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Comparitive study of electrical advantages and disadvantages of polymer based ferrites

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***Abstract*— Composites with Nano size ferromagnetic particles can be useful in microwave absorbers, since nanoparticles exhibit distinct magnetic properties compared to bulk materials. This paper examines theoretically the properties of composites with nanoparticles, the key material parameters, and the characteristics of a single-layer absorber made from a nanoparticle composite. In such an absorber, high magnetic losses over a wide frequency range induce a series of strong and wide absorption peaks at increasing frequencies. By using metallic (iron and cobalt) nanoparticles, absorbers with relatively low volume fraction of metallic inclusions can be made. The paper compares the characteristics of nanocomposite absorbers to those of common dielectric or ferromagnetic absorbers and identifies the potential advantages of nanocomposite absorbers.**

Keywords—Ferrite material, Polymer, Electric conductivity, Eddy current, Ferromagnetic materials

I. Introduction

In the past several decades, more and more attention were focused on electromagnetic wave absorbing cement based composites with broad application in the fields of military stealth technology of large fixed targets and electromagnetic inference (EMI) shielding for the health of human beings and normal work of the electronic devices. Recently, there have been an increased number of applications of electromagnetic (EM) waves in the Ku-band (12.4– 18 GHz) for radar, military aircraft and satellite communication and, consequently, much attention has been devoted to EM wave absorbing materials in the whole Ku-band. Among the candidates for EM wave absorbers, magnetic Nano capsules (i.e., magnetic nanoparticles coated with a nonmagnetic insulator) have attracted particular interest, due to their potential applications as microwave absorbing and shielding materials as well as EM devices Composites material can integrate their properties in one single material. Materials made of conducting polymers and ferrite materials can provide enhanced properties for various applications. Conducting polymer–ferrite composites with an organized structure provide us a new functional hybrid between organic and inorganic materials. Thus, many researchers are focusing their interest on producing materials suitable for large EM wave absorption. The absorption of EM waves occurs in magnetic materials due to their magnetic losses. (Lax, 1962)

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Electronically conducting polymers are the novel class of synthetic metals with widespread application in number of technological devices. Among the conducting polymers, polyaniline (PANI) has been extensively studied due to its easy synthesis, low cost, excellent environmental stability and high electrical conductivity. PANI has attracted much attention because of its potential application in molecular electronics, electromagnetic interference (EMI) shielding, chemical sensors, antistatic coatings, rechargeable batteries, corrosion inhibitors, absorbing materials etc. Nano crystalline ferrites which possess a general formula MFe2O4 (M¼divalent metal ion, e.g. Ni, Co, Cu, Mn, Mg, Zn, Cd etc.) are one of the most attractive class of materials for technological applications.6–11 Among magnetic materials, the spinel ferrites exhibit remarkable magnetic properties particularly in radiofrequency region, physical flexibility, high electrical resistivity, mechanical hardness and chemical stability. 12 Nickel ferrite (NiFe2O4) has been intensively investigated as one of the magnetic nanomaterial. (Sivakumar P, 2011)

Ferrites remain one of the best magnetic materials ever discovered and cannot be easily replaced by any other magnetic material because they are inexpensive, stable and have a wide range of technological applications . Ferrites in the ceramic form and in the composite form, namely rubber ferrite composites (RFC), are increasingly being used for various applications such as in magnetic memories, flexible magnets, microwave absorbers, TV yokes and a multitude of other useful devices. Nickel zinc ferrites are used in many electronic devices such as in highfrequency transformers and inductors, especially because of their low eddy current losses which are attributable to high resistivity.

