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Conducting polymer embedded with nanoferrite and titanium dioxide nanoparticles for microwave absorption

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ABSTRACT

The present paper deals with the synthesis of conducting ferrimagnetic polyaniline nanocomposite embedded with γ-Fe_2O_3 (9–12 nm) and titanium dioxide (70–90 nm) nanoparticles via a micro-emulsion polymerization. The microwave absorption properties of nanocomposite in 12.4–18 GHz (Ku-band) frequency range shows shielding effectiveness due to absorption (SE_A) value of −45 dB, which is much higher than polyaniline composite with iron oxide and polyaniline–TiO_2 composites. The higher EMI shielding is mainly arising due to combined effect of γ-Fe_2O_3 and TiO_2 that leads to more dielectric and magnetic losses which consequently contributed to higher values of shielding effectiveness. XRD analysis of the nanocomposite reveals the incorporation of nanoparticles in the conducting polymer matrix while the thermal gravimetric analysis (TGA) demonstrates that the nanocomposite is stable up to 250 °C.

1. Introduction

Conducting polymer and their composites have attracted the great deal of attention from material scientists world wide because of there wide spread application in organic light emitting diodes (OLED) [1], polymer solar cells [2], sensors [3] and EMI shielding [4]. With the development of electric and electronic industry, the use of electronic products and telecommunication equipment have increased due to which the problem of electromagnetic interference (EMI) has attracted the attention, as it reduces the lifetime, efficiency of the instruments, and also affect the safety operation of many electronic devices. To avoid these problems, all electronic equipments must be shielded against electromagnetic aggression. In recent time, extensive research, have been done for the development of new microwave shielding materials with high efficiency, lightweight and having high durability. This includes composites based on polymers, like hexagonal-ferrite/polymer, metal/polymer composites, and SWCNT-epoxy composites [5–7]. To achieve higher values of shielding effectiveness much attention has been paid to polyaniline and their composites with ferrite particles, which possesses the moderate magnetization and conductivity [8–11].

Here in, we report the synthesis and designing of nanocomposites of conducting polymer polyaniline by incorporation of nanoparticles of γ-Fe_2O_3 and TiO_2 by in situ emulsion polymerization. Two different compositions of nanocomposites were prepared by polymerizing aniline, TiO_2, and γ-Fe_2O_3 in 1:1:1 (PTF11) and 1:1:2 (PTF12) weight ratios in surfactant medium. The results of these composites were compared with the polyaniline–TiO_2 (PT11) and polyaniline–γ-Fe_2O_3 (PF12) composites. The main aim of the present research work is to develop a conducting polymer composite having high shielding effectiveness that can be used as an additive in paints which acts as coating material.

2. Experimental and characterization

2.1. Synthesis of polyaniline nanocomposite embedded with γ-Fe_2O_3 and TiO_2

The γ-Fe_2O_3 was prepared through the conventional precipitation oxidation method described elsewhere [12] whereas TiO_2 was used after ball milling it for 6 h using high-energy ball mill in tungsten carbide jars. The resulting nanosize γ-Fe_2O_3 along with TiO_2 particles are homogenized in 0.3 M aqueous solution of dodecyl benzene sulfonic acid (DBSA) to form a whitish brown emulsion solution. To this emulsion, 0.1 M aniline was added and again homogenized for 2–3 h resulting in the formation of the micelles of aniline with γ-Fe_2O_3 and TiO_2. The micelles so formed are polymerized below 0 °C through chemical oxidization polymerization using ammonium persulfate, $(NH_4)_2S_2O_8$ (0.1 M) as oxidant. The product obtained was filtered after washing with isopropyl alcohol and dried in vacuum oven at 60–65 °C. Different formulation of polymer composite having aniline:TiO_2:γ-Fe_2O_3 weight ratio of 1:1:1 (PTF11) and 1:1:2 (PTF12) were

