

INTISARI

FABRIKASI DAN KARAKTERISASI KOMPOSIT MAGNETIK NANOGRANULAR FERIT DAN FERIT/LOGAM TANAH JARANG UNTUK BAHAN PENYERAP GELOMBANG ELEKTROMAGNETIK

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Penelitian ini bertujuan untuk menyelidiki sifat dan kinerja lapisan tipis ferit dan ferit/logam tanah jarang pada lembaran Kapton sebagai bahan penyerap gelombang elektromagnetik (EM). Hasil karakterisasi dan analisis diharapkan dapat memenuhi kriteria bahan penyerap gelombang EM. Teknik utama yang digunakan dalam penelitian ini adalah penambahan logam tanah jarang Gd dan Ce pada pembuatan lapisan tipis ferit dan modifikasi bentuk geometri permukaan untuk merekayasa gelombang pantulannya (*scattering*). Lapisan tipis BiFeO₃ (BFO), Gadolinia Doped Ceria-Barium Monoferrite (GDC-BaFe₂O₄), Bi_{0,6}Ce_{0,1}Gd_{0,3}Fe_{0,9}Co_{0,1}O₃, dan Bi_{0,8}Ce_{0,1}Gd_{0,1}Fe_{0,9}Co_{0,1}O₃ telah berhasil dideposisikan di atas film kapton menggunakan alat DC *sputtering*. Modifikasi permukaan lapisan tipis menggunakan alat implantasi ion yang bertujuan untuk merekayasa karakteristik pantulannya juga telah berhasil dilakukan. Struktur *nanogranular* yang dihasilkan memungkinkan terjadinya lebih banyak interaksi material penyerap dengan EM. Hasil uji menggunakan *X-Ray Diffractometer* pada lapisan tipis BFO, GDC-BaFe₂O₄, Bi_{0,6}Ce_{0,1}Gd_{0,3}Fe_{0,9}Co_{0,1}O₃, dan Bi_{0,8}Ce_{0,1}Gd_{0,1}Fe_{0,9}Co_{0,1}O₃ menunjukkan bahwa lapisan tipis BFO memiliki struktur kubik dan GDC-BaFe₂O₄ memiliki struktur kristal orthorombik. Analisis *Fourier Transform Infra-Red* mengkonfirmasi terbentuknya gugus fungsi Bi-O dan Fe-O (untuk lapisan tipis BFO), Fe-O, Ce-O, dan Ba-O-Ba (untuk lapisan tipis GDC-BaFe₂O₄), dan Fe-O, Bi-O, dan RE-O (untuk lapisan tipis Bi_{0,6}Ce_{0,1}Gd_{0,3}Fe_{0,9}Co_{0,1}O₃, dan Bi_{0,8}Ce_{0,1}Gd_{0,1}Fe_{0,9}Co_{0,1}O₃). Unsur Bi, Fe, O, Gd, Ce, dan Co terdeteksi melalui pengujian *scanning electron microscopy-energy dispersive X-ray* dan tersebar merata pada hasil *mapping* unsur. Hasil pengujian sifat magnetik menggunakan *vibrating sample magnetometer* menunjukkan karakteristik feromagnetik dengan nilai magnetisasi saturasi menurun dengan bertambahnya waktu *sputtering*. Hasil uji *atomic force microscopy* menunjukkan terjadinya peningkatan nilai kekasaran lapisan tipis. Nilai kekasaran permukaan untuk berbagai lapisan tipis bervariasi dengan bertambahnya waktu deposisi. Nilai kekasaran untuk kapton sekitar $2,2 \pm 1,0$ nm, BFO antara $18,8-25,3 \pm 1,0$ nm, GDC-BaFe₂O₄ antara $6,4-13,1 \pm 1,0$ nm, Bi_{0,6}Ce_{0,1}Gd_{0,3}Fe_{0,9}Co_{0,1}O₃ antara $6,3-38,1 \pm 1,0$ nm, dan Bi_{0,8}Ce_{0,1}Gd_{0,1}Fe_{0,9}Co_{0,1}O₃ antara $9,8-17,9 \pm 1,0$ nm. Meningkatnya kekasaran permukaan dan turunnya nilai magnetisasi saturasi secara signifikan mempengaruhi sifat penyerapan gelombang EM. Dimana kemampuan penyerapan gelombang EM yang diukur menggunakan *vector network analyzer* mencapai nilai *reflection loss* maksimum -51,09 dB (99,99%) pada kisaran 8,87 GHz. Nilai

reflection loss maksimum didapatkan pada lapisan tipis $\text{Bi}_{0,6}\text{Ce}_{0,1}\text{Gd}_{0,3}\text{Fe}_{0,9}\text{Co}_{0,1}\text{O}_3$ dengan durasi waktu *sputtering* 15 menit. Oleh karena itu, material BFO dengan tambahan unsur Gd dan Ce merupakan kandidat yang potensial untuk diaplikasikan sebagai penyerap gelombang EM.