II. LITRETURE REVIEW

1. **(Tahseen H.Mubarak, 2017)** states that Electrical conduction is the process of the transfer of electric charges through a medium from one place to another under the influence of electric field. Electrical conduction is based on two factors First: The type of charge carrier (n) Charge carriers can be electrons, gaps, or ions automatically generated due to the addition of impurities - Second: Mobility (μ) Mobility depends on temperature (T) and the potential exerted (V).Polymers of special structure (alternating) have the properties of semiconductors, whereas most commercial polymers are insulator. Given that polymers are easily formed. Chemists and physician started mid the twentieth century to conduct studies designed to develop conductor polymers characterized by alternating double bonds. In its stable state, alternating polymers are insulators or semiconductors because it is easy for electrons to transfer from one chain to another. These insulator polymers can be transformed into conductors by adding small molecules that have certain properties among polymer chains; these molecules are called Dopants, and the process of adding impurities is called Doping. Dopants can operate as oxidizing or reducing agents. Charge transfer complexes can be created between dopants and polymers that make these polymers conductors. Magnetic nanocomposite have been prepared in different matrices as silicon oxide
2. **(Hemalathaa, 2016)** describe flexible magneto electric polymer nanocomposite films which exhibit ferroelectric and magnetic orderings simultaneously are fabricated. Different weight percentages of NiFe2O4 nanoparticles (particle size of 46 nm) are embedded as fillers in Poly (vinylidene fluoride) (PVDF) matrix. Systematic investigations on the effect of filler on the structural, functional, morphological and thermal properties are discussed. NiFe2O4 content in PVDF plays a main role in controlling the conformations, α and β phases, thereby makes significant effect on the ferroelectric and magnetic properties of PVDF/NiFe2O4 films. The coexistence of ferroelectric and ferromagnetic orderings in the films has been proved by P-E and M-H loops. PVDF/NiFe2O4 film with 10 wt% of NiFe2O4 nanoparticles exhibits maximum polarization (3.07 μC/cm2), indicating the optimum loading that can crystallize PVDF in ferroelectric β phase. Magnetoelectric cross-coupling has been proved by control of electrical polarization relating to applied magnetic field. The conduction mechanism for the observed low leakage current density is investigated.
3. **(Elahi, 2016)** said that polypyrrole (PPy)–Zn0.5Ni0.4Cr0.1Fe2O4 core– shell nanocomposites have been fabricated by in situ chemical polymerization of pyrrole in the presence of ZnNiCr ferrite nanoparticles. The samples were characterized by X-ray diffractometer, FTIR spectroscopy, TGA/ DTA analysis and field emission scanning electron microscopy (FE-SEM). Dielectric and Magnetic properties were investigated by using impedance analyzer and vibrating sample magnetometer respectively. The results of XRD, FTIR showed the presence of the two intended phases. FE-SEM results confirm the formation of core– shell structure. Possible bonding effect between metal cations and PPy resulted in the decrease of the conductivity with increase of ferrite content. Below 500 ——————————C, the TGA and DTA results confirm the thermal stability of these samples. Incorporation of ferrites in the conducting Polypyrrole matrix leads to higher values of dielectric constant and dielectric loss. Under applied magnetic field, the Hysteresis measurements revealed that coercivity, saturation magnetization and remanance were tuned to such values that made the investigated samples suitable for microwave devices and switching applications.
4. **(Elżbieta Jartych, 2016)** defien solid-state sintering method was used to prepare ceramic materials based on bismuth ferrite, i.e., (BiFeO3)1 − x–(BaTiO3)x and Bi1 − xNdxFeO3 solid solutions and the Aurivillius Bi5Ti3FeO15 compound. The structure of the materials was examined using X-ray diffraction, and the Rietveld method was applied to phase analysis and structure refinement. Magnetoelectric coupling was registered in all the materials using dynamic lock-in technique. The highest value of magnetoelectric coupling coefficient αME was obtained for the Bi5Ti3FeO15 compound (αME ~ 10 mVcm−1 Oe−1). In the case of (BiFeO3)1 − x–(BaTiO3)x and Bi1 − xNdxFeO3 solid solutions, the maximum αME is of the order of 1 and 2.7 mVcm−1 Oe−1, respectively. The magnitude of magnetoelectric

coupling is accompanied with structural transformation in the studied solid solutions. The relatively high magnetoelectric effect in the Aurivillius $Bi_5Ti_3FeO_{15}$ compound is surprising, especially since the material is paramagnetic at room temperature. When the materials were subjected to a preliminary electrical poling, the magnitude of the magnetoelectric coupling increased 2–3 times.

