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PAPER

Cost effective Fe/NG/PMMA nanocomposites for high-performance microwave absorbing applications

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Abstract

The microwave (MW) absorbing properties of melt-blended iron nanoparticles/exfoliated nanographites/polymethylmethacrylate (Fe/NG/PMMA) nanocomposites (with 1, 2, 3 and 5 wt% of NG) were investigated in 2–18 GHz frequency range. Le Bail refinement of XRD patterns confirmed the formation of α-Fe (bcc) phase in Fe nanoparticles. The average Fe nanoparticle sizes estimated from transmission electron microscopy (TEM) were found to be ~29 nm. Scanning electron micrographs (SEM) show homogeneous dispersion of NG and Fe nanoparticles in PMMA matrix. The room temperature M-H hysteresis curves of Fe nanoparticles noted the saturation magnetization (M_s) and coercivity (H_c) of ~196.4 emu g^{-1} and ~630 Oe, respectively. The reflection loss (R_L), calculated using transmission line theory, reaches −38.8 dB (MW absorption of 99.98%) at 12.6 GHz frequency in Fe/NG(2)/PMMA (with 2 wt% of NG) nanocomposite sample. In addition, the wide-bandwidth of ~6.3 GHz (in X- and Ku-bands), for $R_L \leqslant -10$ dB (90% MW absorption), was attained in Fe/NG(2)/PMMA nanocomposite sample. These results suggested that the excellent MW absorbing properties of as-prepared Fe/NG/PMMA nanocomposites are mainly controlled by dielectric losses, which are introduced through optimized loading of NG in nanocomposite samples.

1. Introduction

The widespread use of electromagnetic (EM) devices for wireless microwave (MW) communication systems has created the alarming problem of electromagnetic interference (EMI) [1–3]. EMI degrades the performance of an electronic device by affecting its electrical circuit through EM induction and electrostatic coupling etc. Further, some of the literature reports also indicate that MW pollution can be carcinogenic to humans [3–6]. Accordingly, EM absorbing materials have received tremendous attention for reducing the adverse effects of MW pollution. Moreover, these materials have also been remained greatly useful in military applications since World War II; i.e. for the suppression of radar cross-section (RCS) and the stealth technology [7–9]. In this regard, the tremendous efforts have been made to develop a light weight and thin MW absorbing material; that can exhibit strong absorption over a wide range of frequency [10–16]. MW absorbing characteristics of a material are determined by its complex permittivity ($\varepsilon^* = \varepsilon' - i\varepsilon''$) and permeability ($\mu^* = \mu' - i\mu''$) spectra. For strong and wideband MW absorption, the absorbing material should exhibit simultaneous dielectric and magnetic losses. Meanwhile, carbon-based materials, e.g. graphite, graphene, carbon nanotube (CNT), reduced graphene-oxide (rGO) and carbon nanofibre etc, have been explored in light weight MW absorbing applications; owing to their high dielectric loss and low density [11–14]. However, insignificant magnetic loss of carbon limits their use in commercial MW absorbing applications. To overcome this difficulty, the magnetic nanoparticles such as Fe, Ni, Co and their oxides are usually composited with carbon-based materials. Among them, iron (Fe) and its oxide (Fe_3O_4) have attracted extensive interest because of their high saturation

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