Barium Hexaferrite Thin Films Prepared by the Sol-Gel Method

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Nano-crystalline hexaferrite BaFe$_2$O$_{19}$ (BaM) thin films have been prepared by the sol-gel method. A solution of Ba-nitrate and Fe-nitrates was dissolved in solvent with the stoichiometric ratio Ba/Fe=1/10. Films were spin-coated onto SiO$_2$/Si substrates, dried and then heated in air at various temperatures. In films prepared at a drying temperature $T_d$=250 °C and a crystallizing temperature 650 °C, single-phase BaM was obtained. High coercivities were obtained in these nano-crystalline thin films, 4-5.5 kOe for hexaferrite. Polycrystalline BaM/SiO$_2$/
Si(100) thin films were characterized by Rutherford backscattering (RBS), thermogravimetry (TGA), differential thermal analysis (DTA), x-ray diffraction (XRD), and vibrating sample magnetometry (VSM), as well as Fourier transform infrared spectroscopy (FTIR). The perpendicular coercivity $H_{Cp}$ and in-plane coercivity $H_{Cl}$
, after annealing at 650 °C for 2 hours were 4766 Oe and 4480 Oe, respectively, at room temperature, under a maximum applied field of 10 kOe.

1. Introduction

M-type hexagonal barium ferrite (BaM) is well established as a permanent magnetic material. It has excellent chemical stability and is relatively cheap to produce. Barium ferrite magnetic materials with high coercivity also have applications as magnetic recording media, and in microwave devices. [1] Various preparation methods have been developed, including sputtering [2], pulsed laser deposition [3], metalorganic chemical vapor deposition [4], and the sol-gel method [5].

The sol-gel technique has emerged in recent years as a versatile method for synthesizing inorganic materials. Apart from the advantage of low temperature processing, a sol-gel route makes it possible to obtain nano-particle materials [1]. Though the sol-gel process has made an impact on materials technology, the high cost of alkoxides appears to be a hindrance to its large scale use in preparing conventional materials. In this work, thin films of barium hexaferrite (BaM) layers on thermally oxidized silicon substrates were fabricated by the sol-gel method. We have avoided using alkoxides, thereby ensuring that the preparation cost is not high. Polycrystalline barium hexaferrite thin films were characterized with RBS, XRD, VSM, TGA-DTA, and FTIR.

2. Experimental Procedures

A block diagram outlining the preparation process is shown in Fig. 1. Barium nitrate [Ba(NO$_3$)$_2$] and iron nitrate [Fe(NO$_3$)$_3$ · 9H$_2$O] were used as starting materials, and were combined so that the composition ratio Ba/Fe=1/10. These were dissolved in methanol and distilled water. The solution was refluxed at 80 °C for 24 h. The resulting precursor solutions were made 0.2 M. The films were spin-coated onto thermally oxidized silicon substrates (10 × 10 mm), dried, and then heated in air at various temperatures. The crystal structures and stoichiometries were investigated by x-ray diffraction using CuKa radiation and Rutherford back-scattering spectroscopy. Thermal analysis by thermogravimetric analysis (TGA) and differential thermal analysis (DTA) were performed on the dried powder obtained from the BaFe$_2$O$_{19}$ precursor solution. The FTIR studies were done using a FTIR spectrophotometer (Mattson) on films coated onto KBr single-crystal substrates. Magnetic properties were measured using a vibrating sample magnetometer at a maximum applied field of 10 kOe.

3. Results and Discussion

The thermal decomposition characteristic of the gel system with temperature was studied by DTA and TGA, as shown in Fig. 2. In this study, the BaFe$_2$O$_{19}$ (BaM) was pre-dried at 120 °C for 12 hours and the thermolysis behavior was analyzed using a heating rate of 5 °C/min. TGA analysis indicated a major weight loss at 260–600 °C. It can be seen that the gel exhibited approximately 68 % weight loss up to 600 °C. While the rapid weight decrease was due to evaporation of the solution and thermal decomp-