Synthesis and Characterization of Polyaniline/$Co_xCr_{0.5-x}Fe_2O_4$ Nanocomposites for Electromagnetic Interference Shielding

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Abstract. Polyaniline (PANI)/$Co_xCr_{0.5-x}Fe_2O_4$ (x = 0, 0.1, 0.3) nanocomposites with high electromagnetic shielding effectiveness were synthesized via in situ polymerization method. PANI/ $Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3) nanocomposites were characterized by X-ray diffraction, Field emission scanning electron microscopyand Vibrating sample magnetometer techniques. Further, Electromagnetic Interference (EMI) shielding effectiveness (SE) studies have been carried out as a function of frequency at room temperature for PANI/ $Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3)nanocomposites. Conduction mechanisms in PANI/ $Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3) nanocomposites are in accordance with the electron hopping model. Further, SE was found to decrease with an increase in the applied frequency in all the synthesized samples. In the present work SE values for Polyaniline/$Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3) nanocomposites increases with increase in the Copper content in the composite.

INTRODUCTION

All the electronic devices emit electromagnetic (EM) fields at various frequencies. Electromagnetic interference (EMI) occurs when electronic devices are subject to EM radiation from external sources at the same frequency ranges at which these devices operates [1, 2]. Electromagnetic interference (EMI) shielding materials are in demand due to their rapid use of radio or microwave frequencies for satellite-telecommunications, military applications etc. [3]. In order to overcome the electromagnetic interference problems, it is essential to develop electromagnetic shielding materials which restrict the admittance of electromagnetic wave by reflection or absorption[4]. Generally, ferrites have been extensively investigated for distinct electrical and magnetic properties for the applications such as microwave devices, gas sensors, humidity sensors, magnetic tapes and electromagnetic interference (EMI) shielding devices [5]. The polyaniline is a promising EMI shielding material due to its attractive properties like conductivity, adjustable permittivity/permeability, easy synthesis, low density, and non-corrosiveness, good thermal and environmental stability [6-8].Nanocomposite polymeric materials offer several advantages over traditional metals and ceramics used for EMI shielding since they can be easily shaped into a wide variety of morphologies and are substantially lighter [9]. In the present work, Polyaniline/$Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3) nanocomposites were synthesized by in situ polymerization of Aniline monomer with $Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3) nanoparticles. Structural, magnetic and electromagnetic shielding studies have been undertaken on the synthesized composites.

EXPERIMENTAL

PANI/ $Co_xCr_{0.5-x}Fe_2O_4$ (x=0, 0.1, 0.3) nanocomposites were synthesized by in situ polymerization method. (50wt%) $Co_xCr_{0.5-x}Fe_2O_4$ (x=0, 0.1, 0.3) nanoparticles with respect to aniline monomer was suspended in a 1 M HCl solution and stirred for half an hour to get well dispersed. To the above suspension 2mL aniline monomer is added and stirred for 30 min. 1M HCl solution containing 4.98 g ammonium per sulfate (APS) was then added drop wise to the suspension mixture with a constant stirring. The suspension mixture was stirred for 12 hours at room temperature. PANI/ $Co_xCr_{0.5-x}Fe_2O_4$ (x=0, 0.1, 0.3) nanocomposites in powder form was then obtained by filtering and washing the suspension with 1 M HCl and distilled water. Filtrate is then dried at 60 °C for 24 hours [10].The X-ray diffraction patterns of the synthesized samples were recorded using Panalytical X-Pert Pro MPD instrument. The morphological analysis of the synthesized samples were performed using the FESEM CARL ZEISS instrument. Magnetic studies on prepared samples were conducted using Lakeshore vibrating sample magnetometer 7410.

RESULTS AND DISCUSSIONS

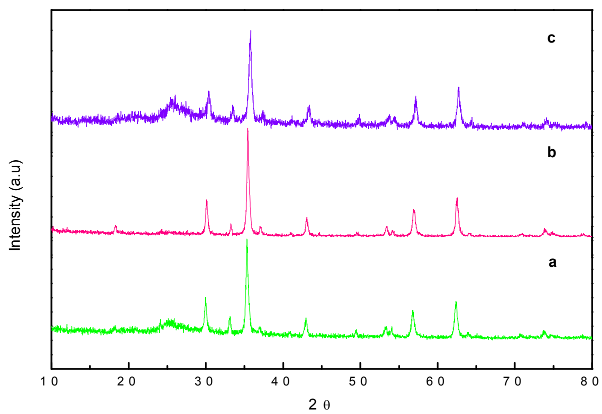


FIGURE 1. XRD patterns of Polyaniline/ $Co_xCr_{0.5-x}Fe_2O_4$(a: x = 0, b: x = 0.1, c: x = 0.3)nanocomposites.