5. **(EL-GHAZZAWY, 2015)** according that nanocrystalline nickel chromium ferrite ($NiCr_xFe_{2-x}O_4$, x = 0.1, 0.2) have been prepared by the chemical co-precipitation method. Half of the samples have been sintered at 620◦C and the other at 1175◦C. Then polypyrrole (PPy)–$NiCr_xFe_{2-x}O_4$ composites have been synthesized by polymerization of pyrrole monomer in the presence of $NiCr_xFe_{2-x}O_4$ nanoparticles. The structure, morphology and magnetic properties of the samples have been characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM) and Fourier transform infrared (FT-IR) spectroscopy and vibrating sample magnetometer. Also, the initial magnetic permeability measurements as functions of temperature and frequency have been performed. The XRD and FT-IR studies have confirmed the well crystalline phase of ferrite nanoparticles, and the presence of amorphous PPy in the composite samples. The SEM and TEM images have obviously clarified the coating of ferrite nanoparticles by PPy in the composite samples. The hysteresis loop of the samples has proved that the samples are soft magnetic material because of their low coercivity.
6. **(M. Khairy, 2015)** define polyaniline–$NiFe_2O_4$ nanocomposite (PANI–$NiFe_2O_4$) with different contents of $NiFe_2O_4$ (2.5, 5 and 50 wt%) were prepared via in situ chemical oxidation polymerization, while the nanoparticles nickel ferrite were synthesized by sol–gel method. The prepared samples were characterized using some techniques such as Fourier transforms infrared (FTIR), X-ray diffraction (XRD), scanning electron microscopy (SEM) and thermo gravimetric analysis (TGA). Moreover, the electrical conductivity and optical properties of the nanocomposite were investigated. Pure (PANI) and the composites containing 2.5 and 5 wt% $NiFe_2O_4$ showed amorphous structures, while the one with 50 wt% $NiFe_2O_4$ showed a spinel crystalline structure. The SEM images of the composites showed different aggregations for the different nickel ferrite contents. FTIR spectra revealed to the formation of some interactions between the PANI macromolecule and the $NiFe_2O_4$ nanoparticles, while the thermal analyses indicated an increase in the composites stability for samples with higher $NiFe_2O_4$ nanoparticles contents. The electrical conductivity of PANI–$NiFe_2O_4$ nanocomposite was found to increase with the rise in $NiFe_2O_4$ nanoparticle content, probably due to the polar on/bipolar on formation. The optical absorption experiments illustrate direct transition with an energy band gap of E_g=1.0 for PANI–$NiFe_2O_4$ nanocomposite.
7. **(Fadzidah Mohd Idris, 2014)** said that prior to their use for microwave absorption, different compositions of $Ni_xZn_{1-x}Fe_2O_4$ (x = 0.5, 0.6, 0.7 and 0.8) were prepared via mechanical alloying and sintering. X-ray diffractometry (XRD) was used to investigate the crystalline phase formation. Scanning transmission electron microscopy (STEM) and field emission electron microscopy (FeSEM) were used to investigate the particle size and surface morphology respectively. The complex-permeability components, μ' and μ'', were also measured using an Agilent 4291B material analyzer from 1 MHz to 1 GHz. From the XRD results it is shown that at 900ºC the full phase of nickel zinc ferrite was formed.
8. **(T.V.Rajendran, 2015)** reserch describes the preparation and characterisation of Ureidopyrimidinone based supramolecular polymer/ferrite nanocomposites for electrochemical applications. The synthesized supramolecular polymer is blended with ferrite nanopar ticles by dispersion method which is used as an energy storage material in electrochemical devices. The structural property of composite was studied by X-ray diffraction method (XRD). The structure of the repeating units in the supramolcular polymer, ferrite and nanocomposite was studied by FTIR spectroscopy. The morphology of substrate was studied by Scanning electron microscopy (SEM). The electrical conductivity measurements such as AC conductivity, dielectric constant and dielectric loss were evaluated at different frequencies (1 kHz to 1 MHz) using Electron Impedance Spectroscopy (EIS). The effect of temperature on the ionic conductivity of the nanocomposite was studied. It is observed that the ionic conductivity is maximum for supramolecular polymer nanocomposite. Further, the results showed that increase in dielectric constant as a function of frequency indicates an increase in AC conductivity.
9. **(Gregor Ferk, 2015)** said in the incorporation of magnetic barium hexaferrite nanoparticles in a transparent polymer matrix of poly(methyl methacrylate) (PMMA) is

