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Title of Thesis: **Synthesis, Characterization and Properties of Nanocrystalline Multiferroic Compounds**

## Abstract

Multiferroic materials have attracted considerable interest and gained attention due to their potential applications for new device development based on the novel electromagnetic properties. Many efforts have been put forward in synthesizing and finding of new multiferroic materials with unexplored multiferroic properties and have a wide range of applications including data storage, transducers, actuators, non-volatile memory and gate ferroelectrics in field-effect transistors.

**Chapter 1** (Introduction) presents the background of the thesis with an introduction to nanomaterials, multiferroic compounds, synthesis methods like polymeric citrate precursor and reverse micellar methods which were used in this work, followed by the characterization techniques, properties and applications which have been discussed and studied in the subsequent chapters. In **Chapter 2** report the synthesis of multiferroic $YMO_3$ (M = Fe, Cr & Mn) nanoparticles by metal organic precursor method. PXRD and FTIR studies showed that the as-prepared nanoparticles with orthorhombic structure of $YFeO_3$ and $YCrO_3$ while hexagonal structure was obtained for $YMnO_3$ after calcined at desired temperature. Dielectric properties as a function of temperature and frequency were also established in $YMO_3$ (M = Fe, Cr & Mn) nanoparticles, with addition of conductivity and impedance. Ferromagnetic and room temperature ferroelectric interactions clearly indicate the multiferroic existence in as-prepared nanoparticles. In **Chapter 3** $YFeO_3$ and $YCrO_3$ nanoparticles have been prepared successfully by the low temperature reverse micellar method using tergitol as the surfactant for the first time. Electronic microscopic techniques (TEM, SEM and SAED) and BET surface area studies show that the $YFeO_3$ and $YCrO_3$ nanoparticles were uniform with high surface area. The evolutions of magnetic properties suggest that $YFeO_3$ and $YCrO_3$ nanoparticles show

weak ferromagnetic behaviour. The P-E hysteresis loops at room temperature exhibits ferroelectric nature which indicates the multiferroic existence. The variation of dielectric properties with temperature at different frequencies has also been discussed. In **Chapter 4** deals the synthesis of $GdFeO_3$ and $GdCrO_3$ nanoparticles by ethylene glycol-assisted metal citrate precursor method. The reverse micellar synthesis of $GdFeO_3$ nanoparticles is also discussed. The as-prepared nanoparticles have been characterized for phase purity as well as for the presence of secondary phases by using powder X-ray diffraction (XRD) and FTIR studies. Magnetic results of $GdFeO_3$ and $GdCrO_3$ nanoparticles possess the well defined ferromagnetic loops, which confirm the ferromagnetic characteristics in these nanoparticles. Our results further exhibit improved P-E loop for $GdFeO_3$ and $GdCrO_3$ nanoparticles showing ferroelectric behaviour at room temperature for the first time which indicates the presence multiferroic nature. In **Chapter 5** discussed the monophasic synthesis of $TbFeO_3$ and $TbCrO_3$ nanoparticles by low temperature synthesis route. The presence ferromagnetic and room temperature ferroelectric orders makes $TbFeO_3$ a truly multiferroic material and may be potentially interesting in reading-writing memory devices. In **Chapter 6** we have successfully synthesized monophasic and highly nano-crystalline oxides of $DyFeO_3$ and $LaMnO_{3+\delta}$ by metal citrate polymeric-organic precursor and reverse micellar methods. High surface area has been achieved for these nanoparticles for the first time. Magnetic measurements indicate that all the samples showed ferromagnetism which was confirmed by excellent hysteresis loops and M-T plots. Room temperature ferroelectricity in $DyFeO_3$ nanoparticles is obtained for the first time which confirms the multiferroic existence in these nanoparticles. In **Chapter 7** discussed the use of reverse micellar and polymeric citrate precursor routes to prepare monophasic $BiFeO_3$ and $LuFeO_3$ nanoparticles. X-ray studies showed the formation of single-phase and well-crystallized $BiFeO_3$ and $LuFeO_3$ nanoparticles. Large surface area of 205 $m^2g^{-1}$ and 214 $m^2g^{-1}$ were found using BET surface area studies with optical absorption band gap of 2.1 eV respectively for both $BiFeO_3$ and $LuFeO_3$ nanoparticles. The electrical properties like dielectric constant and dielectric loss were measured as a function of temperature and frequency. Room temperature ferroelectricity was found in $BiFeO_3$ and $LuFeO_3$ nanoparticles for the first time.