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Investigation of structural and magnetic properties of TiO_2 supported Zinc ferrite

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ABSTRACT

Nanocrystalline TiO_2 loaded $ZnFe_2O_4$ was synthesized by wet chemical process. Phase formation study was carried out by using x-ray diffraction technique and it's reveals that TiO_2 properly supported on the surface of zinc ferrite. Nano sized two different layers such as cubic zinc ferrite and TiO_2 were confirmed by transmission electron microscopy technique. Magnetic data for all samples indicates that ferromagnetism was decreases with increasing non magnetic titania. In this manuscript detailed study of structural and magnetic properties of TiO_2 supported Zinc ferrites nanocomposites samples were investigated.

Introduction

Mixed-metal oxides having general formula AB_2O_4, were A is divalent metal ion, B is trivalent metal ion and O^{2-} is oxide ion. In these mixed-metal oxides Iron is main element, therefore this materials is called as ferrites. In our earlier research work, we have synthesized various mixed-metal oxides or ferrites such as $Li_{0.5}Fe_{2.5}O_4$, $Li_{0.5}Mn_{2.5}O_4$, $CoFe_2O_4$, $ZnTiFeO_4$ and $ZnCrFeO_4$ [1-5].The structural, magnetic and electrical properties of theses ferrites were based on method of preparation, sintering temperature, atmospheric conditions, complexing agent and purity of metal salts.

Several researchers have prepared different nano-sized ferrites by physical and chemical methods such as co-precipitation [6], sol-gel [7], microemulsion method [8], hydrothermal [9], spray pyrolysis [10], reverse micelle[11], precursor [12], combustion synthesis [13] etc. Out of all methods, our interest only in citrate-gel method because this method is superior than others, not require any sophisticated instrument, obtained homogenous uniform grains and require low sintering temperature.

In this article, we have synthesized 10, 20 and 30% TiO_2 supported zinc ferrite by citrate-gel and impregation method. After synthesis, structural properties of all samples were characterized by XRD and TEM analysis. Magnetic study was carried out by using Vibrating sample magnetometer. This research work was already published in one reputed journal [14] but dielectric permittivity study for 10, 20 and 30% TiO_2 supported zinc ferrites nanocomposite samples are not available in literature.

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Therefore, our interest was synthesizing such type of nanocomposites and study their structural and magnetic properties are investigated in this manuscript.

2. Experimental

Crystalline zinc ferrite was synthesized by citrate gel auto-combustion method. High purity (AR grade) ferric citrate, zinc nitrate, citric acid were used as raw materials. The stochiometric amounts of individual metal nitrates and metal citrate were dissolved in doubly distilled deionized water to get a clear, transparent solution. The solution of citric acid was added to separate metal nitrate solutions to form metal-citrate complex. The above solutions were mixed together with constant stirring to get a homogeneous mixture. The mixture was heated slowly upto 373 K to obtain a fluffy mass and combusted to get the dry powder. This sample was further annealed at 973 K for 4h. TiO_2 coating was done by sol–gel hydrolysis of titanium isopropoxide (Ti $(OC_3H_7)_4$) on ferrite nanoparticles followed by calcination treatment. Zinc ferrite nanoparticles were dispersed in titanium isopropoxide-isopropanol mixture (1:1 molar ratio). Water was slowly added to the above suspension under constant stirring. The resulting material was dried and calcined at 873K for 4h in air. Different concentrations of TiO_2 were loaded on zinc ferrite (10 to 30% by weight) to find out the optimum concentration of TiO_2 required.

X-ray diffractometer (Philips model PW-1710) was used to identify the phases and the crystalline nature of the samples using Cr Kα radiation. Particle size was measured using a transmission electron microscope (TEM) (Philips, CM200, Operating voltages 20-200kv). The high field vibrating sample magnetometer (VSM) (LAKESHORE-Model: 7404) at a maximum applied field of 15KOe was used to measure the saturation magnetization, coercivity and remnant magnetization of all the samples.

3. Results and discussion

3.1 XRD studies

10, 20 and 30 percentage of TiO_2 on $ZnFe_2O_4$ nanoparticles. The diffraction pattern of $ZnFe_2O_4$ shows peaks corresponding to planes (111), (220), (311), (222), (400), (422) and (333) confirming the formation of spinel zinc ferrite (JCPDS Patterns No. 22-1086). Diffraction peaks corresponding to planes (101), (020) and (200) of anatase titanium oxide besides that of $ZnFe_2O_4$, are seen in the TiO_2 coated samples indicating the biphasic nature of the samples.

