Abstract

The present thesis explores the synthesis and the characterization of the high- and low-temperature magnetoelectric core@shell nanoparticles, having $CoFe_2O_4$ as a ferrimagnetic core and $BaTiO_3$ (high-temperature) or $NiFe_2O_4$ (low-temperature) ferroelectric shell. The $CoFe_2O_4$@$NiFe_2O_4$ nanoparticles show magnetoelectric coupling below 20 K, and it is an exchange magnet at room temperature, making it an exciting system with multiple applications based on the temperature. To explain the origin of the magnetoelectric coupling and how to control it, first, the magnetic properties of the core were thoroughly studied, and the results are part of this thesis. Firstly, the study of the size dependence of the surface anisotropy constant and surface disorder is reported for three $CoFe_2O_4$ nanoparticle sizes, having the same shape, chemical composition, percentage of surfactant in the absence of interparticle interactions. Within this study, the influence of particle size on the surface spin disorder was observed for the first time. Furthermore, experimentally, it was proven that the surface anisotropy constant is size-independent in the nanoparticle's studied size range. The second part of the thesis concerns the heating release of cubic $CoFe_2O_4$ nanoparticles for magnetic hyperthermia applications. The particles were able to produce 42 °C in 3 minutes, and according to cytotoxicity and biocompatibility tests, the sample shows good biocompatibility and low cytotoxicity, and thus, it is a promising candidate for hyperthermia applications. The next part of the thesis is dedicated to multiferroics materials, focusing on the structural and magnetic studies of Re-substituted $BiFeO_3$. Further thesis emphasis is given to the disentanglement of the anisotropy contributions in Mn-mixed ferrite nanoparticles. Finally, the thesis focuses on the synthesis and characterization of magnetoelectric $CoFe_2O_4$@$BaTiO_3$ and $CoFe_2O_4$@$NiFe_2O_4$ core@shell nanoparticles systems. The study of $CoFe_2O_4$@$BaTiO_3$ was unsuccessful in finding good and reproducible synthesis conditions, and thus $NiFe_2O_4$ was chosen as the material for the shell preparation. The choice of $NiFe_2O_4$ derived from the fact that $NiFe_2O_4$ shows a ferroelectric transition below 98 K, the lattice mismatch with the $CoFe_2O_4$ is tiny, and the synthesis of $NiFe_2O_4$ has been fully mastered. Thus, the choice of this material was a risk-free path toward the synthesis of monodisperse and homogeneous core@shell samples. Indeed, three different core@shell systems with homogeneous morphology and size distribution $< 20\%$ were prepared and fully characterized. The presence of magnetoelectric coupling was investigated in one sample, which showed ferroelectric transition and the presence of coupling at 10 K. As far as we are aware, this is the first time that the magnetoelectric coupling was detected in $CoFe_2O_4$@$NiFe_2O_4$ core@shell nanoparticles.

Keywords: magnetoelectric coupling; magnetoelectric materials; exchange-spring magnets; nanomagnetism.