reported for the first time. The barium hexaferrite nanoplatelets doped with Sc3+, i.e., BaSc0.5Fe11.5O12 (BaHF), having diameters in the range 20 to 130 nm and thicknesses of approximately 5 nm, are synthesized hydrothermally and stabilized in 1-butanol with dodecylbenzenesulfonic acid. This method enables the preparation of monolithic nanocomposites by admixing the BaHF suspension into a liquid monomer, followed by in-situ, bulk free-radical polymerization. The PMMA retains its transparency for loadings of BaHF nanoparticles up to 0.27 wt.%, meaning that magnetically and optically anisotropic, monolithic nanocomposites can be synthesized when the polymerization is carried out in a magnetic field. The excellent dispersion of the magnetic nanoparticles, coupled with a reasonable control over the magnetic properties achieved in this investigation, is encouraging for the magneto-optical applications of these materials.

10. **(GD Prasanna, 2014)** reserch conducting polymer/ferrite nanocomposites with an organized structure provide a new functional hybrid between organic and inorganic materials. The most popular among the conductive polymers is the polyaniline due to its wide application in different Eelds. In the present work nickel ferrite nanoparticles were prepared by sol–gel citrate-nitrate method. Polyaniline/nickel ferrite nanocomposites were synthesized by a simple general and inexpensive in-situ polymerization in the presence of nickel ferrite nanoparticles. The effects of nickel ferrite nanoparticles on the DC-electrical and magnetic properties of polyaniline were investigated. The structural, morphological and thermal stability of nanocomposites were characterized by X-ray diffraction, FTIR, scanning electron micrograph and TGA. The DC conductivity of polyaniline/nickel ferrite nanocomposites have been measured as a function of temperature in the range of 80 K to 300 K. The magnetic properties of the nanocomposites were measured using vibrating sample magnetometer in the temperature range 300–10 K up to 30 kOe magnetic field.

III. MODEL OF SIMPLE ABSORBER WITH NANOCOMPOSITE

To qualitatively assess the potential of a composite with ferromagnetic nanoparticles, a model of a simple one-layer electromagnetic absorber was analyzed. As shown in Fig. 1, such an absorber is constructed by one layer of the absorbing material, backed with a metal layer. Reflection coefficient of this structure for the normally incident EM wave is given by the well-known expression

$$R = 20 \cdot \log_{10}\left(\frac{iZ\tan(kd) - 1}{iZ\tan(kd) + 1}\right)$$

$$Z = \sqrt{\frac{\mu}{\varepsilon}}, \quad k = \frac{\omega}{c}\sqrt{\mu\varepsilon}$$

From the mechanical properties of the composite, the volume fraction of nanoparticles had to be estimated. In case of metallic nanoparticles, the percolation of particles has to be prevented by coating the particles with an insulating layer. As in nanoparticles even a thin additional layer notably reduces the volume fraction of ferromagnetic material. (Bregar, 2004)

