Characterization of Barium Hexaferrite Thick Films Deposited by Aerosol Deposition with an *in situ* Magnetic Field

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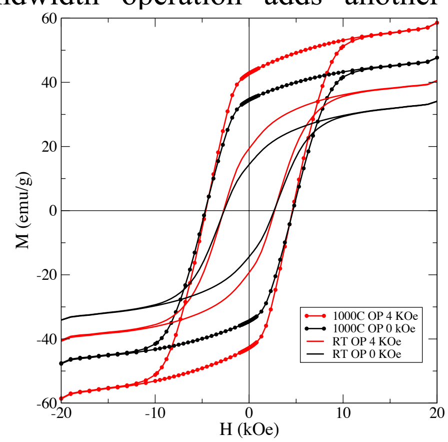
Devices utilizing magnetic materials such as circulators, inductors, and filters are critical components in many of today's electronics [1]. The need for ferromagnetic materials in these devices poses many difficulties for minimizing device size, weight, and cost. One issue that hampers integration of ferromagnetic materials is the high-melting temperature of the ferrite compared with the low-melting temperature component structure [2]. Furthermore, the need for low-loss and narrow bandwidth operation adds another significant barrier to the advancement of integration of ferromagnetic materials. The high-frequency operation regime and strong uniaxial anisotropy of barium hexaferrite ($BaFe_{12}O_{19}$, BaM) makes this material particularly interesting to utilize as an oriented film for microwave components. In this study, we characterize BaM films deposited onto sapphire by a room-temperature thick-film growth technique called aerosol deposition. We performed alternating gradient magnetometry depth studies on a series of as-deposited films that show a variation in magnetization with depth. Cross-sectional SEM images indicate laterally uniform film density. Electron dispersive spectroscopy of the interfacial region suggest significant Al_2O_3 mixing into the film volume. Fe XPS spectra indicate a change in peak weighting as a function of thickness, possibly indicative of modified structure or oxygen incorporation due to Al incorporation. To explore the possibility of magnetically orienting the films we deposited additional films in the presence of a 4 kOe static magnetic field. We report VSM, FMR, and XRD results of these films as-deposited and after sintering from 700C to 1000C. The Figure shows the results of VSM measurements of 5-um-thick films deposited with no applied field compared to films deposited in a 4 kOe applied field. The films deposited in the field presence show an increased saturation magnetization and remanence. Annealing improves the overall properties of the films further increasing the magentic orientation and saturation.



[1] Adams, J., Davis, L., Dionne, G., Schloemann, E., and Stitzer, S., IEEE Transactions on Microwave Theory and Technology, **50** (2002), No. 3, pp.721.

[2] Johnson, S., Newman, H., Glaser, E., Cheng, S.-F., Tadjer, M., Kub, F., and Eddy, C., IEEE Trans. on Magnetics, **51**, (2015), No. 5, pp. 2200206.

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Figure 1 shows a drawing of the experimental setup in the aerosol deposition chamber. The sample is held in-line with the spray nozzle by mounting it onto two Nd-Fe-B magnets. The magnets are held to the translation plate using an additional magnet. The field measured by a Hall probe is about 4 kOe at the magnet surface where the deposition occurs.

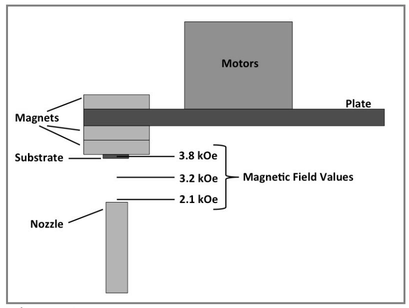

Figure 1

Figure 2 below shows XRD results of all of the films in this study. Good crystallinity is observed in all samples. Rietveld refinement of the data also suggests that the films deposited in the presence of a 4 kOe magnetic field have a smaller unit cell volume compared to films deposited without the applied field. Post-growth sintering increases the crystallite size from about 10 nm to 25 nm.

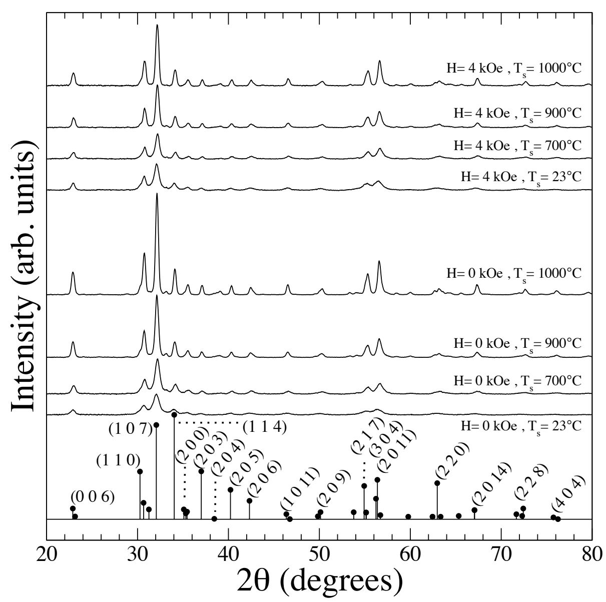

Figure 2