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Ion-Implantation-Induced Damage Characteristics Within AlN and Si for GaN-on-Si Epitaxy

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A systematic study was conducted to further understand the physical origin of stress modification in AlN overgrown on Si(111) upon ion implantation and annealing. Implantation parameters including ion size, energy, dosage, and current density were varied, and their effects on the amorphization process in Si(111) substrates were examined. The creation of a thick (>120 nm) amorphous Si (a-Si) layer was previously shown to result in isolation of an epitaxial AlN film grown on a Si(111) substrate through implantation-induced amorphization of the substrate, and this mechanical isolation resulted in stress dilution in the AlN layer. Results show that implanting at current density of 2 mA/cm^2 allows for only a thin amorphous layer to be created because of the effects of dynamic annealing, which simultaneously eliminates any damage created from the ion implantation, regardless of ion species, dosage, and energy. Lowering the current density to 0.2 mA/cm^2 does create a thick a-Si layer; however, the amorphization disappears during a high-temperature (HT) anneal. Lowering the current further to 0.2 μA/cm^2 creates a thick a-Si layer that can be maintained through a HT anneal, with this difference arising from the interfacial quality of the a-Si and crystalline Si (c-Si) boundary.

Key words: MOCVD, implantation, GaN, Si(111), amorphous, amorphization, dynamic annealing, annealing, epitaxy, SPEG

INTRODUCTION

III-N material quality and device performance have been rapidly improving over the last decade,[1–4] but widespread commercialization of III-N technologies is hindered by the cost of SiC and the low heat dissipation of sapphire, the two most common substrates for III-N epitaxy. Silicon wafers are an attractive substrate for III-N technologies because of their low cost and developed fabrication facilities, but obtaining device-quality GaN-on-Si is marred by a large density of dislocations and cracks arising from both intrinsic and extrinsic stresses during metalorganic chemical vapor deposition (MOCVD) growth. A substrate engineering technique utilizing an implantation-induced amorphous-Si (a-Si) substrate, the details of which are outlined elsewhere,[5,6] has shown success previously in simultaneously reducing the number of both dislocations and cracks over a large scale. A crucial step involved with this technique is implantation of the Si substrate. This requires implantation of a Si substrate through the AlN buffer layer, causing amorphization of the Si prior to GaN epitaxy, and maintaining this a-Si layer through a HT anneal and GaN growth. Many factors (ion energy, dose, ion species, and current density) contribute to the thickness of the a-Si layer created by ion implantation and its ability to withstand high temperatures subsequently. Here, we explore the implantation parameters and their effects in order to determine the optimum implantation

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