Structural characterization of all the synthesized composites was performed using XRD analysis. The XRD patterns of PANI/ $Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3)nanocomposites are shown in Fig. 1. XRD pattern of all the samples consist of faint peaks of PANI in 2Θ range 22° to 28°with intense peaks of ferrite nanoparticles. The average crystallite size of the samples were estimated by Debye-Scherrer method[11].

$$D = \frac{k\lambda}{\beta \cos \theta}$$

Where D is the average crystallite size, λ is the wavelength of the X-ray and βis the full width at half maxima (FWHM) of most intense peak. The average crystallite size of the PANI/$Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3)nanocomposites are estimated to be around 41.78 nm, 41.80 nm and 41.83 nm respectively.

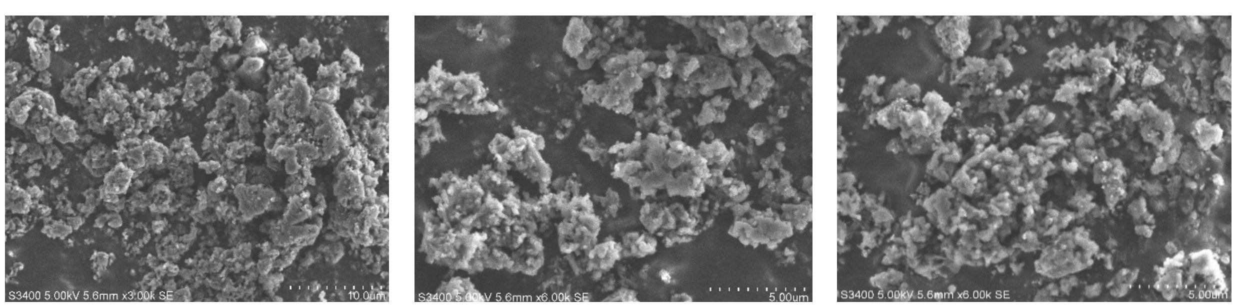
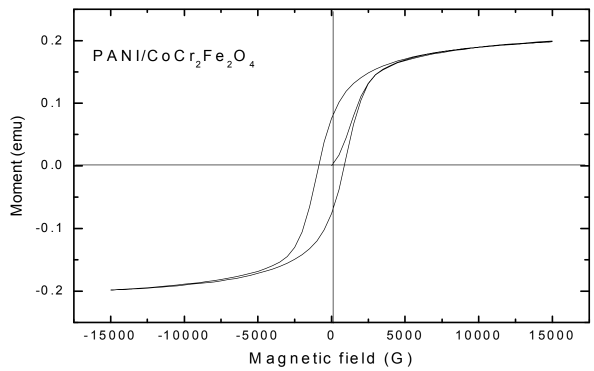


FIGURE 3. FE-SEM images of Polyaniline/ $Co_xCr_{0.5-x}Fe_2O_4$(a: x = 0, b: x = 0.1, c: x = 0.3) nanocomposites.

FE-SEM image of PANI/$Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3)nanocomposites are shown in Fig. 3. FE-SEM micrographs clearly indicates that all the composites consist of particles with non-uniform grain distribution and there is maximum agglomeration of particles. The agglomeration can be attributed to magnetic nature of samples.Magnetic behavior of PANI/ $Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3) nanocomposites was studied by vibrating sample magnetometer analysis at room temperature. Hysteresis loop of PANI/ FE-SEM image of PANI/$Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3) nanocomposites are shown in Fig. 3. FE-SEM micrographs clearly indicates that all the composites consist of particles with non-uniform grain distribution and there is maximum agglomeration of particles. The agglomeration can be attributed to magnetic nature of samples.



(a)

FIGURE 4. Hysteresis loop of Polyaniline/ $Co_xCr_{0.5-x}Fe_2O_4$ (a: x = 0, b: x = 0.1, c: x = 0.3) nanocomposites.

