International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8, Issue-1C, May 2019

Low-Density Polyethylene/Zinc Ferrite Nanocomposites Prepared for Structural, Morphology and Electrical Studies

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Abstract*: The structural, morphological and electrical properties of low density polyethylene (LDPE) /Zinc Ferrite(ZnFe2O4) nanocomposites (NCs) prepared via solution casting are studied. The prepared composites were characterized by powder X-ray diffraction (PXRD), scanning electron microscopy (SEM), TEM and Fourier transform infrared spectroscopy(FTIR) for theanalysis of their structure, morphology and chemical composition with various modes of vibrations. The PXRD measurement confirms that the compound shows spinel cubic phase belong Fd3m (227) space group. Morphology of the NCswas studied with help of SEM and surface profile which reveals thatthe compound composed of nearly spherical agglomerated particles with well-defined grains andgrain boundaries. TEM analysis carried out to study the layered structure of NCs. The frequency dependent AC conductivity measurements were carried out on the NCs at various temperatures.Conductivity is increased with temperature. The present study facilitate in selecting the suitable materials for the nano electronics and spintronic applications.

Index Terms*: LDPE, morphology, solution casting, zinc ferrite.

I. INTRODUCTION

The low-density polyethylene (LDPE) is a polymer attracting many researchers for its significant properties and wide range of applications. It can becommercially produced by co-polymerization of ethylene and higher 1-olefin using metallocene catalysts [1]. LDPE is one of the bestand widely used polyolefin in many applications, especially for plastic films [2]. Due to low mechanical strength, low thermal resistance and poor optical properties, sometimes the use of polyolefin or LDPE may be limited in the pure form. In order to improve the properties of these polymers, the addition of some fillers is required and being known as the polymer composites [3]. Addition of nano composites into the polymer composites are shows good results and well recognized as polymer nanocomposites. Polymer nano composites exhibit large surface area to volume ratio which compare to various fillers. Inorganic oxide materials at nano regime were effectively examined because of their potential applications and logical interests.

Due to the size impact these materials exhibit good physical and chemical properties [4, 5]. NCs comprising of LDPE (natural material) with ZnFe2O4 NPs (inorganic-oxide nano-material) researched increasingly on the grounds that their properties are very not quite the same as LDPE and comparing ZnFe2O4 NPs NPs attributable to interfacial interactions among the LDPE and ZnFe2O4 NPs NPs.due to the direct synthesis via polymerization along with the presence of nano materials.

Hybrid composites of polymer and inorganic nano oxides have been broadly utilized as a part of the different fields, for example, military types of gear, safety, defensive suits of clothing, car, aviation and optical gadgets as a result of their exceptional properties rising up out of the combination of natural and inorganic hybrid materials.For utilizing in various application zones consistently request extra properties and capacities, for xample, high mechanical properties, fire hindrance, resistance to chemicals and various radiations,ecological steadiness, water repellency, electro-magnetic field resistance. In addition, powerful features of the polymer and inorganic oxide nano-particles hybrid composites are dependent upon the constituents and their volume fraction,geometrical structure and incorporations of matrix and filler material, surface interactions among the matrix and inclusion. With the ongoing advancements in the materials science, the relationship of material properties with fille estimate has turned into a convergence of huge intrigue [1-2].The aim of the present work is to prepare LDPE / ZnFe2O4 polymer nano ferrites by solution casting method and to study the structural, morphological and electrical transport properties in detail..

II. EXPERIMENTAL ANALYSIS

High purityanalytical grade chemicals were used and purchased from Sigma Aldrich, India. The chemicals received were used as such without further purification.

Revised Manuscript Received on May 23, 2019.

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A. Combustion synthesis of $ZnFe_2O_4$ nanoparticles (NPs)

Low temperature combustion route is utilized to prepare $ZnFe_2O_4$ NPs using organic fuel. 2.14 grams of Zinc nitrate and Ferrous nitrate was taken in a ceramic crucible and 15 ml of organic fuel was poured into the crucible, mixed homogeneously.

