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Electromagnetic shielding behavior of Conductive Polypyrrole Coated Cotton Composite

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Abstracts

Polypyrrole (PPy) is an electrically conductive organic material perspective for application in the field of electromagnetic interference shielding (EMI). In situ polymerization was employed to deposit polypyrrole on the cotton fabrics by using ferric chloride as oxidizing as well as doping agent. The conductive cotton fabric deserves the high electrical conductivity, and was effective in electromagnetic shielding application by surface reflection and transmission.

Keywords: conductive fabrics, polypyrrole, EMI

Introduction

In recent years intrinsically conductive polymers (ICPs) have been investigated widely because of their excellent electrical and optical properties and many potential applications [1]. Among them polypyrrole (PPy) has attracted much attention because of its high electrical conductivity, comparatively high stability in air with low toxicity, ease of preparation and simplicity of the doping process [2]. Textile substrates have many advantages like, high surface to mass ratios, good mechanical performance, resistance to chemicals and harsh environmental conditions, flexibility, and ability to be shaped in various forms and formability to fit end user requirements. Polypyrrole coated fabrics used in electromagnetic shielding insulation, microwave absorbance, heat generation, etc. due to the combination of both the mechanical properties of the flexible fabrics and the electrical, microwave properties and biocompatibility of the PPy coatings [3].

Oxidation of pyrrole causes polymerization to takes place on the fabric substrate which gives the continuous thin conducting film and current will flow through these fabrics without incorporation of any wiring through them. The continuous conductive film also produces a more even flow of heat than that of fabrics containing wires [4]. The absence of wires also allows for a thin, flexible construction, if tactile properties are important, for instance in a heated seat, the use of conducting fabric necessitates no additional cushioning. Regardless of conductive material, textiles are particularly well suited for large area radiant or contact heating. Hence it gives rise to fast, even heating over the entire surface and also improves reliability, since a tear in any area will not disrupt the current [5].

Considering these advantages, there are many applications where a conducting fabric, such as car seats, mattress pads, heating winter sports wear, gloves, blankets and clothing could be easily be made to provide warmth simply by including a piece of conducting fabric in the construction and providing a power source. This type of smart and electro-active fabrics are mostly used for the protective purpose such as military, sports, and medical, etc. Materials with conductivity and electromagnetic screening capabilities are widely used to attenuate the strength of electromagnetic fields in certain area. Textiles are intrinsically non-EMI shielding materials and are rather insulating materials; however, they can successfully turn to be EMI shielding materials after raw-material changes, new production process or process adaptations that can make them electrically conductive (6). The present attempt has been made to prepared conductive cotton fabrics by Ppy deposition for electromagnetic shielding application.

2 Materials and Methods

2.1Materials

Commercially desized, scoured and bleached 100% cotton fabric having weight of 120 g/m^2, and plain weave was used as textile substrate. AR grade chemicals such as pyrrole (Spectrochem, India) as monomer and ferric chloride anhydrous (SDFCL, India) as oxidant were used to develop in situ Ppy. The monomer to oxidant molar ratio was used 1:1, with the 0.3M of concentrations of pyrrole and ferric chloride.

2.2Methods

2.2.1 Polymerization of pyrrole

The solutions of 0.3M Pyrrole and 0.3M Ferric chloride of desired concentrations were prepared separately, each in 50 ml distilled water. The cotton fabric was treated with $FeCl_3$ solution for 30 minutes. Thereafter, polymerization was initiated by the drop wise addition of pyrrole solution in the same bath with continuous stirring for 4h at the 4°C temperature. After the completion of treatment fabric samples were removed, washed thoroughly with distilled water and air dried.

2.2.2 SEM Imaging

Scanning electron microscopy-imaging was carried out using a EVO 50 microscope for surface characterization of PPy deposited cotton fabric.

2.2.3 Measurement of surface Resistance

The resistance of Ppy coated cotton fabric samples was measured by Digital multimeter Mic 6000Z. From these resistance values, the resistivity and conductivity of the Ppy-cotton composites was calculated. The conductivity of the resulted composites was expressed in S/cm. The conductivity was computed according to following equation.

$$\rho = \frac{R.t.b}{l}$$

$$\sigma = \frac{1}{\rho}$$

Where, ρ and σ is the resistivity and conductivity of Ppy cotton composites. R, t, b and l be the resistance reading, thickness, width and length of Ppy cotton composite fabrics.

