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Surface Resistivity and EMI Shielding Effectiveness of Polyaniline Coated Polyester Fabric

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ABSTRACT

In this study electrically conductive polyester fabrics were prepared by using conductive polyaniline polymer. The conductive fabrics were prepared by in-situ chemical oxidative polymerization of aniline using ammonium persulphate as the oxidant by a process of diffusion polymerization in a mixed bath.

These fabrics were characterized by ATR-FTIR, WAXD, SEM, DSC and two-probe conductivity. The evaluation of electromagnetic shielding effectiveness of the polyaniline treated fabrics was carried out using Agilent E5061A/E5062A ENA series RF network analyzer. The structural studies show that the crystalline region of fabric structure is not affected by the polyaniline and the interaction of polyaniline molecules with fabric molecules. The SEM studies reveal a very uniform deposition of polyaniline molecules on the fabrics. The thermal studies show that the PANI-treated fabrics have better thermal stability. The conductivity studies show that the treated fabrics have good electrical conductivity with the resistance value of 5 K ohm/sq. The EMI Shielding tests show that polyaniline treated polyester fabric has the Electromagnetic Interference value of -2.78 dB and which makes it a promising candidate for EMI Shielding and Anti-static discharge matrix for the encapsulation of the micro-electronic devices.

Keywords: conductive fabrics, insitu-polymerization, polyaniline, surface resistance

I. INTRODUCTION

With the advent of electrical and electronic devices worldwide, electromagnetic interference among the appliances is one of the major problems to be resolved. Various researches and industrial companies have shown keen interest in providing solutions to overcome this problem. Among the various solutions offered, textile products have caught the attention of researchers owing to their versatility and conformability to different structures. Conductive fabrics based on incorporation of metals (such as copper, stainless steel, and aluminum), electroplating of metal on the fabric and deposition of conducting polymers have been widely used for electromagnetic shielding. The incorporation of metal wires and electroplating of metal is likely to affect the pliability of material and moreover corrosion of these metals in hostile environments is likely to hamper their shielding properties.

The deposition of conducting polymers such as polyaniline, polypyrrole, and polythiophene on textile fabrics is likely to overcome the disadvantages mentioned above. Among the various classes of conductive polymers, polyaniline has attracted great attention as a conducting material due to its ease in synthesis, low cost and good environmental stability. Polyaniline can be coated on various substrates like plastics, glass and ceramic materials and it can also be coated on the surface of the textile materials by chemical or electrochemical method .The electrical conductivity of polyaniline coated fabric is higher than the other conventional textile fabrics and lower than the metal coated fabrics [1-4].

A Das et al reported there are some effects of type of material, yarn count, type of moderant and number of layers of fabrics on the electromagnetic shielding properties of textile materials [5].Dhawan et al reported that fabrics coated with PANi had -3 to -11 dB of electromagnetic shielding efficiency in the frequency range 8-12 GHz [9]. In their other study, these authors determined that the shielding efficiency values of silica and polyester fabrics coated with PANi were 35 and 21 dB at 101 GHz ,respectively [10].

In our study, the 100% polyester fabrics are coated with polyaniline with the chemical oxidative in-situ polymerization method. After the production process, the treated fabrics were characterized by ATR-FTIR, WAXD, SEM, and DSC. Moreover the electrical resistivity and EMI Shielding efficiency measurements of the fabric samples were carried out.

II. EXPERIMENTAL

A. MATERIALS

Commercially available 100% Plain woven polyester fabric having GSM 86 was used. Aniline, concentrated HCl, and ammonium persulfate (APS), all A.R. grades were purchased from S.D. Fine Chemicals Ltd., India and used as a monomer, dopant and oxidizing agent respectively, to coat conductive polymers on the fabric surface.

