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Optical Properties and Potential Applications of Nanoferrites

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The real challenge of researchers of nanotechnology lies in fabrication of nanometre-scale particles and their controlled interaction with each other and with surroundings. Nanoferrites are found to showcase superior and substantially distinct electrical and magnetic properties. Historically, the industrial usage of magnetic and electrical materials was based mainly on iron and its alloys [1]. But the conventional methods of minimising losses due to eddy current could no longer be utilized competently and economically at high frequency operations [1]. This limitation stimulated interest in "magnetic Insulators" which were first testified by Hilpert in 1909 [1]. The researchers combined metal oxides having high value of electrical resistivity with preferred magnetic features to devise magnetic material, suitable for high frequency applications. The generic molecular formula of ferrites is presented as $M^{2+}OFe2^{3+}O_3$ whereas, chemical formula is typically given as MFe_2O_4, where M represents the divalent metal ions like Cu^{2+}, Fe^{2+}, Ni^{2+}, Co^{2+}, Zn^{2+}, Mn^{2+}, Mg^{2+} etc. [2]. Magnetically recyclable $ZnFe_2O_4$/ZnO nanocomposites, immobilized on different contents of graphene, validate favourable photo-catalytic activity under solar light irradiation [3].

The theoretical concept for logical understanding of such magnetic materials was provided by the Neel theory of ferromagnetism in 1948 [1]. The nature of these ferrites basically resembles with that of ceramics. These are homogeneously constituted of different oxides with iron oxide as their prime composition. The soft ferrites can be categorised into two major parts based on their chemical compositions: nickel-zinc ferrites and manganese-zinc ferrites. By adopting different synthesizing techniques, various grades of NiZn- and MnZn-ferrite material are being synthesized by varying the chemical composition in both categories. The right from low audio frequencies to high hundred mega-hertz can be used by the two families of NiZn- and MnZn-ferrite materials as soft ferrites because they accompaniment each other well.

The spinel ferrites represent an important sub-class of ferrite materials. Mg-Mn ferrites belong to this class. Important magnetic properties evolve when these spinel ferrites are substituted with Al^{3+}, In^{3+}, Co^{2+} ions [2]. Optical band gap energy $Mg_{1-x}Zn_xFe_2O_4$ nanoferrite found to be in the range 4.77 to 4.95 eV for samples with different ratio of Mg and Zn [4]. Cu in the $Ni_{1-x}Cu_xFe_2O_4$ ferrites causes appreciable alterations in its structural and electrical properties [5]. It is experimentally confirmed that the Curie temperature increases with increase in doping concentration of cobalt ions. The strength of various magnetic exchange interactions can elucidate the cause of change in such property. With increase in doping concentration of indium and cobalt ions, the saturation magnetization increases whereas increase in concentration of aluminium ions decreases the saturation magnetization of ferrite. The increase in indium ion doping concentration also increases the magnetic permeability but enhanced aluminium and cobalt doping concentration give rise to continuous decrease of the permeability. The researchers have not yet found any ideal ferrite which could incorporate all the relevant electrical and magnetic properties. Experimentalists have further concluded that some ions enhance electrical properties while few other ions lead to improvement of magnetic properties. Superior ferrites, especially from application point of view, can be synthesized via simultaneous doping of such ions. Aiming this, researchers keep trying to achieve ferrites with such optimum properties.

Traditionally, the optical properties of nanoferrites have long been extensively employed for amazing coloring effects glasses and paints. Due to awareness of renewable solar energy worldwide in the 1970s, researchers worked a lot on nanoparticle optics. Nowadays, specific solar wavelengths are usually absorbed by the commercial coating made up of metallic nanoparticles. The application of novel sensors is also based on optical absorption of nanoferrites. Single molecule is being detected through surface enhanced spectroscopy due to presence of enhanced local fields in the vicinity of surface of the particle. High level of accuracy of models of optical properties is required in designing optical coatings. Application of nanoparticle based coatings can be further be optimized by making calculative changes in dimensional parameters. Different situations demand different classes of models due to complexity of optics [6].

The ferrite industry, which initially flourished in the 1950s, mainly due to massive demand of TV sets, as the Ferrite cores were being exhaustively used in TV sets. Of late, scientists have shifted their focus from bulk ferrites to nanoferrites. The significant differences are observed in the properties of bulk and nanoferrites synthesized by different techniques [2]. Use of electronic gazettes, radio, TV, video tape recorders and the internet technology by masses throughout the world changed the market scenario consequently, the demand of nano and bulk ferrites also increased. LC filter used in frequency division multiplex equipment required first commercial soft ferrite for its inductor [1]. The filters working in the frequency range of 50-450 kHz require both good magnetic properties as well as high resistivity. The present sophisticated technologies and software have enabled the modelling of unique optical properties and composites of nanoferrites. And, ultimately mankind could be gifted with novel and superior nanoferrites based devices where not only their core magnetic, magneto-electric, multiferroic but more notably their fusion with optical properties could also be harnessed.

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