Obtained reaction mixture was introduced to the already heated muffle furnace whose temperature was maintained at 400 0C. Here, combustion reaction takes place between metallic nitrates and fuel yielding nanopowders of $ZnFe_2O_4$.The chemical reaction of synthesis process is represented by:

$$Zn(NO_3)_2.6H_2O_{(aq)}+2Fe(NO_3)_3.9H_2O_{(aq)}+4C_2H_6N_4O_2(aq)\rightarrow ZnFe_2O_{4(s)}+36H_2O_{(g)}+12N_{2(g)}+8CO_{2(g)}\text{---------}(1)$$

B. Characterization

The powder XRD patterns of the present nano composites were recorded on Shimadzu PXRD-7000 modelfor the phase confirmation. Surface properties of hybrid nano composites such as morphology were analyzed using Scanning Electron Microscopy (SEM)and Transmission Electron Microscopy (TEM). The spectrograms of SEM were recorded on Hitachi-3000 model. TEM images were recorded on Hitachi H-8100 with accelerating voltage up to 200 KV. AC conductivity measurements were performed on pure and doped LDPE using Newton-PSM-1735 model LCR meter. The AC conductivity data calculated. The schematic illustration for the synthesis of LDPE/$ZnFe_2O_4$ NCs is shown in **Fig.1.**

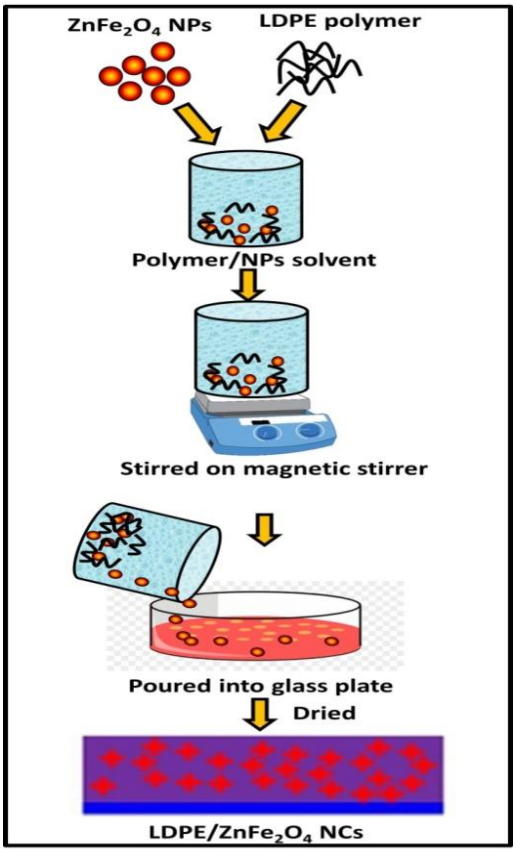

Fig.1. Schematic illustration for the synthesis of LDPE/ZnFe2O4 NCs.

III. RESULTS AND DISCUSSION

A. Structural analysis

Fig.1 represents the powder X-ray diffraction patterns(PXRD) ofthezinc nano ferrite compound. The search-match was done with crystallographic search-match of oxford cryo-systems. Further, Scherer's formula is used to estimate the average crystallite size [18]

$$D=0.9\lambda/\beta\cos\theta \text{……..} \quad (2)$$

whereβ, λ and θ are the full width at half maxima, wavelength of X-rays and angle of diffraction respectively. The strain induced the prepared NCs are estimated by utilizing the Williamson-Hall plot (Fig.2b) method [19].

---------- (3)

where, λ-wavelength of the X-ray radiation, β-full width at half maximum (FWHM) of PXRD peaks, ε-total strain present in the system.The estimated average crystallite size (D)and micro-strain of the prepared NCs are listed in Table.1.

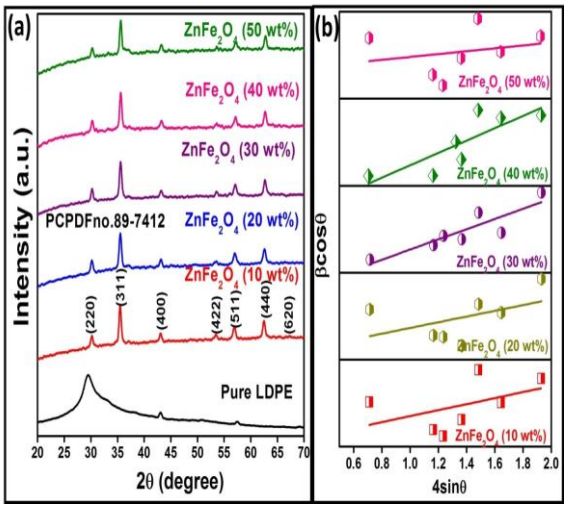

Fig.2 (a) PXRD patterns and (b) W-H plots of LDPE/ZnFe2O4 (10-50 wt%) NCs.

