Epitaxial Growth of Thick $NiFe_2O_4$ Films using Chemical Vapor Deposition for Microwave Device Applications

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Abstract

Multiferroic heterostructures, such as the ferrite-ferroelectric layered structures, have attracted a lot of attention due to their potential applications in tunable microwave devices. The simultaneous tunability of magnetic and electric fields in such structures is very useful for planar microwave and millimeter wave devices such as tunable phase shifters, resonators and delay lines. Growth of high quality and thick (10-100μm) ferrite films is an essential step to obtain satisfactory final devices. In this work, the growth of single crystal nickel ferrite ($NiFe_2O_4$, NFO) films with high growth rate by direct liquid injection chemical vapor deposition is investigated. The liquid precursor source for injection was prepared by dissolving corresponding metalorganic precursors into a solvent. In our case, anhydrous $Ni(acac)_2$ and $Fe(acac)_3$ (acac=acetylacetonate) (mole ratio 1:2) were dissolved in N, N-Dimethylformamide (DMF). The as-prepared solution was fed into a commercial vaporizer system through a liquid mass flow controller (10g/h range). Epitaxial growth of NFO films on $MgAl_2O_4$ (100) and MgO (100) were observed using X-ray diffraction. Out-of-plane and in-plane texture were analysed by ω scan and φ scan. Field emission scanning electron microscopy (FE-SEM) and atomic force microscopy study showed dense and atomically smooth NFO films. Films deposited at 800C showed saturation magnetization of 299emu/cc (bulk value, 300emu/cc). The growth rates of the NFO films were in the range of 0.6~0.8 μm/h under our experimental conditions.