3.2 Transmission Electron Micrographs Study

Fig. 2 (a and b) depict the transmission electron micrographs of zinc ferrite and TiO_2 on $ZnFe_2O_4$ samples. It is evident from **Fig 2a** that the average particle size of zinc ferrite is around 80 nm. The superimposition of the bright spot with Debye ring pattern seen in the SAED pattern indicates polycrystalline nature of the sample. Formation of a single phase of zinc ferrite can be further confirmed from the SAED pattern of this sample. **Fig 2b** clearly shows the presence of a dispersed phase of TiO_2 on $ZnFe_2O_4$. The particle size of TiO_2 is estimated to be around 10 nm.

3.3 Magnetic study

Magnetic properties of the uncoated and anatase TiO_2 coated zinc ferrite as measured by VSM are shown in **Fig. 3.** From this figure, it can be seen that all samples showed two magnetic components. At low applied fields, a ferromagnetic behaviour is seen whereas at higher applied fields, a conversion to paramagnetism is observed. The magnetic parameters such as coercivity and remanent magnetization have very low values indicating that these are soft magnetic materials.

Conclusions

A composite of TiO_2–$ZnFe_2O_4$ ferrites of nanocrystalline nature were synthesized by sol-gel method. Phase formation was studied by using x-ray diffraction analysis. Transmission electron micrographs indicated the presence of a dispersed phase of TiO_2 on $ZnFe_2O_4$. As the samples have ferromagnetic properties at low applied fields.

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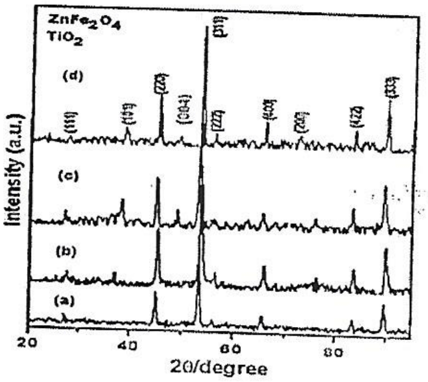

Fig 1. Powder XRD patterns of (a) ZnFe$_2$O$_4$ (b) 10%TiO$_2$ ZnFe$_2$O$_4$ (c) 20%TiO$_2$ – ZnFe$_2$O$_4$ & (d) 30%TiO$_2$ -ZnFe$_2$O$_4$

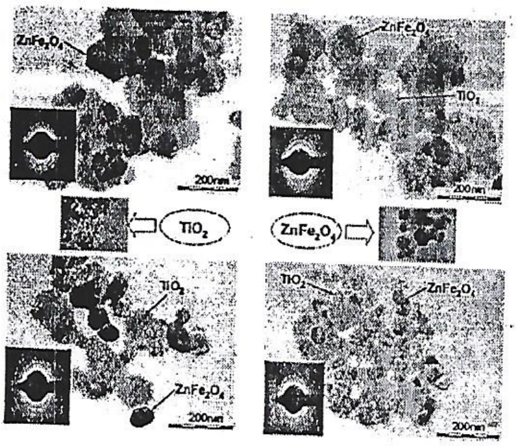

Fig 2. TEM micrographs of ZnFe$_2$O$_4$ and TiO$_2$ -ZnFe$_2$O$_4$

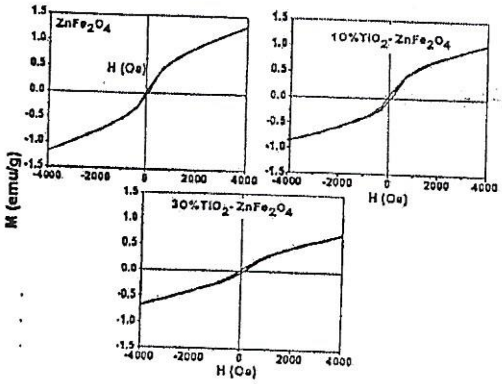

Fig 3. Magnetization as a function of applied magnetic field for (a) ZnFe$_2$O$_4$ (b) 10%TiO$_2$ -ZnFe$_2$O$_4$ & (c) 30%TiO$_2$ -ZnFe$_2$O$_4$

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