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# Phase evolution and temperature dependent magnetic properties of nanocrystalline barium hexaferrite

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**Abstract**

Barium hexaferrite nanoparticles were prepared by the sol–gel auto combustion method and were annealed at different temperatures in air for 4 h. Structural properties showed the evolution of nanocrystalline Ba-hexaferrite with the increase in annealing temperature. The lattice constants did not show any systematic variation and the grain size increased with the increase in annealing temperature. The magnetization value increased with the increase in annealing temperature and the highest values of 58.9 and 82.7 emu/g were observed at 300 and 60 K respectively for the sample annealed at $T_A = 1200$ °C. The highest coercivity of 5250 Oe was observed at 300 K for the nanoparticle sample annealed at 950 °C with critical single domain size of 48 nm. The coervity decreased with the decrease in measurement temperature from 300 to 60 K. The observed magnetic behavior can be understood on the basis of grain growth, the exchange interaction between the $Fe^{3+}$ ions sitting at different lattice sites in the magnetoplumbite structure and inter-granular interactions in these nanoparticle samples.

## 1 Introduction

Magnetic anisotropy plays a significant role in deciding a magnetic material for permanent magnets, high density magnetic and magneto-optic recording [1–4]. Due to the high uniaxial anisotropy M-type barium hexaferrite ($BaFe_{12}O_{19}$) has attracted much attention. It shows very high coercivity ($H_c$) [5], magnetocrystalline anisotropy ($K_1$) [6], magnetization, Curie temperature [7], excellent chemical stability [8], high corrosion resistivity [9], and multiferroic behavior [10] which are suitable for many applications. The high crystalline anisotropy of Ba-hexaferrite comes from the distribution of $Fe^{3+}$ ions in five different crystallographic sites in the magnetoplumbite structure. The only magnetic ion $Fe^{3+}$ present in Ba-hexaferrite occupy five different lattice sites with Wyckoff positions 2a, 2b, $4f_1$, $4f_2$ and 12 k. The 2a, $4f_2$ and 12 k sites are octahedrally coordinated; $4f_1$ is the tetrahedrally coordinated; the 2b site is trigonal bipyramidal site. These five non-equivalent sites behave as five magnetic sublattices. Moreover the unit cell with two molecular units consists of two structural blocks; the spinel S block and the hexagonal R block. These blocks are stacked as SRS*R* to form the complete crystal structure; where * indicates a 180° rotation of the block around the c-axis. The R-block is in between two S-blocks which are 180° rotated to each other and similarly the S-block is in between two R-blocks which are also 180° rotated to each other. Five different magnetic sublattices and the way of stacking of the S and R blocks make the exchange coupled complex magnetic structure of Ba-hexaferrite. The superexchange interactions between the $Fe^{3+}$ ions sitting at these five different lattice sites in these four blocks explain its magnetic behavior. The magnetization decreases with the increase in temperature and becomes zero at $T_C = 723$ K (Curie temperature), with the weakening of superexchange interaction and the random orientation of magnetization in these five magnetic sublattices [11].

The magnetocrystalline anisotropy of the Ba-hexaferrite has been reported to be modified by substitution of different ions like $Zn^{2+}$, $Ni^{2+}$, $Gd^{3+}$-$Nd^{3+}$, $Sn^{4+}$,$La^{3+}$, $Ti^{4+}$ [12–18]. Depending on the site occupancy of these substituted ions the superexchange interactions between the $Fe^{3+}$ ions are modified and magnetic properties are tailored in these compounds. Temperature dependent superexchange interactions

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