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Cluster and Thickness Dependence of Ferromagnetism in Nickel *In Situ*-Doped Amorphous AlN Thin Films

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We report on magneto-optical investigations of Ni-doped amorphous AlN (a-AlN) thin films. The a-AlN was grown by radiofrequency (rf) sputtering on Si (0001) substrates at low temperature and doped with Ni at fixed concentrations with different a-AlN layer thicknesses. As-grown a-AlN:Ni layers were annealed up to 900°C for 5 min and 15 min time duration in nitrogen ambient at atmospheric pressure. Each sample was characterized by the magneto-optical Kerr effect (MOKE) in both polar and longitudinal geometries. Only the 65-nm-thick a-AlN:Ni layers showed linear enhancement of magnetization after thermal treatment up to 900°C, indicating the presence of a critical a-AlN:Ni layer thickness supporting the formation of magnetic domains. No measurable MOKE signal was observed in the longitudinal geometry for any tested samples with different thicknesses. This observation confirms that the easy magnetization axis in a-AlN:Ni layers is out of plane due to the strong magnetic anisotropy observed in polar MOKE geometry. The morphology of as-grown and annealed a-AlN:Ni films was characterized by atomic force microscopy (AFM), magnetic force microscopy (MFM), and scanning electron microscopy (SEM) and revealed the existence of nanoclusters. The size distribution of nanoclusters was studied as a function of annealing time and temperature, and the results correlate well with those obtained from the MOKE measurements.

Key words: Amorphous, AlN, transition metal, nanoclusters, magneto-optics

INTRODUCTION

Transition metal (TM)-doped dilute magnetic semiconductors (DMSs) have been extensively investigated for the past decade.[1,2] TM (V, Cr, Mn, Cu, Fe, Co, and Ni)-doped crystalline or polycrystalline AlN, among other TM-doped III-nitride semiconductors, exhibited ferromagnetism at, below, or above room temperature.[3–9] However, TM-doped amorphous AlN (a-AlN) has not been intensively investigated before. Magnetically ordered amorphous materials exhibit a wide range of technologically important properties that rely on magnetic ordering and the dynamic interactions between spin excitations and electronic transport phenomena.[10,11] Amorphous III-nitrides doped with TMs are an interesting alternative for prospective applications in spintronics because of a strong magnetic moment associated with their metallic impurities and the possibility of easy modification of the magnetic domain environment.[12] The unique feature of a-AlN:TM, in general, is that long-range magnetic ordering is possible while the long-range order does not exist in the distribution of constituent atoms. This implies that magnetic and nonmagnetic atoms in a-AlN:TM completely lose the periodicity of the lattice in their crystalline counterparts and form a noncrystalline solid. High-concentration doping of magnetic TMs is difficult when using common doping techniques (e.g., thermal diffusion) because the solubility of the magnetic impurities is too low,

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