Table.1 The estimated average crystallite size and micro strain values of pure LDPE and LDPE/ZnF2O4 (10-50 wt %) NCs.

ZnF2O4 (wt %)	Crystallite size (nm)		Micro strain x 10-3
	Scherrer's method	W-H plots	
10	24	28	2.71
20	27	24	2.73
30	29	33	3.21
40	31	34	3.47
50	35	36	3.49

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B. Morphological analysis

Fig.3 shows the SEM micrographs of pure LDPE and LDPE/ZnF_2O_4 (10-50 wt %) NCs.It can be observed from the Fig.3 (a) that, for pure LDPE, a layered like structure was obtained.

If the filler ($ZnFe_2O_4$) concentration is increased for 10-50 wt %, micron sized particles with irregular shapes were deposited on the pure LDPE (Fig.3 b-f). For 50 wt % of $ZnFe_2O_4$ NPs, the particles with large density were observed on the surface of LDPE (Fig.3 f).

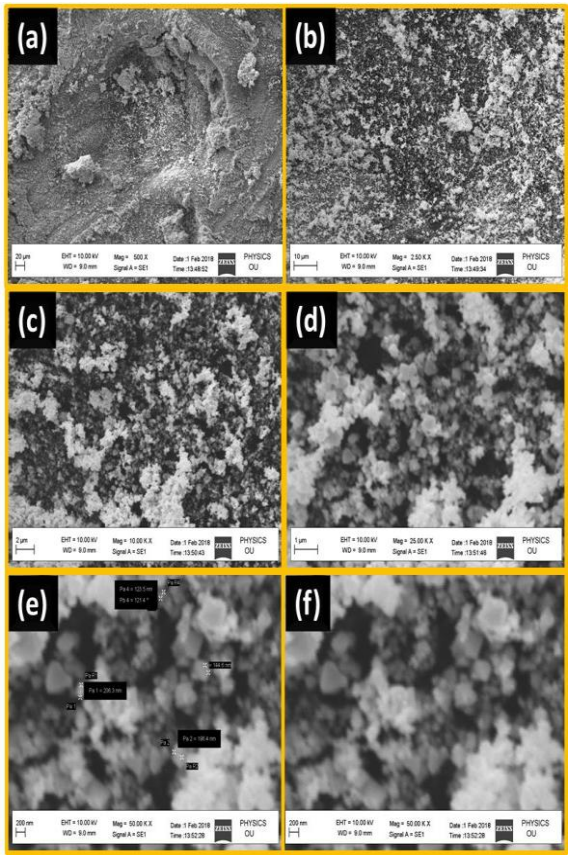

Fig.3 SEM micrographs of (a) pure LDPE, (b) 10 wt%, (c) 20 wt%, (d) 30 wt%, (e) 40 wt% and (f) 50 wt% of ZnFe2O4 NCs.

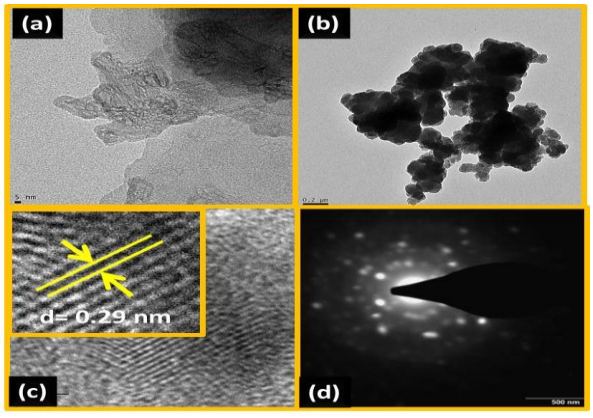

Fig.4 TEM images of (a) pure LDPE and (b) LDPE/ZnF2O4 (50 wt %) NCs. (c, d) HRTEM and SAED patterns of LDPE/ZnF2O4 (50 wt %) NCs.

To estimate the particle size, TEM analysis was carried out as shown in Fig.4. The TEM images of pure LDPE and LDPE/ZnF_2O_4 (50 wt %) NCs were shown in Fig.4 (a, b). From the figure, it was observed that, for pure LDPE a layered structure and for LDPE/ZnF_2O_4 (50 wt %) NCs agglomerated particles were observed. The particle size was found to be ~ 25 nm. The interplanar spacing (d) value is estimated to be ~0.29 nm as shown in Fig.4 (c). The crystalline nature is confirmed from the SAED patterns (Fig.4d).

