High Quality AlN and GaN Grown on Compliant Si/SiC Substrates by Gas Source Molecular Beam Epitaxy

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Epitaxial layers of AlN and GaN were grown by gas source molecular-beam epitaxy on a composite substrate consisting of a thin (250 nm) layer of silicon (111) bonded to a polycrystalline SiC substrate. Two dimensional growth modes of AlN and GaN were observed. We show that the plastic deformation of the thin Si layer results in initial relaxation of the AlN buffer layer and thus eliminates cracking of the epitaxial layer of GaN. Raman, x-ray diffraction, and cathodoluminescence measurements confirm the wurtzite structure of the GaN epilayer and the c-axis crystal growth orientation. The average stress in the GaN layer is estimated at 320 MPa. This is a factor of two less than the stress reported for HVPE growth on 6H-SiC(0001).

Key words: Si/SiC, substrate, composite, AlN, GaN

INTRODUCTION

One of the problems in the epitaxy of nitrides is the lack of a suitable substrate material on which lattice-matched group III-nitride films can be grown. The large lattice mismatch of most of the available substrates leads to high interfacial strain between the substrate and the epitaxial layer, resulting in three-dimensional (3D) growth and formation of misfit dislocations.[1] Growth on compliant substrates offers a way of minimizing such interfacial strain.[1–6] The idea is to produce a free-standing thin layer by placing the layer on a bulk substrate with frictionless glide on each other.[7] There are additional advantages of bonding the compliant layer to a polycrystalline substrate. More specifically, polycrystalline SiC substrate offers an excellent match of thermal expansion coefficient to GaN. Low cost, large diameter polycrystalline SiC substrates are commercially available, offer high thermal conductivity (300 W/m·K), and can be made electrically conducting or insulating (>5000 ohm-cm), an important feature for optical devices and microwave power applications. The concept of a strain-relaxed compliant substrate and the behavior of epitaxial films grown on such substrates are well known.[2] However, the influence of the free-standing layer thickness and its plasticity on the subsequent growth of AlN and GaN are still under study.

This work describes preparation of AlN and GaN on a thin (250 nm) Si(111) film that is wafer bonded to a 100 mm diameter polycrystalline SiC substrate. We also discuss the investigation of growth mechanisms, stress relaxation, and optical properties of epitaxial AlN and GaN layers.

EXPERIMENTAL DETAILS

AlN and GaN films were grown by gas source molecular beam epitaxy (GSMBE) with ammonia on a thin (250 nm), chemically-mechanically polished (CMP) silicon (111) layer that was bonded to a polycrystalline SiC substrate. The poly-SiC substrates were polished using the technology developed previously for SiC mirrors, which makes wafer bonding possible.[8] Atomic force microscopy (AFM) of the top Si layer shows a RMS roughness of 0.2 nm.

The influence of growth conditions on the structure and homogeneity of the epitaxial layers of AlN and GaN was studied using 10 kV reflection high energy electron diffraction (RHEED), x-ray diffraction (XRD), Raman spectroscopy, and cathodoluminesence (CL).

Ammonia was introduced into the growth chamber through a mass-flow controller operating in the range of 30 sccm. The substrate temperature was measured by a pyrometer, corrected for the emissivity of the

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