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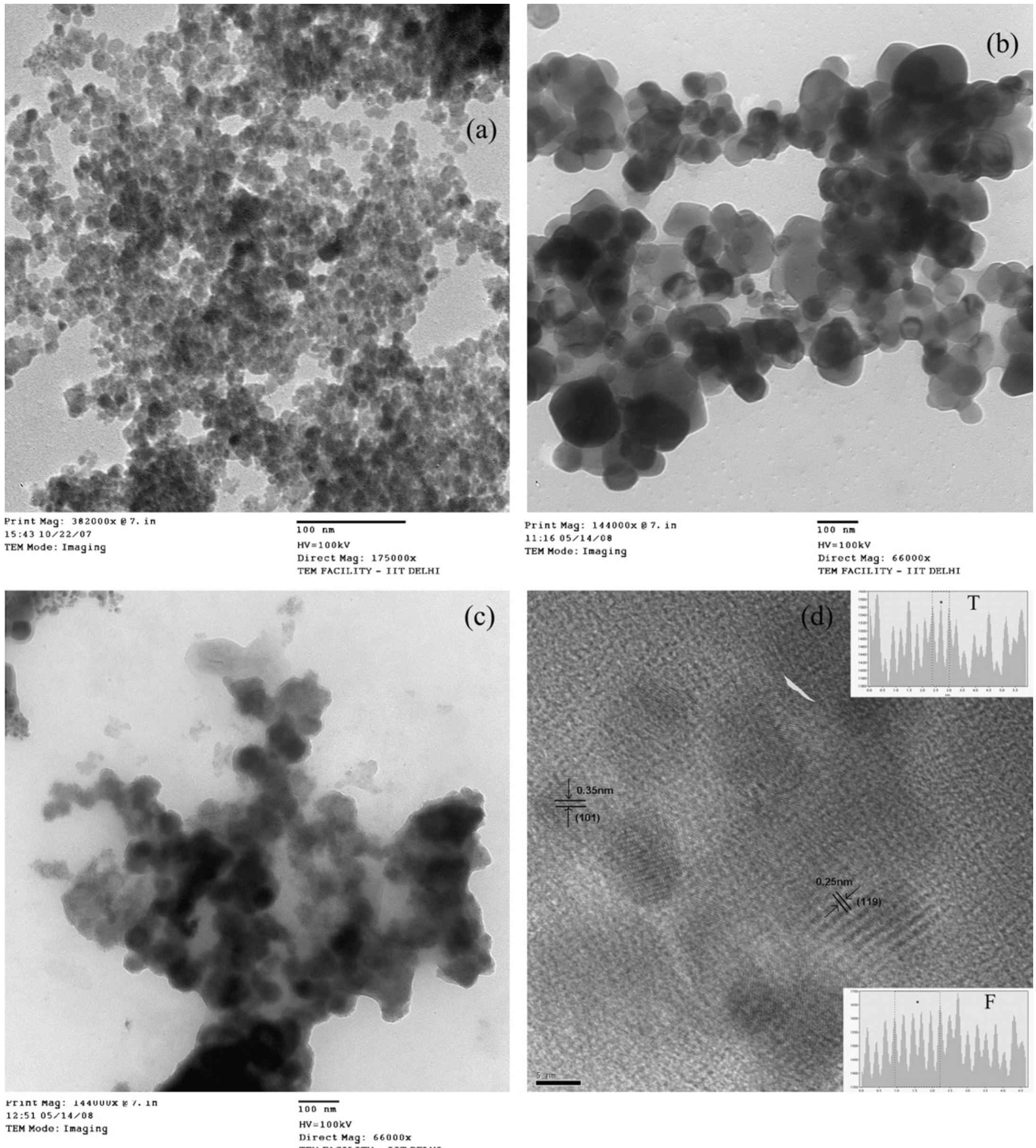

Fig. 1. TEM images of (a) γ-Fe_2O_3, (b) TiO_2, (c) PTF12, showing the nanoparticles of γ-Fe_2O_3 (9–12 nm) and TiO_2 (70–90 nm), and (d) HRTEM image of PTF12 showing the lattice spacing whereas inset shows the lattice profile of TiO_2 (T) and Fe_2O_3 (F).

synthesized in DBSA medium to check the effect of ferrite constituents on the properties. Beside this, for comparison of results, polyaniline–TiO_2 (PT11) composite having monomer to TiO_2 weight ratio of 1:1 and polyaniline–Fe_2O_3 (PF12) having monomer to Fe_2O_3 weight ratio of 1:2 were also synthesized under similar conditions.

3. Result and discussion:

TEM images of γ-Fe_2O_3, TiO_2, and polyaniline composite (PTF12) were shown in Fig. 1 whereas Fig. 1(d) shows the HRTEM image of the PTF12 nanocomposite. From Fig. 1(a) the particle size of γ-Fe_2O_3 was estimated to be 9–12 nm while TiO_2 has slightly larger particles of 70–90 nm (Fig. 1(b)). When these nanoparticles were incorporated in the polymer matrix, they show the agglomerated morphology (Fig. 1(c)). Presence of TiO_2 and γ-Fe_2O_3 in the polymer composite is also confirmed from the lattice parameters of constituents, as shown in the HRTEM image (Fig. 1(d)). Inset to the Fig. 1(d) shows the profile of the lattice fringes from which the *d*-spacing of TiO_2 and γ-Fe_2O_3 is measured.

Fig. 2(A) shows the X-ray diffraction patterns of TiO_2, γ-Fe_2O_3 and composites of polyaniline with TiO_2 and γ-Fe_2O_3. All the observed peaks were matched with the standard XRD pattern of TiO_2 (Powder Diffraction File, JCPDS No. 84-1285) and γ-Fe_2O_3 (Powder Diffraction File, JCPDS No. 39-1346). The peaks of γ-Fe_2O_3 were observed in all the compositions of polyaniline composites with TiO_2 and γ-Fe_2O_3, which designate the presence of ferrite particles in the polymer matrix and the increase in intensity of peaks demonstrate the increase in the ratio of iron oxide. Sharp peaks were observed for the TiO_2 nanoparticles as compared to the iron oxide because of larger crystallite size, calculated using the Scherer's formula

$$D = \frac{k\lambda}{\beta \cos \theta} \quad (1)$$