

TEM analysis of Pulse Laser Deposited BaFe₁₂O₁₉ films on SiC

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BaFe₁₂O₁₉ is a ferrite (barium hexaferrite, BaM) with magnetoplumbite structure. Its high permeability ($\mu > 100$) and strong uniaxial anisotropy ($H_A \sim 17\text{kOe}$) combined with the easy direction of magnetization along the c-axis makes BaM of great importance for microwave device applications [1]. The progress in ferrite devices and next generation monolithic microwave integrated circuits strongly depends of ability to integrate BaM with semiconductor processing technologies. Integrating BaM with wide band gap semiconductors (e.g. SiC or GaN), which can function in high-temperature, high-power, and high-frequency environments is especially desirable [2]. In order to achieve effective integration of BaM on semiconductors, such challenges as lattice mismatch, thermal mismatch, and interface mixing need to be overcome, while maintaining tight stoichiometric control of the BaM film.

In this work we study the structural properties on the BaM thin films prepared by pulse laser deposition (PLD) on SiC(0001). Prior the PLD BaM deposition MgO films with various thicknesses were grown as a diffusion barrier for Si, and to provide better lattice matching between the SiC and BaM. TEM/STEM and EDX analysis were performed using JEOL 3000F and JEOL 2011.

FIG.1 shows BaM PLD film (on 10 nm MgO template) with low roughness and thickness of ~ 400 nm. The bright contrast band shown at the interface indicates formation of an interface phase(s) different from the BaM film. HRTEM from the interface region (FIG. 2) clearly shows two distinct interface regions. First (close to SiC substrate) is amorphous SiO_x with thickness of $\sim 5\text{-}10$ nm, while the second, mainly cubic region, has spacings corresponding to magnesium ferrite. In addition we observed regions that do not correspond to any of the Ba-Fe-Mg-O bulk reported phases. STEM-EDX scan line across the interface confirms the presence of the Si and O in the near substrate region, and Mg, Fe, Ba and O in the cubic band. The high temperature deposition combined with high kinetic energies of the deposited atoms make the SiC-film interface rather rough. In addition the MgO template layer reacts with the incoming atomic species and form a 40-50 nm interface transition region. Surprisingly, crystallographic orientation between BaM film and SiC substrate is preserved beside the oxidation of the substrate, FIG.4. This implies that the oxide layer at the interface, resulting from the O diffusion towards the substrate during the deposition, is formed after the seeds film layer is being created. It should be noted that films with 4 nm MgO template do not form single crystal BaM films, thus their magnetic properties are inferior compared to the films grown on 10 nm MgO template. Magnetic properties of the BaM films deposited on 10 nm MgO template were reported elsewhere [3].

References:

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- [2] W. Wondrak, E. Niemann, K. Held, R. Constapel, and G. Kroetz, ISIE '98. 1, 153 (1998).
- [3] Z. Chen, A. Yang, A. Gieler, et al., Appl. Phys. Lett. **91**, 182505 (2007).

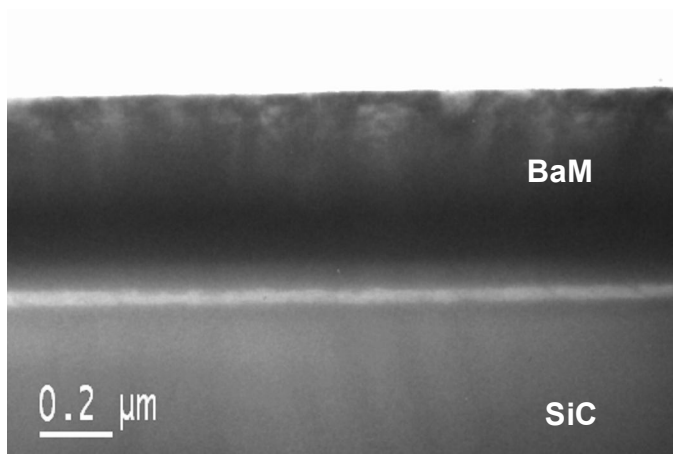


FIG. 1 BF TEM image from BaM/SiC.

