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Barium ferrite and graphite integrated with polyaniline as effective shield against electromagnetic interference

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ABSTRACT

Barium ferrite was incorporated into polyaniline matrix along with expanded graphite (EG) in order that the resultant conductive composite can be used for electromagnetic shielding. The different properties like complex permittivity (ε″), permeability (μ″), and effectiveness of shielding have been studied by vector network analyzer using theoretical enumeration given in Weir and Nicholson–Ross algorithms. The microwave absorption characteristic of the composites have been calculated in the X-band (8.2–12.4 GHz) frequency range which shows a shielding effectiveness up-to 37.1 dB, which strongly depends on dielectric loss.

1. Introduction

The problem of protection against electromagnetic interruption has a very important technical aspect subjected to a reduction in the level of electromagnetic interference (EMI) that occurs between electronic instruments. As the knowledge and advanced technology progressed the exploitage of various types of electrical and electronic equipment in different applications increased rapidly. These appliances are origin of electromagnetic radiation (EMR), which depend on the exigency, can be regarded either as a desirable or undesirable phenomenon. Furthermore an important aspect of safety against EMR is the health protection of persons present in the surrounding of equipment emitting EMR and exposed to its prolonged effects. This has increased the attention in evolutive materials for EMR shielding [1].

A variety of materials have been developed and used in the manufacturing of shields. Shielding substance could be absorbing and/or conductive materials such as polymeric composites with metallic and non metallic conducting inclusions and metallic conductor etc. In order to overcome these shortcomings, carbon-based nanomaterials fillers, such as EG, CNT, carbon black, and CNF [2–7] have been introduced potential candidate for designing microwave shielding materials. A viable lightweight absorber is the current need for stealth technology as well as microwave absorption [8]. These materials must have specific attributes; as desirable shielding effectiveness (SE), lightness, suitable mechanical properties, good processability, and low cost [9].

Among many new microwave absorbers, conducting polymer polyaniline (PANI) hasbeen considered as propitious material as microwave absorbers due to its high conductivity, low density, good environmental stability, and ease of preparation [10,11]. In the past decade, a number of ferrites like Ba, Mn, Ni, Co, Zn, γ-Fe_2O_3 ferrites and their composite [12–15] were used for microwave shielding materials because it offers good magnetic properties i.e; high saturation magnetization, high value of permeability. The shielding effectiveness (SE) of a material depends on its magnetic permeability, dielectric properties, frequency and thickness [16].

This is a pioneering work which reports electromagnetic shielding effectiveness of Expanded graphite (Carbon material), Nanoferrite (magnetic material) and Polyaniline (conductive polymer) composite for technological application (Electromagnetic Interference Shielding) which is compatible with experimentally revealed findings. It correspond the experimental data with other composite material reported by different groups but not reported the above composite. Such materials are of immense current interest for their applicability in EMI Shielding. The theory of such materials makes for frontline research since it is yet to be explored completely.

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2. Experimental

2.1. Materials

Aniline, Propanol, Citric acid, Barium Nitrate [$Ba(NO_3)_2$], ferric nitrate [$Fe(NO_3)_3$], ammonium hydroxide solution, ammonium peroxy disulphate (APS) were acquired from Merck, India. Dodecyl benzene sulphonic acid (DBSA) from Acros organics, U.S.A, Natural graphite powder (Loba Chemie, India). Sulphuric acid (H_2SO_4) (98%), Nitric acid (HNO_3-69%) (Merck India), were used in this study. The aniline monomer was purified by distillation before use. The other chemicals were used as received without further purification.

2.2. Synthesis of barium ferrite

Barium ferrite was synthesized by citrate precursor method. Ba $(NO_3)_2$, $Fe(NO_3)_3$ and citric acid were taken as starting materials. Required amounts of $Ba(NO_3)_2$ and $Fe(NO_3)_3$ were dissolved in minimum amount of deionized water. The molar ratio of Ba to Fe was kept 1:12. Solution of citric acid in distilled water was mixed with Nitrate solution [mixture of $Fe(NO_3)_3$ and $Ba(NO_3)_2$]. The molar ratio of $C_6H_8O_7$ to total moles of nitrate ions was fixed at 1:1. Ammonia solution was gradually added to balance the pH at 9. Finally the mixed solution was allowed to evaporate by heating at 100 °C with continuous stirring. As water vaporized, the solution became viscous and finally brown gel was formed. With continuous heating and increasing the temperature, the gel bubbled in combustion manner to form a brown colored porous powder. This powder was calcinated for 2 h at 900 °C in air to obtain the $BaFe_{12}O_{19}$ phase [17]. The resultant powder of the combustion was milled by Mechanical Laboratory Ball Mill (Make-U-TECH, India, Milling speed 400 rpm, Electrically operated on 220 AC Mains, Having stainless steel jar and steel balls, Fitted with FHP Motor). The ball-to-powder weight (gm) proportion was kept 10:1. The milling was operated at 400 rpm, using solid steel balls with a diameter of 10 mm.