2.2.4 Measurement of Electromagnetic shielding

The measurement of electromagnetic shielding is basically measurement of attenuation and reflection of the sample. The sample is placed in holder (WR-284 waveguide flange) of size 76.14X38.03 mm. The sampler holder flange is placed in the WR-284 waveguide to co-axial adaptor. The Vector Network Analyser (VNA) is calibrated for the frequency range of 2 to 4 GHz. The s-Parameters were measured with using HPE8363B model (Vector Network Analyzer) in coaxial mode. EMI shielding parameters of as-prepared sample was recorded with dimension ~3.00mm (inner), ~7.00mm (outer) with the thickness is about 2.4 mm.

3. Results and Discussion

3.1 Morphological Studies

The SEM images of untreated cotton fabric and Ppy in situ treated sample with 0.2M pyrrole and 1:1 ratio of monomer and oxidant are as shown in fig No. 1 under 5,000 x magnifications. SEM Image (1b) shows a clear surface and deposition of polypyrrole on the cotton fibers. The polymerization of polypyrrole on cotton fabrics takes place through diffusion of polymer inside the fiber bulk as well as the deposition on the fiber surface and the interstices in the fabric [7].

Fig 1: SEM micrographs at 5000x magnification of (a) untreated cotton (b) Polypyrrole deposited cotton fabric

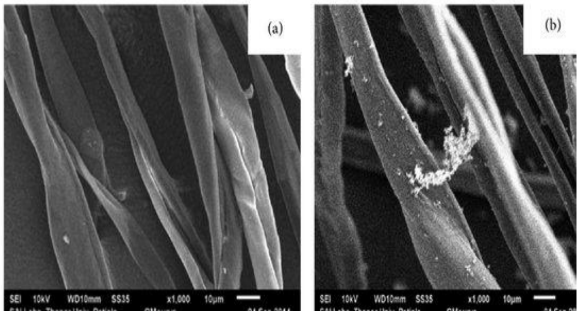


Fig 1: SEM micrographs at 1000x magnification of (a) untreated cotton (b) polypyrrole deposited cotton fabric

3.2 Surface Conductivity

At 1:1 ratio of pyrrole to oxidant, surface conductivity was observed as 0. 28S/cm. Surface resistance was measured on the multimeter before temperature measurement; resistivity and conductivity calculated by the value of the fabric resistance i.e. 230 Ω. Due to the deposition of polypyrrole on cotton fabric gives the conducting layer which enhances the conductivity of conducting cotton fabrics and due to the higher conductivity it improves heating properties of the conducting cotton fabrics.

3.3 EMI Shielding

EMI shielding is the practice of attenuation of electromagnetic radiations by using conductive materials. EMI shielding is based on three processes, (i) reflection (SE_R), (ii) absorption (SE_A) and (iii) transmission (SE_T) at the interface [8]. Mathematically, EMI shielding process expressed as Eq. (1),

$$SE_{Total} = 10 \log \{Pi/Po\} = SE_{A} + SE_R + SE_M \quad (1)$$

Where, P_i is power incident and P_o is power transmitted. The term SE_M is dropped for $SE_{Total} \geq 10$ dB. The individual contribution for SE_R, SE_A and SE_T is given by (Eq. (2), (3) and (4)),

$$SE_R = \left[\frac{1}{1-|S_{11}|^2}\right] \quad (2)$$

$$SE_A = \left[\frac{1-|S_{11}|^2}{|S_{21}|^2}\right] \quad (3)$$

$$SE_T = SE_R + SE_A = 10\log\left[\frac{1}{|S_{21}|^2}\right] \quad (4)$$

Where, S_{11} and S_{21} are the surface reflection coefficients and transmission coefficient of the samples [9].