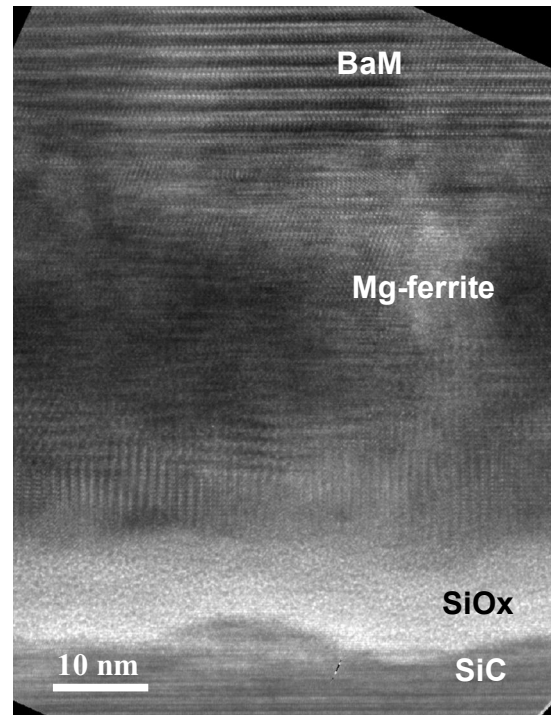


FIG. 2 HRTEM from the interface region of BaM/SiC.

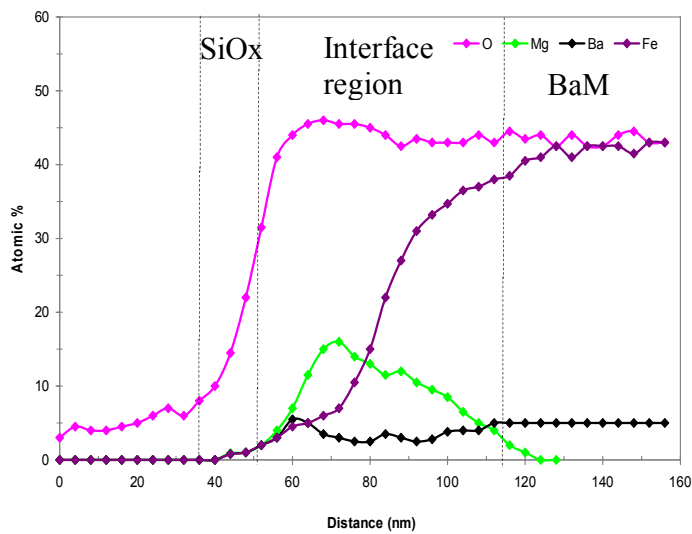


FIG. 3 EDX scan line across the interface region showing elemental distribution in the interface region.

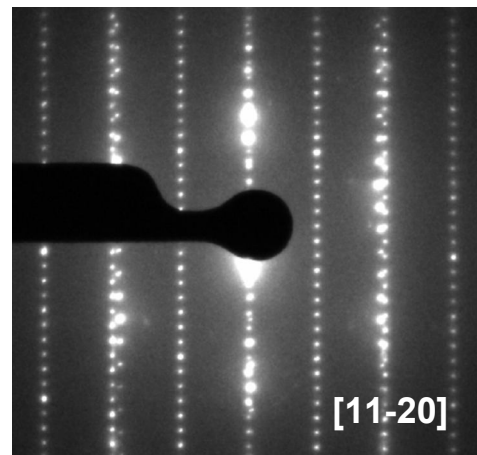


FIG. 4 SAD from BaM/SiC shows epitaxial growth of the film: BaM[0001]||SiC[0001] and BaM[11-20]||[11-20]SiC.