B. METHODS

I. PREPARING CONDUCTIVE FABRICS

Conductive fabrics were developed by in-situ chemical polymerization of aniline on polyester fabric. In this process, freshly distilled 0.5M aniline was dissolved in the bath containing 0.35N HCL solution for diffusion. A vigorous stir was given to the bath containing mixtures of aniline and aqueous acid to attain the homogeneous mixing. The dry pre-weight fabric sample was placed in the above solution at 40°c and allowed for 2 hours to soak well with the monomer and dopant solution. 0.25M ammonium per sulfate was separately dissolved in 0.35N HCL solution for polymerization. The aqueous oxidizing agent in the separate bath was then slowly added in to the diffusion bath to initiate the polymerization reaction. The oxidant to aniline ratio was kept at around 1.25 .The whole polymerization reaction was carried out at 5°c for 1hour. After completing the polymerization process, the polyaniline coated fabric was taken out and washed in distilled water containing 0.35N HCL and dried at 60 °c in the oven [1-4].

II. CHARACTERIZATION METHODS

The infrared absorption spectra of the various samples were recorded in the range of 400- 4000 cm^{-1} using a SHIMADZU FTIR spectrophotometer, at a resolution of 2 $cm^{-1}$with background correction for 350 scans in the ATR mode. The XRD patterns were recorded by SHIMADU XRD -6000 X-ray diffractometer unit.

The SEM images were recorded by JEOL SEM model JSM -6360 to study the surface morphology of these samples in the longitudinal view. The resistivity of the samples was measured using a standard two-probe resistivity apparatus. The thermal studies of the polyaniline coated fabrics were made with a Perkin Elmer differential scanning calorimeter model DSC 7. The evaluation of Electromagnetic Shielding

Effectiveness of textile fabrics was carried out using Agilent E 5061 A5062A/E 5062A ENA series RF network analyzer.

III. RESULTS AND DISCUSSION

A. SEM STUDIES

The surface views of SEM micrographs of the control polyester and polyester+PANi are shown in figure 1. Just a glance at the fabrics with the naked eye shows a uniform color (in this case, green), suggesting that PANI has penetrated into the fabric. However, the SEM studies reveal how evenly the surface has been coated and the depth of penetration [2].

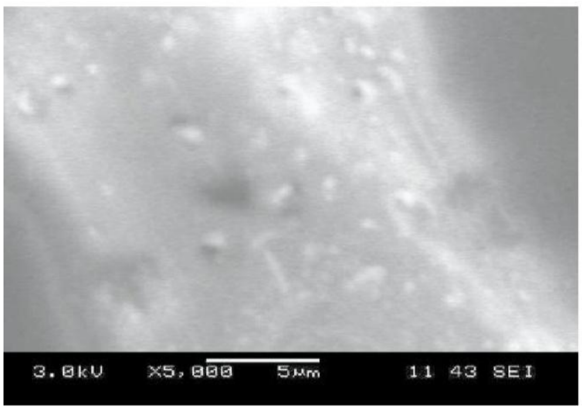


Fig 1(a). Control polyester fabric

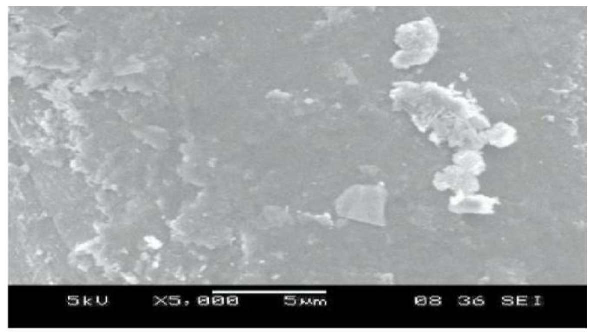


Fig 1(b). Polyester+Pani Fabric

From these SEM studies, it is clear that the PANI particles are very evenly deposited on the fabric, and are seen as small globules. The surface studies clearly reveal uniform distribution even at the microscopic level, which is necessary for the reproducibility and reliability of applications. The diffusion and polymerization of aniline in the fabric was evident at the macroscopic level in terms of the increased thickness of the fabric (from0.195 to 0.2 mm).

