Synthesis, structural, magnetic and optical properties of ($Bi_{1-x}Ho_x$)-ferrites

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Magnetoelectric multiferroics, due to simultaneous ferroelectric and ferromagnetic ordering, have attracted wide attention in recent years, offering a wide range of potential applications in data storage media, spintronics and multi-state memories [1]. One of the well-known materials exhibiting such properties is bismuth ferrite (BFO) $BiFeO_3$. Because of the technological progress in the direction of nanotechnologies our interest is to obtain this compound in a form of nanoparticles. Since those particles are thermodynamically stable only in a very narrow temperature interval, the main challenge is to obtain a high-quality, uniform, single-phase material. Here we report the hydrothermal synthesis of BFO and $Bi_{1-x}Ho_xFeO_3$ ultrafine nanopowders, with a diameter of ~ 300 nm with no tendency to agglomerate. The diffraction patterns show that all obtained particles belong to the *R3c* space group. Regularity of the particle's geometric shape was demonstrated by Scanning electron microscopy (SEM), while the high-resolution transmission electron microscopy (HRTEM) reveals an excellent crystallization with non-fragmented surfaces. Individual grain analysis confirmed the existence of an ultra-fine crystal structure, with an interplane distance of 0.297 nm (d = 0.297 nm), which corresponds to (012) crystal planes. Magnetometry revealed a magnetic phase transition at T_N= 220 K, from a paramagnetic to canted antiferromagnetic phase. Doping with Ho increased the value of magnetization showing that weak ferromagnetic moment grows with the introduced defects, originating from the non-compensated magnetic moments due to the distortions of both the spin-cycloid order and the super-exchange bridges. Both distortions promote the additional spin-canting and increase the magnetization. The optical properties of the material were examined by the spectroscopic ellipsometry method and the energy gap was found to be 2.71 eV. Using the structure prediction method, which is based on the bond valence calculations, 11 additional perovskite-related structure candidates in different space groups were obtained, including a novel tetragonal $BiFeO_3$ phase which has never been reported before. With this, we have demonstrated that the hydrothermal method has good potential in obtaining BFO, for achieving better properties for the multiferroic application and offers an overall conclusion that the local magnetic properties of nanoparticles mainly depend on the particle size and their diverse morphology due to the different preparation methods and annealing temperatures.

[1] T. Rojac, A. Bencan, B. Malic, G. Tutuncu, J.L. Jones, J.E. Daniels, D. Damjanovic, $BiFeO_3$ ceramics: processing, electrical, and electromechanical properties, J. Am. Ceram. Soc. 97 (2014).