2.3. Synthesis of EG

Chemical oxidation and thermal treatment technique are employed for preparation of expanded graphite (EG) from natural graphite (NG) powder. NG powder was mixed with saturated acid be composed of H_2S0_4 and concentrated HNO_3 in a volume proportion 3: 1 for 12 h to form graphite intercalated compound (GIC). These chemically handled flakes are then thoroughly gargled with water until the pH scale of the solution reach 7 (neutral) and dried at 600 °C in vacuum oven for 5 h. GIC was suddenly exposed to high temperature in a muffle furnace retained at temperature 800–900 °C to form EG (Fig. 1).

2.4. Synthesis of PANI/BF/EG composite

The nanocomposite was synthesized by in situ polymerization method in which DBSA was taken as surfactant and dopant and APS [$(NH_4)_2S_2O_8$] as oxidant. DBSA was dissolved in deionized water with cogent stirring for about 30 min. Then barium ferrite and RGO were added to the DBSA solution under stirring for 1 h. Thereafter, polyaniline monomer was mixed to the suspension and agitated for 30 min. BF and RGO nanoparticles were dispersed well in the mixture of PANI/DBSA under stirring for 1 h. APS (equal to molar ratio of aniline) dissolved in 100 ml deionized water and gradually

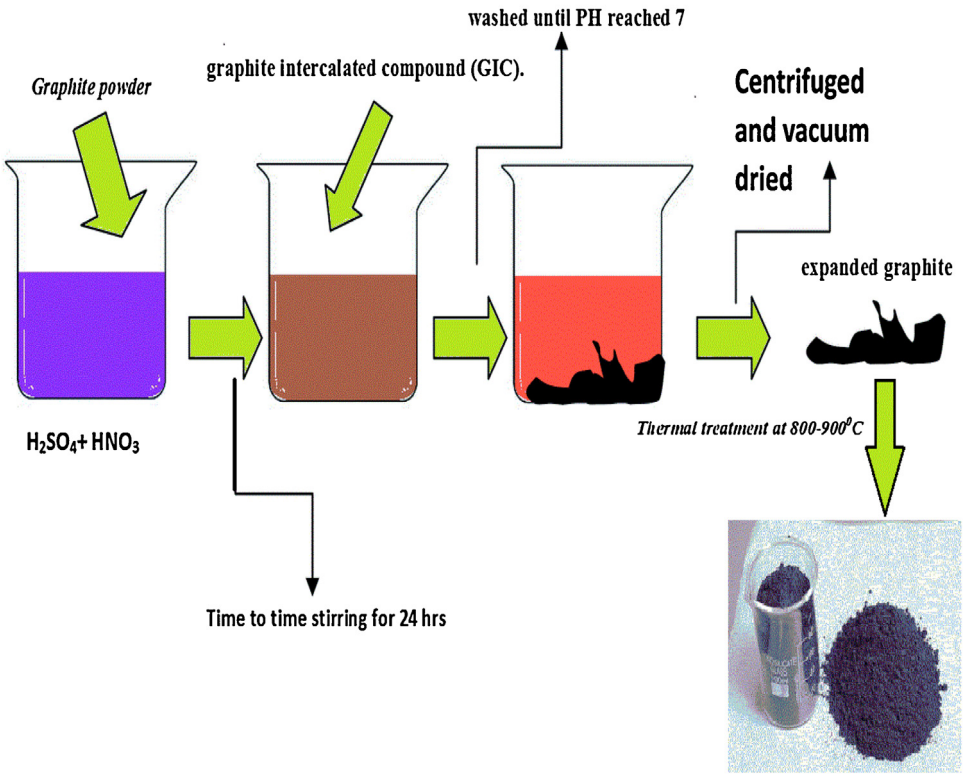

Fig. 1. Schematic diagram for synthesis of EG.