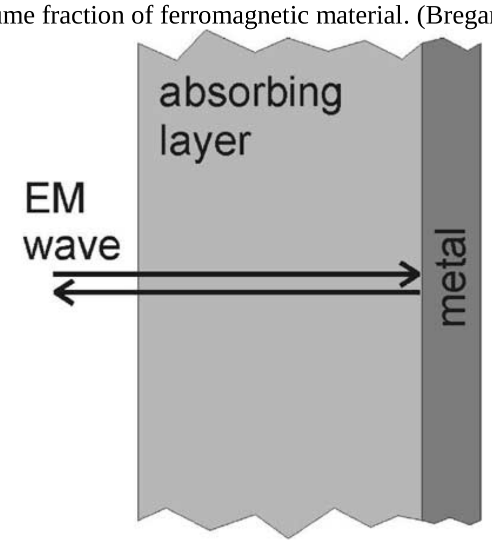

Fig.1 Scheme of a one-layer electromagnetic absorber

IV. STRUCTURAL STUDIES

The samples were subjected to XRD analysis by using an X-ray diffract meter (JDX-60PX, JEOL Boston model) with Cu-Ka (k = 1.5406 A °) radiation and morphology of the obtained samples was studied by a field emission scanning electron microscope (TESCAN, MIRA II LMH), respectively. The samples for infrared (IR) studies were prepared by mixing the powdered sample with KBr in the ratio 1:100 by weighing to ensure uniform dispersion. The IR spectra were recorded on Shimadzu 8400S IR spectrophotometer in the near infrared region 400–4000 cm-1. Thermal stability of samples were also studied by TGA/DTA using Thermo-Gravimetric and Differential Thermal Analyzer (Diamond Series, Perkin Elmer, USA) with heating rate of 10 °C/min and gas flow rate at 20 ml/min in the temperature range from 35 to 800 and 900 °C for pure and composite samples respectively. By applying silver paste on pellets of 10 mm diameter, dc conductivity of these samples was measured by two-probe method using Keithley 2400 source meter. The dielectric measurements were carried out using Agilent, E4991A RF impedance/material analyzer (frequency range 1 MHz–3 GHz). Magnetic properties of these samples were studied at room temperature using a vibrating sample magnetometer (VSM, Lakeshore 7407) with a maximum magnetic field of 15 kOe. (Elahi, 2017).

V. CHERECTRESTIC OF POLYMER BASE FERRIDE

A. Preparation

The example of polymer is NiZnFe2O4 having the general formula Ni1−xZnxFe2O4 for various x D 0 to 1 in steps of 0.2 were prepared by employing ceramic techniques. For the preparation of NiZnFe2O4 appropriate amounts of analytical reagent (AR) grade precursors namely iron oxide, nickel oxide and zinc oxide were employed. These were mixed thoroughly in an agate mortar to produce a homogeneous mixture of fine particles. This homogeneous mixture was preferred at 773 K for 5 h. These pre-sintered powders were then finally sintered at 1273 ± 15 K for 24 h.

B. Structural characterization

Structural parameters and the identification of the phase were carried out by using XRD. The x-ray diffract grams of these powder samples were recorded on a Philips (PW1130) x-ray diffract meter using CuK radiation, D = 1:5418 Å. The particle sizes of the ceramic samples were determined using Scherer's formula.

C. Incorporation of ferride in rubber matrix

Powder samples of Ni1−xZnxFe2O4 prepared by the mixed oxide route were dispersed in a butyl rubber matrix for various loadings of the magnetic filler such as 20 phr, 40 phr, 80 phr, 120 phr (phr—parts per hundred rubber by weight) according to a specific recipe. The mixing of rubber with ceramic Ni1−xZnxFe2O4 was carried out by employing a Brabender plasticorder. The details of the Brabender plasticorder are given elsewhere (Mathew, 1990). The recipe and conditions for mixing are cited elsewhere (Anantharaman M R, 1999).

D. Dielectric characterization

The dielectric properties of ceramic nickel zinc ferrites and the RFCs were studied using a dielectric cell and an impedance analyzer (model: HP 4192 A) in the frequency range 10 kHz to 13 MHz. A sample cut in the form of a circular disc having a diameter of 10 mm was loaded into the dielectric cell. The lead and fringe capacitance was eliminated by a method described by Ramasastry and Syamasundara Rao. The capacitance at room temperature was measured in the frequency range 1 kHz to 13 MHz. This was repeated at different temperatures: 333, 363, 393, 423, 448 and 473 K. The dielectric constant was calculated using the formula

$$C = \varepsilon_0 \varepsilon_r A/d$$

Where A is the area of the sample piece used, d is the thickness of the sample, . ε_r is the dielectric constant of the medium, ε_0 is the dielectric constant of air, and C is the observed capacitance of the sample. The dielectric constants at different temperatures were also determined at different frequencies.

VI. COUNCLUSION

- The conduction mechanism has been explained according to the three-dimensional hopping model proposed by Greaves.
- The magnitude of magnetoelectric coupling depends on the concentration of barium titanate and neodymium in the bismuth ferrite structure.
- The dielectric constant of the composite as well as the filler increases with an increase of temperature. For blank butyl rubber the dielectric constant decreases with an increase of temperature, because in non-polar dielectrics, due to thermal expansion of matter, the ratio of the number of molecules to the effective length of the dielectrics diminishes with an increase of temperature.

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