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Synthesis, characterization and electrical properties of polyaniline/$SrTiO_3$ composites

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ABSTRACT

In the present work, synthesis of Polyaniline (PANI) is carried out by chemical oxidation method by using ammonium persulphate as an oxidant. PANI- SrTiO3 composites were synthesized by using various weight percentages (10, 20, 30, 40 and 50wt %) of SrTiO3 in PANI by insitu polymerization. The composites are characterized by using various techniques such as XRD and SEM. XRD micrographs indicate that SrTiO3 is homogeneously distributed in the PANI. SEM micrograph indicates that PANI / SrTiO3 have many aggregated pores. The Dielectric constant and Dielectric tangent loss are studied by sandwiching the pellets of these composites between the silver electrodes. It is observed that dielectric constant decreases with increasing frequency where as at higher frequencies dielectric constant remains constant. PANI and its composites exhibit small value of dielectric loss at higher frequency. The AC conductivity is studied in the frequency range from 10^2Hz-10^6Hz. From these studies it is found that, AC conductivity remains constant at lower frequency and increase rapidly at higher frequency, which is characteristics behaviour of disordered materials. Hence, this composite finds applications such as sensor devisees.

Key words: Polyaniline (PANI); Polyaniline composites (PANI/ $SrTiO_3$); Transport properties.

INTRODUCTION

Conducting polymers, more commonly known as, synthetic metals possess a striking ability of getting switched ‘on’ and ‘off’. It is possible to switch between conducting and insulating stages by virtue of doping and undoping, which can be attained by applying electric potentials. The novel concept that plastic can be fabricated into wires, films and other accessories carrying electric current is fascinating, if scientists can regulate the electrical, mechanical, and optical properties of these substances. Thus these conducting polymers have tremendous potential for making of many application devices. The studies on these conducting polymers has offered many advantages in today’s industries in the field of synthetic metals because of its versatile applications right from rechargeable storage battery, sensors to artificial muscles[1]. The most consequential application of conductive polymers is the development of sensors for bio-chemical species. A bio-sensor is an analytical tool assembling a biological or biologically derived component. Thus this development of effective sensing devices for industrial process control and environmental monitoring is a fast growing need. Also in recent years, the synthesis and characterization of electro-active polymers have become important research area in Polymer Science[2]. Polyaniline (PANI) is one of the most promising amongst conductive polymers because of inexpensive monomer, ease of synthesis, good environmental stability, moderately high value of dc conductivity and excellent chemical stability in conductive form[3-11]. It can be prepared either by a chemical or an electrochemical oxidative polymerization. The electrical insulator form of polyaniline is the emeraldine base consisting of two amine nitrogen atoms followed by two amine nitrogen atoms. Polyaniline emaraldine base can be converted into a conducting form by two different doping processes: the protonic acid doping and the oxidative doping. Protonic acid doping of emeraldine base corresponds to the protonation of the amine nitrogen atoms in which there is no electron exchange[12]. In the oxidative doping, emeraldine salt is obtained from leucoemeraldine through electron exchanges[13].Organic polymer Ceramic composites have also received a greater attraction in today's industry. The dielectric composites are made up of an active ceramic phase embedded in a passive polymer. The properties of these composites depend on the connectivity of the phases, volume percent of ceramic, and the spatial distribution of the active phase in the composite .The concept of connectivity developed by Neunhham[14] describes the arrangement of the component phases within a composite. Many excellent reviews on the processing and properties of Piezoelectric /polymer composites have been reported in the last few years[14-15].

The present work is thus an investigation of the electrical properties of PANI / $SrTiO_3$ Composites.

EXPERIMENTAL

Material and Synthesis

Ammonium peroxi -di-sulphate and Aniline used were of AR grade. Strontium Titanate ($SrTiO_3$) is commercially procured from Sigma Aldrich. The monomer aniline was synthesized chemically by oxidative polymerization of aniline in an aqueous HCl solution. Aniline (0.1M) was dissolved in 1M aqueous HCl solution before 5°C and an aqueous solution of Ammonium peroxi-disulphate (0.1 M) was added to the above solution over a period of 30 min with vigorous stirring and it is added to polyaniline (PANI) solution in order to keep $SrTiO_3$ suspended in the solution. This process of treatment with the solvents was repeatedly done for three hours. The precipitated was finally obtained after the filtrate was dried in vacuum oven at 60-80°c for 24 h so as to achieve a constant weight. Further, PANI/$SrTiO_3$ composites were prepared in weight percent ratio in which the concentration of $SrTiO_3$ (10, 20,30,40,50 wt %) was varied. The test samples were prepared in the forms of pellets of diameter 10mm and thickness 2mm by applying pressure of 5-6 tones using hydraulic pressure. The pellets thus obtained are coated with silver paste on both the surfaces.

