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Thermal oxidation of lattice mismatched $Al_{1-x}In_xN$ films on GaN

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ABSTRACT

Lattice-mismatched $Al_{1-x}In_xN$ layers grown on GaN and with varying *x* are thermally oxidized to understand how alloy content affects the oxidation process and oxide films. The samples are oxidized in a horizontal tube furnace at 830 °C and 900 °C for 2 h under O_2. The samples are characterized using atomic force microscopy to determine root mean square roughness before and after oxidation. The oxide thickness for each sample is determined by spectroscopic ellipsometry. The AlInN layers with less indium produce smoother oxide layers, and the oxidation rate of the samples increases with increasing indium content. Energy dispersive X-ray spectroscopy of scanning transmission electron microscopy images of the oxide layers show the In collects on or near the surface of the oxide layer. Overall, the results indicate that oxides formed from AlInN layers with less indium produce smoother oxide films and are more suitable for device applications.

Introduction

As a wide band gap semiconductor, Gallium Nitride (GaN) has favorable intrinsic properties such as high critical electric field, thermal stability, and transport properties, including high electron mobility and saturation velocity when implemented in heterostructures [1–3]. These properties make GaN promising for electronic devices such as metal oxide semiconductor field effect transistors (MOSFETs) and high electron mobility transistors (HEMTs). Unlike Silicon, GaN lacks a native oxide that would be useful as a gate oxide to prevent gate leakage or provide passivation. Instead, deposited oxides with high dielectric constants and large band offsets are implemented [4]. Typically, these oxides are deposited via chemical vapor deposition (CVD) or atomic layer deposition (ALD) but require thorough surface pretreatments before their deposition to reduce surface contamination [5–7]. Thermally oxidized AlInN layers on GaN are an interesting alternative to deposited oxides and do not require surface pretreatments since the GaN interface is not exposed to air.

The thermal oxidation of both lattice-matched and mismatched AlInN layers to GaN has been examined in AlInN/GaN HEMTs [8,9]. In these papers, thin oxide layers, ~2 nm, are formed and used for gate leakage suppression. Additionally, the oxidation of lattice-matched AlInN to GaN, forming thick insulating oxide layers (~250 nm) and with breakdown electric fields >2 MV/cm has been demonstrated [10]. The oxidation rates of these AlInN layers were also studied and exhibit diffusion and reaction-limited regimes similar to Si and can be fit using the Deal Grove model [11]. The ability to oxidize thick AlInN layers without exposing the GaN surface broadens the possible applications for this oxide in MOSFET devices. In this paper, the thermal oxidation of lattice-mismatched $Al_{1-x}In_xN$ layers on GaN is examined. The influence of indium content on the oxidation process is investigated to determine what compositions are better for semiconductor device applications.

Experimental methods

The $Al_{1-x}In_xN$ layers are grown on 4.5 µm thick, unintentionally doped GaN templates on sapphire substrates via metal-organic chemical vapor deposition (MOCVD). Four lattice-mismatched $Al_{1-x}In_xN$ layers are studied with indium content, x, of 0.132, 0.145, 0.192, and 0.21. The In-content for each sample is determined using X-ray diffraction (XRD) measurements. In addition to the lattice-mismatched samples, data from a previously studied lattice-matched sample is included in this work with x of 0.172 [11]. To prevent the complete oxidation of the AlInN layers during oxidation, each sample has an AlInN thickness between 200 nm and 250 nm. More detailed growth conditions of similar AlInN layers are previously reported [12–16]. After growth, the samples are cleaned with acetone and isopropyl alcohol before thermally oxidizing in dry conditions. The oxidation is performed at 830 °C and 900 °C in a horizontal tube furnace for 2 h with an O_2 flow of ~13 SCFH.

To characterize the samples, atomic force microscopy (AFM),

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