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Dr. Rekha Rani
Assistant Professor, Department of Physics, SD (PG) College, Panipat, Haryana, India

Corresponding Author:
Dr. Rekha Rani
Assistant Professor, Department of Physics, SD (PG) College, Panipat, Haryana, India

Ferroelectric Rich Magnetoelectric Composites

Rekha Rani

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Abstract
Many of modern technologies require materials with unusual combinations of properties that cannot be met by the metals, conventional metallic alloys, ceramics and polymers e.g. Engineers working in aircraft industry are looking and searching for structural materials that have low densities, are strong, stiff and are not easily corroded. Obviously this is a rather formidable combination of characteristics i.e. they need any multiphase material that exhibits a significant proportion of the properties of constituent phases such that a better combination of properties is realized. A composite is a multiphase material that is artificially made, as to one that occurs naturally. In addition, the constituent phases in a composite must be chemically dissimilar. This is why most metallic alloys and many ceramics do not fit this definition because in these materials multiple phases are formed as a consequence of normal phenomenon.

Keywords: Thermoelectronics, semiconductor electronics, Stanislav Ordin

Introduction

Magnetoelectric Composites is a ceramic composite consisting of magnetostrictive and ferroelectric materials are observed to show a strong magnetoelectric effect. The magnetoelectric (ME) effect [1] is the variation of dielectric polarization under an applied magnetic field, or the presence of an induced magnetization under an applied electric field through a stress-mediated interaction.

The most widely studied ferrite-ferroelectric composite systems that have been reported correspond to composites of $NiFe_2O_4$, $CoFe_2O_4$, $MnFe_2O_4$, $ZnFe_2O_4$ ferrites and terfenol with PZT, PMN-PT, PVDF and $BaTiO_3$. The present study is concerned with the synthesis of bulk lead zirconate titanate and nickel zinc ferrite composites and studies of the structural, dielectric, ferroelectric and ferromagnetic properties of these composites. PZT has been selected due to higher resistivity, stronger dielectric and piezoelectric properties as compared to other ferroelectrics. Further, by varying Zr/Ti ratio and substitution of some suitable ions improves its piezoelectric and dielectric properties. Furthermore, zinc doped Nickel ferrite particles are very stable in the PZT matrix and do not react even at high sintering temperature, have high resistivity and high piezomagnetic coefficient.

Owing to their special electronic configurations, the substitutions at different sites (for both phases) can modify the properties of composite ceramics so that they can be utilized in number of multifunctional applications.

Review of Research and Development

From 2000 onwards, the field of magnetoelectrics is in limelight and extensive work has been done and reported by a number of research groups. Number of publications per year on magnetoelectrics is also increasing drastically because this topic is attracting researchers from both groups i.e. of ferroelectricity and magnetism. Kothale *et al.* [2] studied ME composites of $Cu_{0.6}Co_{0.4}Fe_2O_4 + Ba_{0.8}Pb_{0.2}TiO_3$ and the maximum value of ME coefficient was observed for 15% ferrite + 85% ferroelectric phase. Tang *et al.* [3] showed the frequency dependence of ME effect in $CoFe_2O_4/Ba_{0.55}Sr_{0.25}Ca_{0.2}Nb_2O_6$ composites. The 50%$CoFe_2O_4$–50%$BaTiO_3$ composites with four different building structures, namely: $CoFe_2O_4$–$BaTiO_3$ core–shell structure with $CoFe_2O_4$ in core, $BaTiO_3$–$CoFe_2O_4$ core–shell structure with $BaTiO_3$ in core, $CoFe_2O_4$–$BaTiO_3$ mixed structure, and $BaTiO_3$–$CoFe_2O_4$–$BaTiO_3$ layer structure have been synthesized and studied by Duong *et al.* [4].

The core–shell structures give higher magnetoelectric (ME) coefficients compared to the other structures. Duong *et al.* [5] also studied the effect of preparation conditions on the microstructure of samples and the coupling between two phases (magnetostrictive and piezoelectric). Bonaedy *et al.* [6] systematically studied composites of $Ba_{0.6}Sr_{0.4}TiO_3$ and $La_{0.7}Ca_{0.3}MnO_3$ (where constituents $Ba_{0.6}Sr_{0.4}TiO_3$ and $La_{0.7}Ca_{0.3}MnO_3$ have nearly the same ferroelectric and ferromagnetic Curie temperatures). Magnetoelectric composite of $CoFe_2O_4$ and strontium doped $BaTiO_3$ were synthesized and studied by Kanamadi *et al.* [7]. Gridnev *et al.* [8] reported magnetic and magnetoelectric properties of particulate $PbZr_{0.53}Ti_{0.47}O_3$–$Mn_{0.4}Zn_{0.6}Fe_2O_4$ composites. CFO/PZT multiferroic composite thick films assisted by poly vinyl pyrrolidone were prepared by hybrid sol–gel processing and spin coating technique by Chen *et al.* [9]. The dynamic and static magnetoelectric effects were strongly dependent on the applied dc/ac magnetic field but their values were very low. Recently Chao *et al.* [10] experimentally studied the phase structure, microstructure, piezoelectric properties, dielectric characteristic and the ME effect of magnetoelectric $Pb[Zr_{0.23}Ti_{0.36}+0.02(Mg_{1/2}W_{1/2}) + 0.39(Ni_{1/3}Nb_{2/3})]O_3$ and $Ni_{0.8}Co_{0.1}Cu_{0.1}Fe_2O_4$ composites. Sheikh *et al.* [11] systematically studied magnetoelectric composite system $CoFe_2O_4+Pb(Mg_{1/3}Nb_{2/3})_{0.67}Ti_{0.33}O_3$.

Work is going on at a number of academic and R & D centers. Multiferroic magnetoelectric group at School of Chemistry and Materials Science, Shaanxi Normal University, China has done pioneer work in this area. Group working at Institute of Electron Technology (Poland), Institute of Materials Research Engineering (Singapore) and Department of Materials Sciences and Engineering (Zhejiang University, Hangzhou) have done a lot of work on the magnetoelectric composites. Work on the development of composites is going on at number of material research centers, CSIR labs, DRDO Labs. Work being pursued at these centers is mainly of applied nature. Work is also going on in IIT Delhi and number of other Universities and Institutions. IIT Delhi and IIT Kanpur have reported a number of composite materials based on bulk and thin films.

Significance of the Study

There are innumerable materials that show ferroelectric properties or ferromagnetic properties but in recent years, materials having coexistence of ferroelectricity and magnetism simultaneously have been drawing increasing interest due to multifunctional behavior. There are many ideas for device applications [12-19] based on magnetoelectric effect due to their multifunctionality. Some of the applications of magnetoelectric materials include ac magnetic field sensors, multiple state memory elements, transducers, electro-optic devices, magnetically tuned capacitor, electrically tunable microwave devices such as filters, oscillators and phase shifters.

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