Characterization instruments

The X-ray diffraction patterns were recorded for these materials with CuK± radiation of wavelength »=1.5420 A° in the 2¸ range 8-90º. The powder morphology of polyaniline and its composites sintered in the form of pellets are investigated using Philips XL30 ESEM scanning electron microscope (SEM).

Conductivity measurement

The frequency dependent AC conductivity of PANI and PANI/SrTiO3 composites are studied in the frequency range10^2 Hz-10^6 Hz at room temperature using Hiokie LCR Q meter Japan. The Dielectric constant and Dielectric tangent loss are also studied by sandwiching the pellets of these composites between the silver electrodes and is studied in the frequencies 10^2 Hz-10^6 Hz, using Hiokie LCR Q meter Japan.

RESULTS AND DISCUSSIONS

Figure 1 shows the X-ray diffraction pattern for PANI and PANI/$SrTiO_3$ composite. The XRD diffraction studies of the samples were found that the peaks are broadened and were possible due to the formation of oxide particles. By comparing the XRD patterns of the PANI / $SrTiO_3$ composite, it is confirmed that $SrTiO_3$ has retained its structure even though it is dispersed in PANI during polymerization reaction. The structure of the composite resembles with that of cubic system with a=b=c=3.936AU and a = b =g =90°. Prominent four peaks of PANI/SrTiO3 correspond to (110), (111), (200) and (211). (No. 40-1500, 1997 JCPDS- International Centre for Diffraction Data. PCPDFWIN. V 1.30). The SEM study performed on these samples indicates many aggregated particles and pores that have been reduced due to the homogeneous distribution of strontium titanate in PANI/ $SrTiO_3$ composites as shown in Fig. 2a) and 2b).