C. Fourier transforms infrared (FTIR) spectroscopy

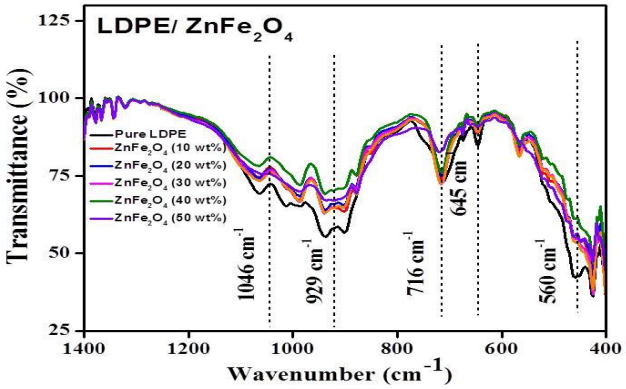

Fig.5 FTIR spectra of pure LDPE and LDPE/ZnF_2O_4 (10-50 wt %) NCs.

The FTIR spectra of the pure and doped nano ferrite composites are shown in Fig.5. The spectra of the pure and doped nano ferrite describe the vibrational modes of ions which are present. FTIR spectra give very useful in the investigation of the nature of the chemical bonds formed and their vibrations of various types of materials such as polymers, glasses and ferrites. In the present study, the absorptionbandobservedat560cm-1,. The intrinsic stretching vibrations of the metal were generally observed at the tetrahedral sites Mtetra↔O (v1 → 700-645 cm-1) and octahedral stretching Mocta↔O (v2 / 450-400cm-1).It confirms that only localized burning has occurred with out the presence of oxidant that helps to start high temperature self-propagationre action.

D. Electrical properties

Fig.6shows the frequency dependent AC conductivity of LDPE/ZnFe2O4 (10-50 wt %) NCs. Conductivity of LDPE/ZnFe2O4 (10-50 wt %) NCs remain constant up to the frequency of 2x104 Hz. At higher frequencies i,e above 2x104 Hz, there is an increase in the conductivity. Maximum conductivity showed for LDPE/ZnFe2O4 (10-50 wt %) NCs (40 wt %) samples may be due to the chain length that can be confirmed from IR graph.
Increased conductivity may be due to increased charge

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polarization.

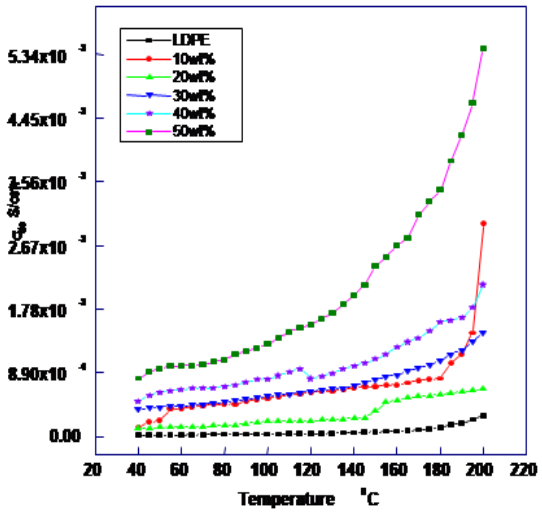

Fig.6 AC Conductivity studies of LDPE and LDPE/ZnF2O4 (10-50 wt %) NCs.

IV. CONCLUSIONS

Nano-$ZnFe_2O_4$compound with stoichiometric composition was successfully prepared by self-sustainable propellant chemistry technique. XRD patterns confirmed the inter planar spacing (d) value to be ~0.29 nm. TEM analysis confirmed that thepure LDPE show layered structure and for LDPE/ZnF_2O_4 (50 wt %) NCs agglomerated particles were observed. The particle size was found to be ~ 25 nm. SEM micrographs of pure LDPE and LDPE/$ZnFe_2O_4$ (10-50 wt %) NCs confirmed that the addition of nano particles to LDPE causes the deposition of irregular shaped particles on LDPE and increase of density. The FTIR spectra of the ferrite describe the vibration mode of ions in the spinel lattice and the deformation of spinel structure. Maximum conductivity observed for 40wt%nano particles in LDPE/$ZnFe_2O_4$. AC conductivity measurements confirmed that charge polarization takes place in the NCs and also Conductivity is increased with temperature as well as frequency.

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