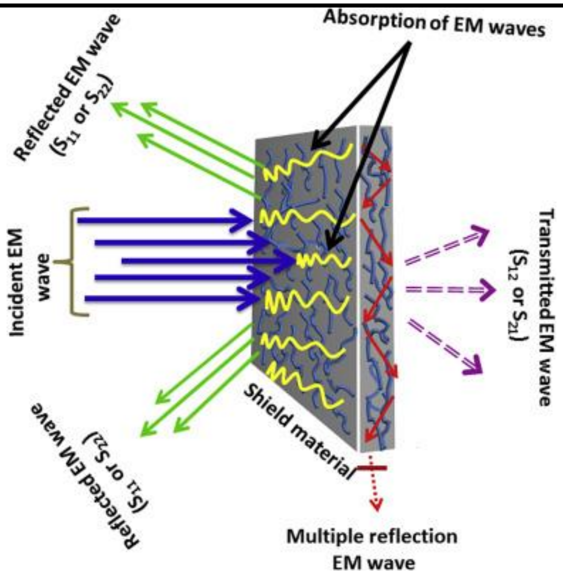
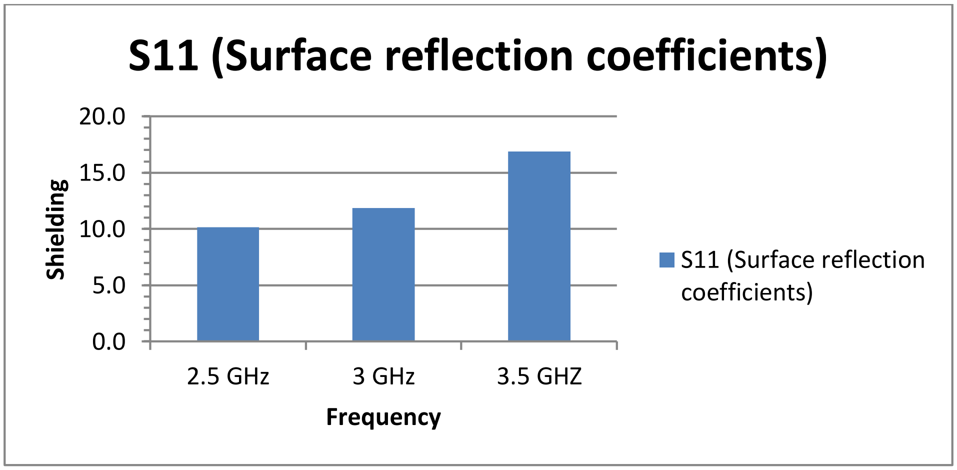
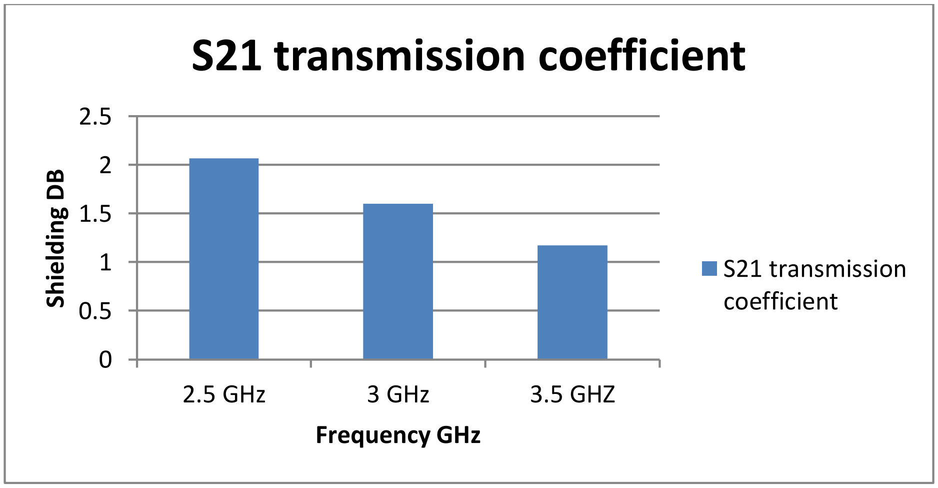


Fig. 2. Schematic of EMI shielding process



Surface reflection coefficients (S_{11}) at different frequency



Transmission coefficient (S_{21}) at different frequency

Conclusion

In conclusion, it is successfully analyzed the EMI shielding properties of Ppy-composites. In EMI shielding, the magnitude of reflection coefficient S_{11} is more than transmission coefficient S_{21}, which makes Ppy composite enable for coating application also to protect electronic devices in space from energetic radiation. Similarly, good SE_R of Ppy composite indicates ability to reflect microwave radiation. The performance of Ppy composite, attributed to various factors such as larger contact surface area due to Ppy, good AC conductivity and smaller skin depth. The surface conductivity was 0.28 S/cm because of oxidative degradation of the conductive polymer which causes loss of conjugation of the polymer.

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