Kata kunci: BiFeO_3 , GDC- BaFe_2O_4 , Gadolinium, kapton, DC *sputtering*, implantasi ion, *reflection loss*, penyerap gelombang EM

ABSTRACT

FABRICATION AND CHARACTERIZATION OF NANOGRANULAR MAGNETIC COMPOSITE OF FERRITE AND FERRITE RARE/EARTH METAL AS ELECTROMAGNETIC WAVE ABSORBING MATERIALS

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This study aims to investigate the properties and performance of ferrite and ferrite/rare earth metal thin films on Kapton sheets as electromagnetic (EM) wave-absorbing materials. The characterization and analysis results are expected to meet the criteria of EM wave-absorbing materials. The main techniques used in this research are the addition of rare earth metals Gd and Ce to the ferrite thin film and the modification of the surface geometry to engineer the scattering wave. Thin films of BiFeO_3 (BFO), Gadolinia-Doped Ceria-Barium Monoferrite (GDC- BaFe_2O_4), $\text{Bi}_{0,6}\text{Ce}_{0,1}\text{Gd}_{0,3}\text{Fe}_{0,9}\text{Co}_{0,1}\text{O}_3$, and $\text{Bi}_{0,8}\text{Ce}_{0,1}\text{Gd}_{0,1}\text{Fe}_{0,9}\text{Co}_{0,1}\text{O}_3$ have been successfully deposited on Kapton film using DC sputtering. Surface modification of the thin film using an ion implantation device aimed at engineering its scattering characteristics has also been successfully carried out. The resulting nanogranular structure allows for more interaction of the absorbing material with electromagnetic (EM) waves. Test results using X-ray diffractometer on BFO, GDC- BaFe_2O_4 , $\text{Bi}_{0,6}\text{Ce}_{0,1}\text{Gd}_{0,3}\text{Fe}_{0,9}\text{Co}_{0,1}\text{O}_3$, and $\text{Bi}_{0,8}\text{Ce}_{0,1}\text{Gd}_{0,1}\text{Fe}_{0,9}\text{Co}_{0,1}\text{O}_3$ thin films show that BFO thin films have a cubic structure and GDC- BaFe_2O_4 thin films have an orthorhombic crystal structure. Fourier transform infrared analysis confirmed the formation of Bi-O and Fe-O (for BFO thin films), Fe-O, Ce-O, and Ba-O-Ba functional groups (for GDC- BaFe_2O_4 thin films), and Fe-O, Bi-O, and RE-O (for $\text{Bi}_{0,6}\text{Ce}_{0,1}\text{Gd}_{0,3}\text{Fe}_{0,9}\text{Co}_{0,1}\text{O}_3$, and $\text{Bi}_{0,8}\text{Ce}_{0,1}\text{Gd}_{0,1}\text{Fe}_{0,9}\text{Co}_{0,1}\text{O}_3$ thin films). The elements Bi, Fe, O, Gd, Ce, and Co were detected through scanning electron microscopy-energy dispersive X-ray testing and were evenly distributed in the elemental mapping results. The results of testing magnetic properties using a vibrating sample magnetometer show ferromagnetic characteristics with saturation magnetization values decreasing with increasing sputtering time. The atomic force microscopy test results showed an increase in the roughness value of the thin layer. The surface roughness values for the various thin films vary with increasing deposition time. The roughness values for Kapton are around 2.2 ± 1.0 nm, BFO between 18.8 and 25.3 ± 1.0 nm, GDC- BaFe_2O_4 between 6.4 and 13.1 ± 1.0 nm, $\text{Bi}_{0,6}\text{Ce}_{0,1}\text{Gd}_{0,3}\text{Fe}_{0,9}\text{Co}_{0,1}\text{O}_3$ between 6.3 and 38.1 ± 1.0 nm, and $\text{Bi}_{0,8}\text{Ce}_{0,1}\text{Gd}_{0,1}\text{Fe}_{0,9}\text{Co}_{0,1}\text{O}_3$ between 9.8 and 17.9 ± 1.0 nm. Increasing surface roughness and decreasing saturation magnetization values significantly affect the absorption properties of EM waves. EM wave absorption capability measured using a vector network analyzer reached a maximum reflection loss value of -51.09 dB

(99.99%) at 8.87 GHz. The maximum reflection loss value was obtained in the $\text{Bi}_{0,6}\text{Ce}_{0,1}\text{Gd}_{0,3}\text{Fe}_{0,9}\text{Co}_{0,1}\text{O}_3$ thin layer with a sputtering time duration of 15 minutes. Therefore, BFO material with additional Gd and Ce elements is a potential candidate to be applied as an EM wave absorber.

Keywords: BiFeO_3 , GDC- BaFe_2O_4 , Gadolinium, kapton, DC sputtering, ion implantation, reflection loss, EM wave absorber