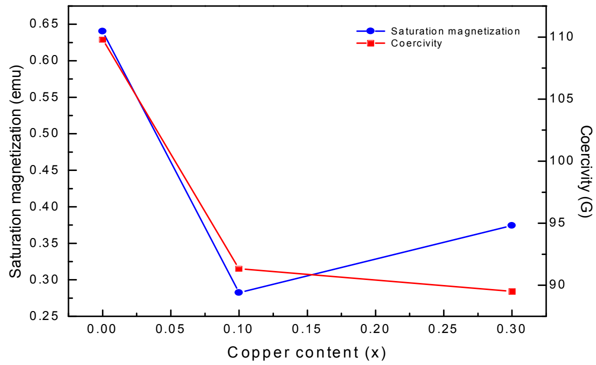
Hysteresis loop of Polyaniline/ $Co_xCr_{0.5-x}Fe_2O_4$ (a: x = 0, b: x = 0.1, c: x = 0.3) nanocomposites are shown in Fig. 4. The variation of saturation magnetization (Ms) and coercivity (Hc) of PANI/ $Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3)nanocomposites with Copper content is represented in Fig. 5. It is observed that the coercivity (Hc) values found to decrease with increase in Copper content in all the composites. And also it is observed that the saturation magnetization (Ms) decreases from 0.64 emu to 0.28 emu with the addition of Copper content (x=0.1) due to increase in magnetic moment on B-sitesand it increases the B–B exchange interaction. The increased B–B exchange interaction induces anti-parallel spin coupling, which decreases the magnetization [12]. With further increase in the concentration of Cu^{2+} ions,the saturation magnetization increases slightly from 0.28 emu to 0.37 emu, this may be attributed to parallel spin coupling within the composite.

Electromagnetic Interference (EMI) shielding can be achieved by three major mechanisms: reflection of the wave from the material, absorption of the wave by the material and multiple reflections of the waves at various interfaces [13]. Multiple reflections can be ignored when the total SE is greater than 10dB. Thus by neglecting the multiple reflections, total shielding effectiveness (SE_{Total}) of the material is the sum of SE due to reflection and absorption losses i.e. $SE_{Total}= SE_R + SE_A$[14].

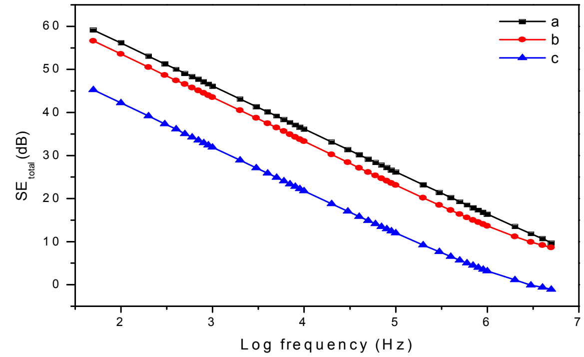
$$SE_R = 20\log\left[\frac{\left(\frac{\sigma_{ac}}{\omega_H \varepsilon_0 \mu_r}\right)^{\frac{1}{2}}}{4}\right] \text{(dB)} \qquad (1)$$

$$SE_A = 20\log\left[\exp\left(\frac{t}{\delta}\right)\right] \text{(dB)} \quad (2)$$

$SE_{Total}$of the synthesized samples were calculated using equations (1) and (2), variation of $SE_{Total}$with the applied frequency inPANI/ $Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3)nanocomposites are shown in Fig. 6. The SE_{Total} values of all the samples are high in lower frequency region and decreases as the applied frequency increases. The Shielding in ferrites is mainly due to domain wall resonance and spin resonance [15]. The absorbing property of PANI-Ferritecomposites is due to the dipolar polarization and relaxation effects between PANI and ferrites [16]. The highest level of shielding achieved in this work for PANI/ $Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3)nanocomposites are 59.11 dB, 56.61 dB and 45.26 dB respectively at 50 Hz. High value of SE_{Total}in all the synthesized samples clearly indicates that these composites are suitable for EMI shielding application.



(a)



(b)

FIGURE 5. (a) Variation of saturation magnetization (Ms) and coercivity (Hc) of Polyaniline/ $Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3) nanocomposites with Copper content. **FIGURE 6.** (b) Frequency dependence of shielding effectiveness for Polyaniline/ $Co_xCr_{0.5-x}Fe_2O_4$ (a: x = 0, b: x = 0.1, c: x = 0.3) nanocomposites.

CONCLUSION

PANI/ $Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3) nanocompositeswere synthesized by in situ polymerization of Aniline monomer with $Co_xCr_{0.5-x}Fe_2O_4$(x=0, 0.1, 0.3) nanoparticles. Synthesized composites were characterized by XRD, FESEM and VSM techniques. Further, SE studies have been undertaken on the prepared composites. Higher values of SE for all the synthesized composites makes them suitable for the application of electromagnetic interference (EMI) shielding.

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