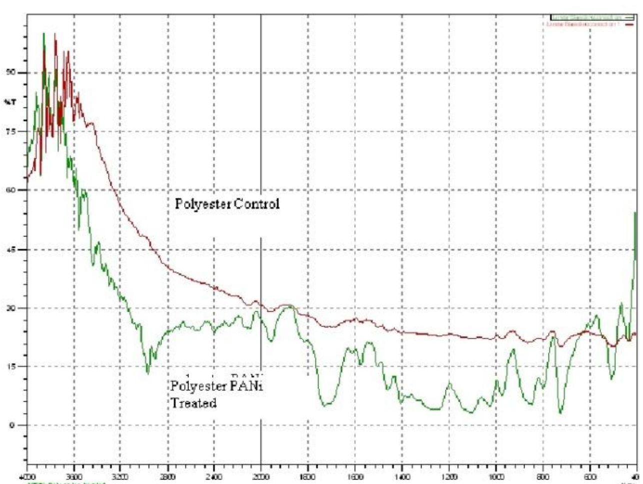


Fig 2. FTIR Pattern of polyester control and treated fabric

B. ATR-FTIR ANALYSIS

The figure.2 shows ATR-FTIR spectra of control polyester and polyester +PANi fabric. The band at 3437 cm^{-1} for the fabric coated with PANi was attributed to OH stretching. The bands at 1813, 1732 and 1705 cm^{-1}were attributed to C=O stretching (carboxyl group).The bands at 1464, 1504 and 1576 cm^{-1} were attributed to benzene ring, CH out of plane vibrations. Hence we deduced that PANi was attached to polyester fabric [4, 7].

C. WAXD ANALYSIS

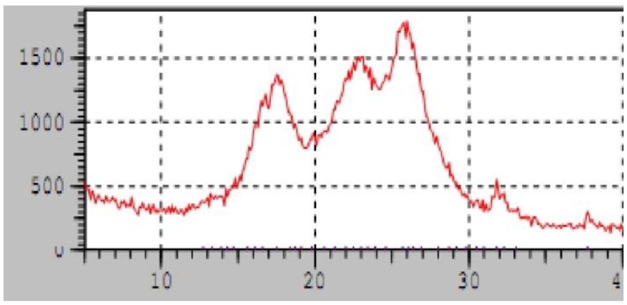


Fig 3(a). XRD pattern of polyester control fabric

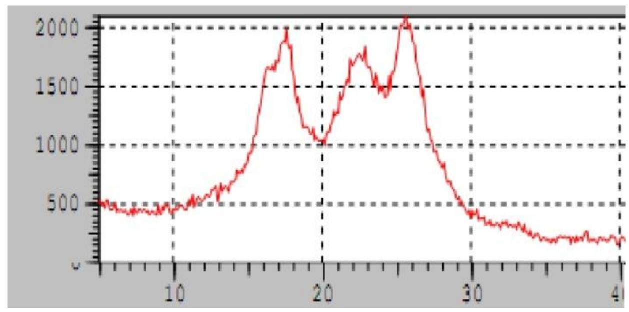


Fig 3(b). XRD Pattern of polyaniline treated polyester fabric

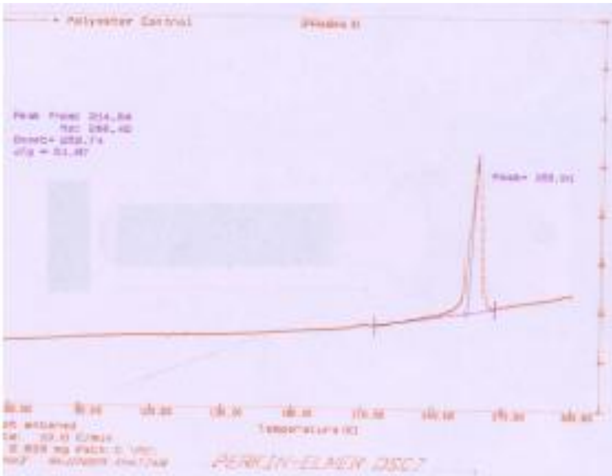
The patterns for the control polyester and the polyester+PANi fabrics are shown in fig 3(a) & 3(b). The X-ray diffraction pattern of the control polyester fabric contained maxima at 2Ǿ values of 17.5,23 and 25.7. The peak maxima of PANi –polyester fabrics located at 2Ǿ =17.32, 22.6 and 25.7. The 2Ǿ values were slightly decreased in PANi-polyester fabric. It indicates the reaction of polyaniline on polyester fabric [1, 2, 3].

