Template Free Synthesis of Anisotropic Strontium Ferrite Nano Particles and Their Shape Influence on Materials Properties

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1. Introduction

Magnetic nano particles have been the focus of an increasing amount of the recent literature, which has chronicled into both the fabrication and application of magnetic nano particles. The exponential increase in research in this area is driven by the extensive technological applications of magnetic nano particles which include single-bit elements in high-density magnetic data storage arrays, magneto-optical switches, and novel photo luminescent materials and in bio medicine. Nano sized hard ferrite with hexagonal structure is a known high performance permanent magnetic material [1], owing to its fairly large magneto crystalline anisotropy, high Curie temperature, and relatively large magnetization, as well as excellent chemical stability and corrosion resistivity. For an ideal performance, hard ferrite particles are required to be of single magnetic domain, good chemical homogeneity and narrow particle size distribution. The interest in these nano size particles lies in our ability to affect their physical properties through manipulation of size, composition, shapes and aspect ratio to produce changes in overall physical properties. Here, we have synthesized the strontium ferrite ($SrFe_{12}O_{19}$) nano particles with different shapes like elongated hexagonal, rods, bipod, tripod and cubic shapes with the addition of 4% (volume) capping agent PVP (Poly Vinyl Pyrollidone) thro combustion technique. The materials shapes on materials property have been studied. In this synthesis technique, we have used citric acid as a fuel and the nitrate to fuel ratio has been maintained at 1:1, 1:2 and 1:3 and the pH of the starting solution was 7.

2. Experiment

For the preparation of strontium ferrite nano particles, analytical grade strontium nitrate $Sr(NO_3)_2$ of purity 99.5%, analytical grade ferric nitrate $Fe(NO_3)_3$ of 98% purity and analytical grade citric acid of 99.5% were used. A stoichiometric amount of strontium nitrate and ferric nitrate were first dissolved in distilled water. Citric acid was then added to this metal nitrate solution in 1:1 ratio. After complete dissolution of all starting materials an appropriate amount of nitric acid / ammonia solution was added drop wise to this solution with constant stirring until the pH of the solution was 7. The resulting solution was heated on a hot plate and maintained around 80 to 90°C for 3 to 4 hrs during which the transparent solution turned into viscous brown gel. The brown foam formed was kept at 150°C and allowed to ignite spontaneously by combustion of metal nitrates and fuel with the release of gases like N_2, CO_2 and H_2O. After the completion of combustion reaction within few minutes, the powder obtained was crushed and characterized further. Similar procedure was followed for other samples with nitrate to fuel ratio of 1:2 and 1:3.

3. Results and Discussion

In addition to hexagonal and elongated hexagonal shapes of the strontium ferrite nano particle, we have observed rods with bipod, tripod and cubic shape with the addition of capping agent PVP (Poly vinyl pyrollidone). Different mechanisms have been proposed for the formation of various shapes based on the synthetic conditions involved in the technique. But in general, the formation of different shapes mainly depend on whether the process is driven by kinetic or thermodynamic process and also on the ratio (R) between the growth rates along <100> and <111> directions as described by Wang [2].

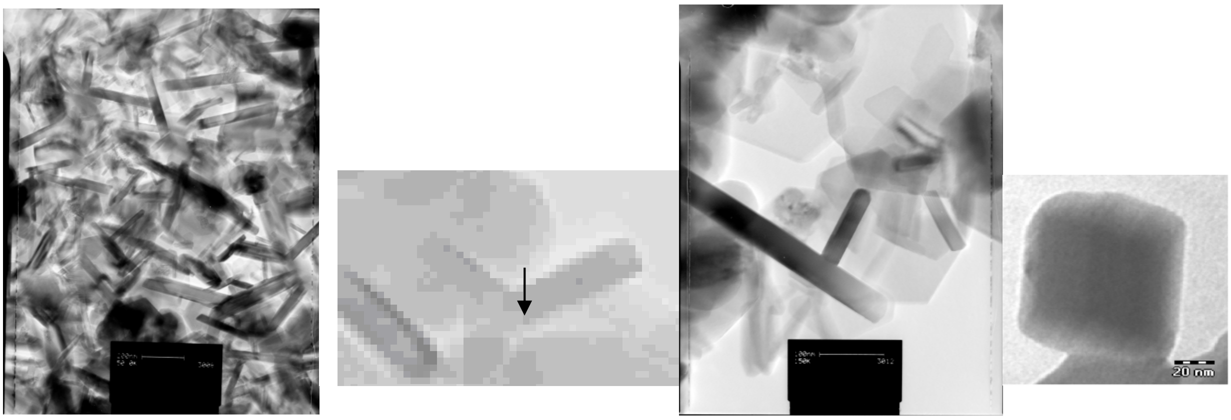

Fig. i. Rods (100nm) ii. Bipod iii. Tripod (100nm) iv. Cube (20nm)

For R values of 0.58, 0.7 and 1.73, cube, truncated cube and octahedral shapes were obtained respectively. However, the kinetic or thermodynamically driven growth is determined based on the free energies which is given as $\gamma_{\{110\}} > \gamma_{\{100\}} > \gamma_{\{111\}}$. In hexagonal shaped structure, the long axis c is parallel to the [100] direction. At low-temperature synthetic conditions (~140ºC) high flux results in kinetically controlled growth and hence the growth on {100} face is favored [3], which indicated the oriented growth along c-axis leading to form rods. The synthesis parameters used for strontium ferrite preparation were similar which would have favored kinetically controlled growth along [100] direction resulting in multipod vis, rods (Fig.i). The enlarged image of the bipod (Fig. ii and T-shapes tripod formation (Fig. iii), cubic shape (Fig iv) are shown. The bipod and T-shaped tripods formation might be the consequence of the rods sharing the common faces as shown in schematic. The presence of PVP hindered the formation of rods while allowing the formation of cubic particles. For the formation of rod, the growth along {100} direction is kinetically controlled as discussed earlier, but the presence of PVP retarded the growth along {100} by selective absorption of PVP and/or enhance the growth along <111> that lead to the cubic shapes as discussed by Sun and Xia [4]. The magnetic Properties have been greatly influenced by the shapes, which is due to the shape anisotropy contribution.

4. Conclusion

1) Anisotropic Strontium ferrite nano particles with different shapes and size can be synthesized by controlling the synthetic parameters, such as pH and nitrate to citrate ratio.
2) Addition of capping agent, PVP produced smaller size strontium ferrite nano particles with irregular and cubic shapes, Gel combustion technique with some control on different parameters can yield interesting anisotropic magnetic nano structures.

5. References

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