ABSTRACT

The present research work reports on synthesis of Fe_3BO_6 crystallites with a bonded surface layer (B_2O_3 or carbon) in a shape of nanoplates, nanobars and nanorods, and their characterization with thermal, magnetic, dielectric, electrical, optical, and gas sensing properties. An idea behind selecting such unique multifunctional material includes both technological and fundamental aspects. A surface layer develops surface magnetism with a localized distribution of electronic charges so it tunes magnetodielectric and other useful properties for gas sensors, catalysts, color pigments, and electronic devices.

The structural (in terms of X-ray diffraction and microstructure), thermal, magnetic, dielectric, electrical, optical, and gas sensing properties on the Fe_3BO_6 samples prepared under selective experimental conditions are presented in five different Chapters 3-7. The work is supported with a general introduction in Chapter-1 on the basic research interest and overview of the work done on different iron oxyborates, typical properties of nanomaterials, a statement of the problem, a literature review along with the motivation behind choosing the present research work, and several intriguing properties and applications of such materials. The sample preparations and measurements/analyses of selective properties are briefed in Chapter-2. The results of phase formation and structural analysis of the various Fe_3BO_6 samples are described in Chapters-3 while those of the magnetic properties are included in Chapter-4. It is demonstrated that a bonded surface layer stabilizes the surface spins in small crystallites so as it promotes a canted spin structure over Fe^{3+} sublattices. At room temperature, a sample Fe_3BO_6 of nanoplates with a bonded B_2O_3 surface layer (3-5 nm thickness) behaves to be a highly antiferromagnet. The surface magnetism shares a very small magnetization of an order of $< 5\times10^{-4}$ emu/g in an open hysteresis loop with a huge coercivity $H_c \sim 1.643$ kOe. The electrical and dielectric properties of the various Fe_3BO_6 samples are described in Chapter-5. At low frequencies such as 100 Hz, the Fe_3BO_6 nanorods exhibit a markedly large dielectric permittivity of 40,000, i.e. compatible to, or even larger than high permittivity dielectrics. Fe_3BO_6 with antiferromagnetic spin-ordering seems a futuristic candidate material of magnetodielectrics of a single compound. Temperature dependent impendence describes an ionic Fe_3BO_6 conductor, with small $E_a \sim 0.18$ eV, when it is crystallized from an iron borate glass. An enhanced value $E_a \sim 0.73$ eV is observed in the sample obtained from a self-propagating combustion of a solid precursor with camphor in open air. Chapter- 6 describes the electron absorption, IR, Raman, and XPS spectra of the various samples. The XPS bands in Fe^{3+}, B^{3+} and O^{2-} species and IR bands in the oxygen polygons confer the results of forming Fe_3BO_6 with a bonded surface B_2O_3 layer. The gas sensing Fe_3BO_6 properties described in Chapter-7 elucidate a reasonably good sensitivity for methane. A summary of the work and important implications achieved in this work are reported in the last Chapter-8 along with future scope of the work in this series.

Keywords: Iron oxyborate, Canted antiferromagnet, Magnetodielectrics, Core-shell nanostructure, Ionic conductor, and Gas sensing properties