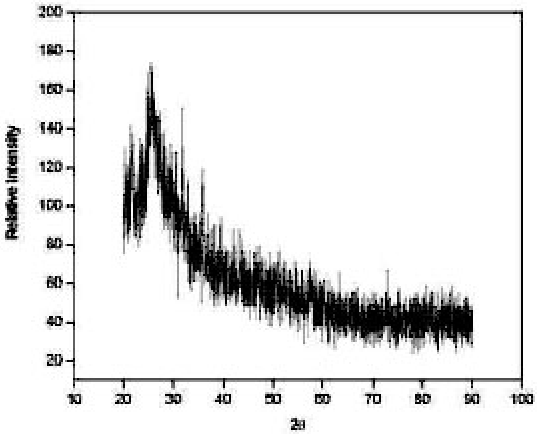

Fig. 1(a): XRD Pattern of pure PANI

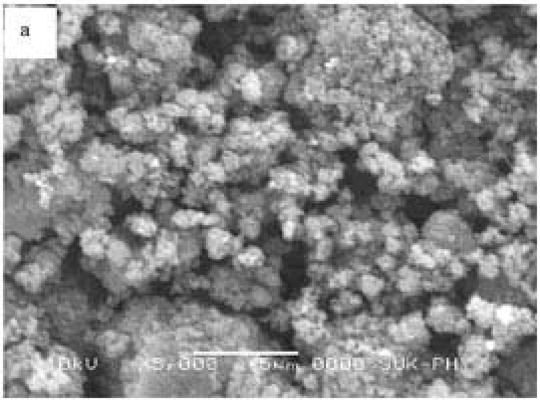

Fig. 2(a): SEM image of PAN

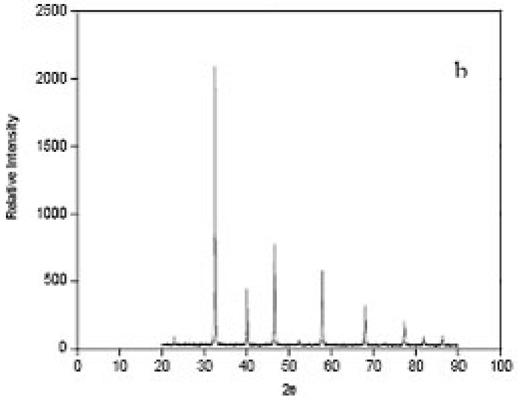

Fig. 1(b): XRD Pattern of pure $SrTiO_3$

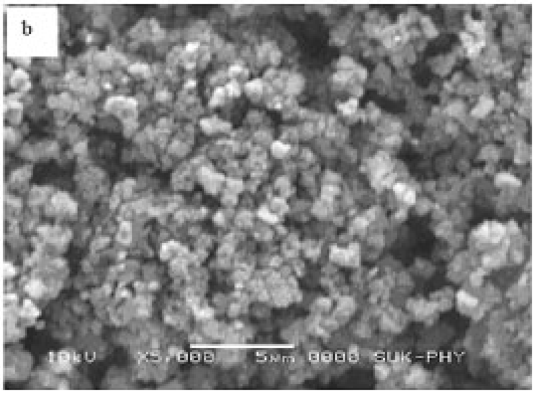

Fig. 2(b): PANI/$SrTiO_3$ (50wt%)

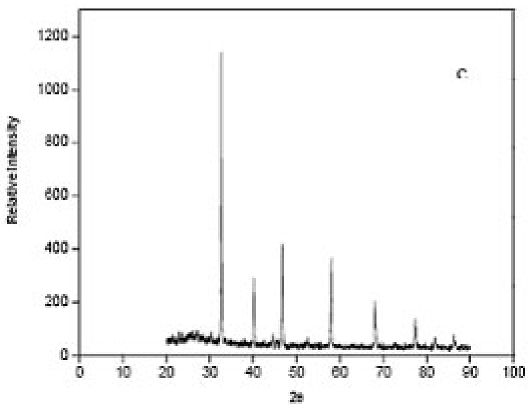

Fig. 1(c): XRD Pattern of pure PANI/$SrTiO_3$ (50wt%)

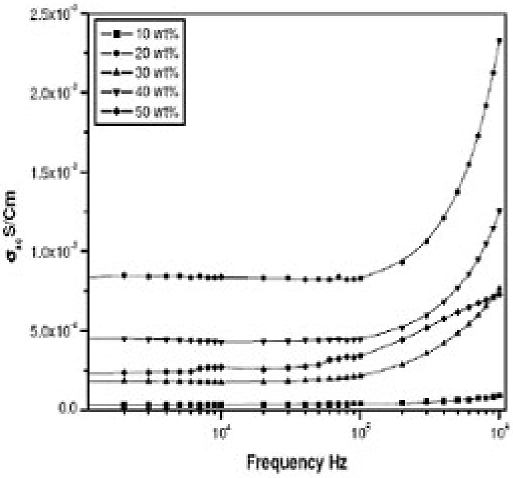

Fig. 3(a): Shows the AC conductivity versus frequency for different weight percentages $SrTiO_3$ in PANI

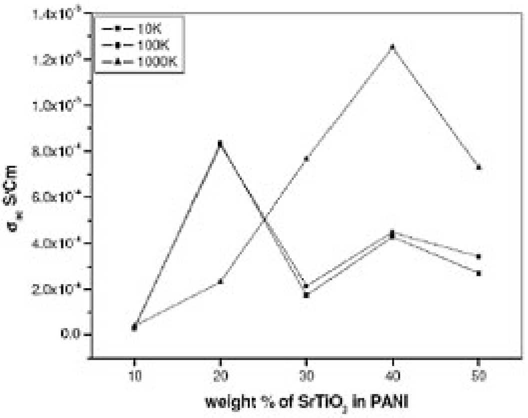

Fig. 3(b): Shows the AC conductivity versus weight percentages of $SrTiO_3$ in PANI for different frequency

