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Shape-dependent magnetoelectric coupling in nanoscale $BiFeO_3$

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Abstract

The nanorods and nanocuboids of multiferroic $BiFeO_3$ exhibit remarkable shape dependence of crystallographic, ferroelectric, and magnetoelectric properties. The nanorods, for example, assume R3m space group (as against R3c observed both in bulk and nearly spherical nanosized particles) and are found to be oriented preferentially with long axis ∥ [101]. The magnetic and electric coercive fields as well as magnetoelectric coupling - measured from change in remanent polarization under a magnetic field - are found to be larger in nanocuboids. The shape dependence of multiferroic properties originates from that of microstrain and anisotropy.

1. Introduction

The interest in the room temperature multiferroicity of $BiFeO_3$ persisted [1] during the last decade and a half since 2003 [2] because of seminal observations such as electric-field-driven switching of magnetic domains in a single crystal [3] and complete 180^o rotation in an epitaxial thin film via a two-step process [4]. The size dependence of ferroelectric and magnetic properties together with magnetoelectric coupling has also been investigated thoroughly using either epitaxial thin films or isolated nanosized particles [5]. Interplay among size, strain, and dimensional effect gives rise to a rather complex phase diagram for crystallographic, electrical, and magnetic properties in nanoscale $BiFeO_3$. An intriguing issue, in this context, is the shape dependence of the properties. Nanosized particles of different shapes such as cubes, rods, wires, fibers etc have earlier been synthesized and their ferroelectric, magnetic, and even photocatalytic properties have been studied [6]. However, a thorough investigation of the shape dependence of multiferroic properties - especially, confronting the question: how shape of a particle is intrinsically influencing the magnetoelectric properties - in nanoscale $BiFeO_3$ is still missing.

In this work, we investigated the multiferroic properties of nanoscale $BiFeO_3$ using two different shapes with large variation in the aspect ratio - rods and cuboids. The crystallographic structure, ferroelectric and magnetic properties, and magnetoelectric coupling have been examined. The nanocuboids are found to possess stronger multiferroicity than the nanorods.

2. Experimental

We synthesized nanorods and nanocuboids of $BiFeO_3$ hydrothermally [7] without using any template. The $Bi(NO_3)_3.5H_2O$ and $Fe(Cl_3).6H_2O$ crystals were dissolved under stirring in 50 ml ethylene glycol and 10 ml polyethylene glycol in stoichiometric ratio. For the synthesis of nanorod,

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