D. THERMAL STUDIES

The thermograms of the control and polyaniline treated polyester fabrics are shown in fig 4.The thermal properties of both the control and polyaniline treated polyester fabrics were analyzed and compared in table 1. The heat of fusion and degree of crystallinity of PANi-polyester fabric were slightly higher temperature. The overall results indicate that the crystal structures of polyester in the PANi-polyester composite fabrics are improved by the presence of polyaniline [1, 2].

Table 1. Thermal properties of PANi treated and untreated fabrics

Fabric sample	Melt on set temperature	Melt peak temperature	Enthalpy	Percent Crystallinity
Polyester control	253.74	258.91	51.87	17.7
Polyester treated	251.89	259.64	55.81	19.05



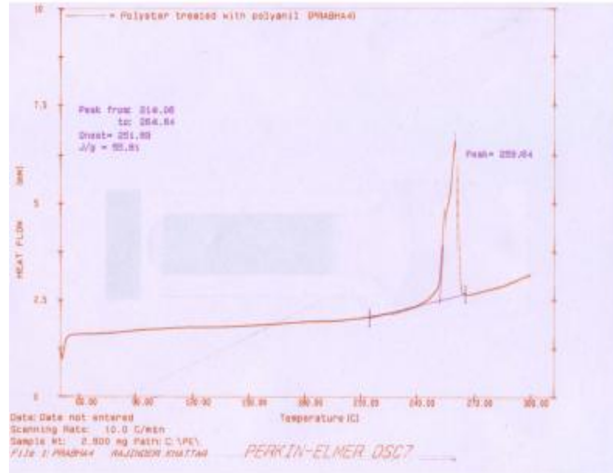


Fig 4. DSC thermograms of polyester control and polyaniline treated fabric

E. SURFACE RESISTIVITY AND EMI SHIELDING EFFECTIVENESS STUDIES

We studied the electrical resistivity of the samples by two probe resistivity measurement in a normal environment at 65% RH . The conductivity studies show that the treated fabrics have good electrical conductivity with the resistance value of 5 K ohm/sq.

EMI SE of polyaniline treated polyester fabric was measured as per the ASTM D4935 standards using Agilent E5061 A/E 5062A ENA series of RF network analyzer. EMI SE was studied with electro-magnetic waves having frequency in the range of 8-12 GHZ. The tests were carried out to measure the electromagnetic shielding effectiveness in terms of S11 (reflected/incident) and S21 (transmitted /incident) values. The actual shielding effectiveness is only transmitted /incident values (i.e. primarily S21 values), [5-6] and polyaniline treated polyester fabric has the S21value of -2.78 dB and which makes it a promising candidate for EMI Shielding and Antistatic discharge matrix for the encapsulation of the micro-electronic devices

IV. CONCLUSIONS

Preparing conductive fabrics by the DPMB process is possible due to in-situ polymerization of the aniline monomer by an oxidative polymerization reaction at low temperatures. The diffusion of aniline monomers on to the fabrics is taking place at room temperature and subsequent polymerization is possible even at low temperatures. From the structural studies, we can conclude that the fabric structures are not affected, and the fabric molecules interact with the PANI molecules. SEM studies reveal a very uniform and dense deposition of the PANI molecules. The thermal studies show that the PANi impregnated fabrics have better thermal stability.

The conductivity studies clearly show that the conduction mechanism is that of the virgin conducting polymer and the fabrics can be used for heating pads and carpets. The EMI Shielding tests show that the polyester fabrics have the Electromagnetic Interference value of -2.78 dB respectively and which makes it a promising candidate for EMI Shielding and Antistatic discharge matrix for the encapsulation of the microelectronic devices.

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