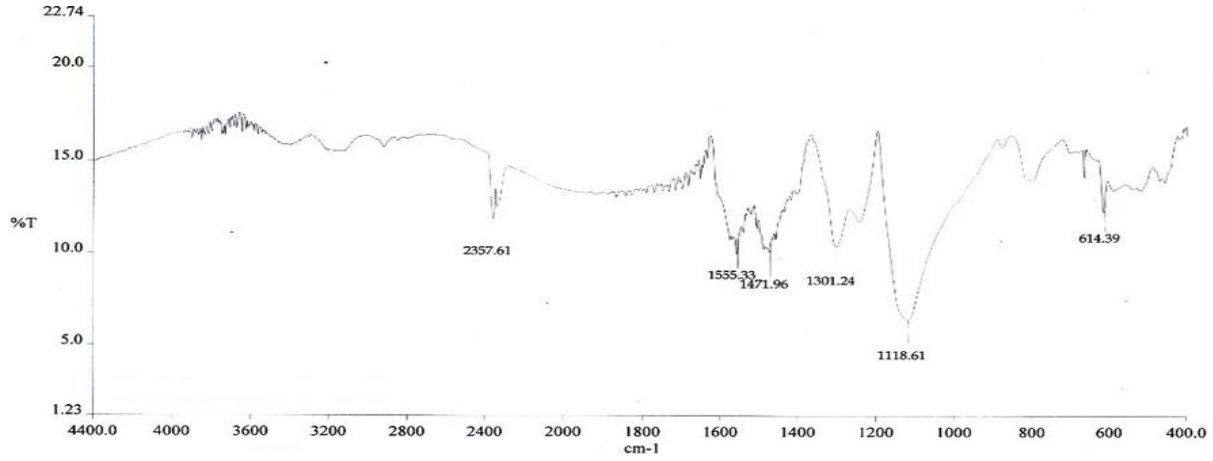


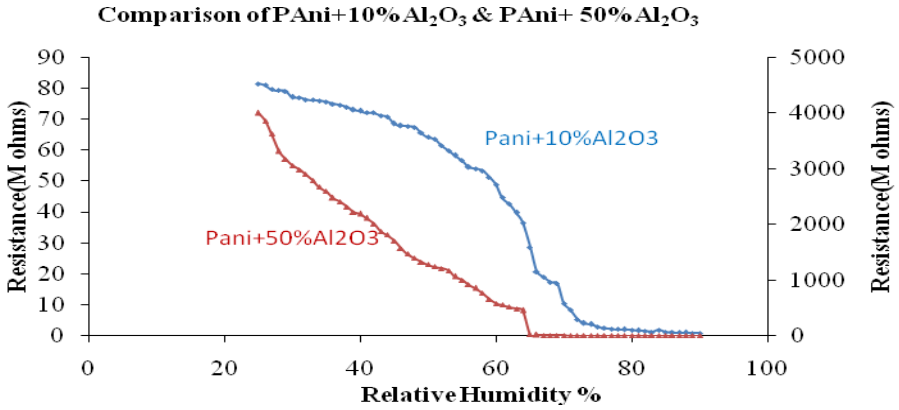
Figure 3 FTIR of PANI/Fe2O3 (50% by wt.)

The FT-IR spectra of the composite exhibited absorption peaks for polyaniline at 1555 cm^{-1} and 1483 cm^{-1} that corresponded to the stretching modes of the quinonoid and benzenoid rings

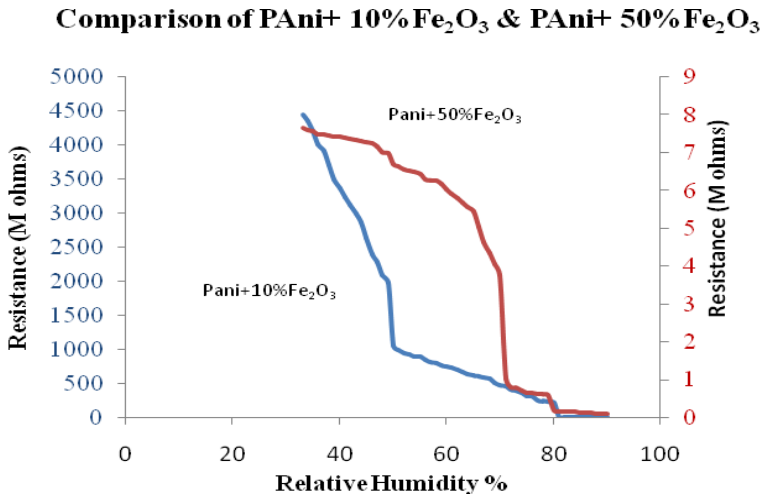
respectively, as well as C-N stretch of aromatic amine at 1301 cm^{-1}. The peaks observed between 400 to 700cm^{-1} correspond to Fe-O bonding in iron oxide. This peak does not appear in the sample with 10%Fe2O3 whereas it appears in case of composite with 50%Fe2O3. Thus, the metal oxygen peak appears with the increase in the percentage of metal oxide.

Humidity sensing

The change in the resistance with relative humidity for these composites was monitored using a laboratory set-up. The resistance of the composite was seen to decrease as the level of relative humidity (%) was increased. Resistance for both the composites of alumina doping decreases as humidity increases from 25 to 90%. In case of 10% doping of Al_2O_3, the resistance of the composite falls from 81.391 to 10.485 Mega ohms almost linearly as relative humidity varies from 25 to 70%, then falling to 0.8741 Mega ohms as relative humidity approaches 90%. In the case of 50% doping of Al_2O_3, the sample exhibits almost linear response in the range of 25 to 66% relative humidity with resistance falling from 3996 to 15.229 Mega ohms and then dropping to 0.2418 Mega ohm at 90% relative humidity.



Resistance for both the composites of iron oxide doping, decreases as humidity increases from 33 to 90%. In case of 10% doping of Fe_2O_3, the resistance of the composite falls from 4.45 to 1.97 Giga ohms almost linearly as relative humidity varies from 33 to 49% , 1056 to 221 Mega ohms as relative humidity varies from 50 to 80 % and then falls to 79.5 Kilo ohms as relative humidity approaches 90%. In the case of 50% doping of Fe_2O_3, the resistance falls from 7.66 Mega ohms to 5.45 mega ohms as relative humidity varies from 33 to 65% and then falls to 89.8 Kilo ohms as relative humidity approaches 90%.



The decrease in resistance with increase in relative humidity is because of adsorption of water molecules by the pellet surface. The reaction of water and polyaniline can be attributed to the fact that there is an exchange of protons between water vapor and polyaniline which helps in conduction by creating pathways for charge transfer [3].

References

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