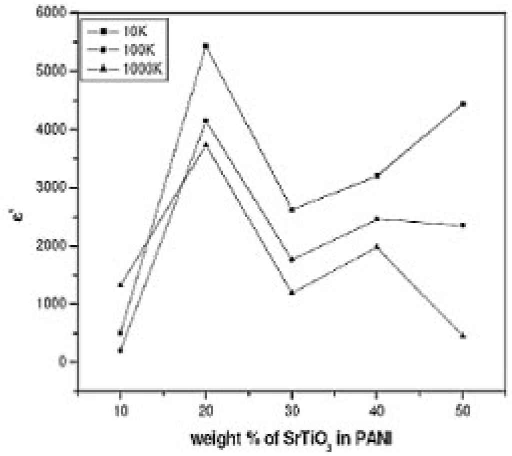

Fig. 4(b): Shows the variation of dielectric constant (e') as function of weight percentage at different frequency

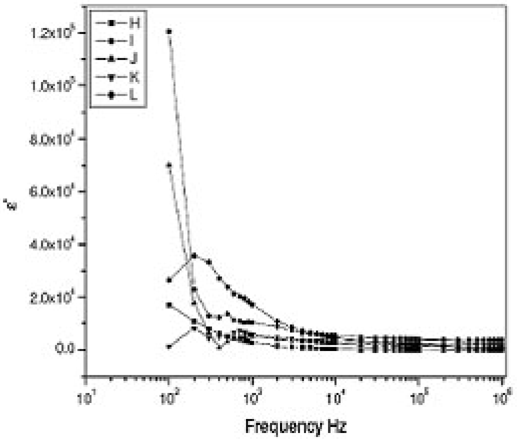

Fig. 4(a): Shows the variation of dielectric constant (ε') as function of frequency

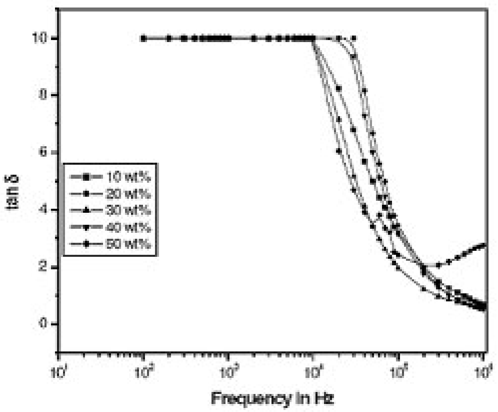

Fig. 5: Shows the variation of tan d as function of frequency for PANI/$SrTiO_3$ composites of different weight percentages

AC Conductivity

Fig 3(a) illustrates the AC Conductivity of PANI/ $SrTiO_3$ composites. It is found that AC conductivity remains constant up to 10^6Hz and there after it increases steeply, which is a characteristics feature of disordered materials. In Fig. 3(b) the values of sac are plotted as a function of different weight percentage of $SrTiO_3$ in PANI at room temperature with different frequencies (10 KHz, 100K Hz and 1000 KHz). It is observed that for all the frequencies, the value of sac is found to increase for 20 wt% and 40 wt%, and decrease for 30 wt% and 50 wt%. The initial increase in the value of sac is due to the extended chain length of PANI, between which the localized charge carriers polarons under going polarization significantly leading to increase in conductivity. As the wt% of $SrTiO_3$ exceeds more than 20 or 40 wt% the partial blocking of polarons takes place, which makes the polarization condition more difficult, as a result, the conductivity decreases.

Dielectric constant

Fig. 4 (a) shows the variation of dielectric constant e' with frequency for different wt% of PANI/ $SrTiO_3$ composite. It is found that dielectric constant decreases as frequency increases. Figure 4 (b) shows the variation of dielectric constant as a function of weight percentage of $SrTiO_3$ in PANI. It is found that the dielectric constant increases for 20wt% and 40 wt% for all the frequencies (10, 100 and 1000 KHz). This means that at higher frequencies they behave as dielectric materials. The dielectric tangent loss (tand) as a function of frequency for PANI and PANI/$SrTiO_3$ is shown in Figure 5 for the different wt%. It is observed that the dielectric loss decreases as a function of frequency. PANI and PANI/ $SrTiO_3$ exhibit small value of dielectric loss at higher frequencies, which suggests that these materials are lossless materials beyond 10^6 Hz. The observed behaviour is consistent with the conductivity and dielectric constant results in these composites.

CONCLUSION

The efforts have been made to synthesize Polyaniline /$SrTiO_3$ composite to tailor these properties. Detail characterizations of the composites were carried out using XRD and SEM techniques. The result of AC conductivity and dielectric constant shows a strong dependence on weight percentage of $SrTiO_3$ in PANI.

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