Frontiers in Selective Area Growth, Etching, and Doping of GaN by MOCVD

Jung Han[1]

[1]*Department of Electrical Engineering, Yale University, New Haven, Connecticut, USA 06520*

The ability to selectively add or remove semiconductor materials *in-situ* over specific regions or sites could introduce much freedome in device design and fabrication. Selective area growth (SAG) of silicon and GaAs was demonstrated more than 50 years ago. SAG of GaN has also been studied for more than 20 years. Because of the interest in GaN power electronics, there has been a growing interest in the past 10 years in developing selective area doping (SAD) of GaN in order to achieve lateral junction devices. In the development of SAD of GaN using MOCVD, one particular need is to replace *ex-situ*, reactive ion etching (RIE) with *in-situ*, selective area etching (SAE) to minimize RIE-related damages and contaminations, and to ensure the preparation defect-free electronic interfaces and junctions through in-situ regrowth.

In this talk we will review several topics related to SAG, SAE, and SAD that have been investigated at Yale. In the area of SAG, we will discuss as novel process of using SAG in combination with evolutionary selection (ES) growth to prepare single-crystalline GaN on amorphous surface such as SiO_2. This was implemented by sputter deposition of an (0001) oriented AlN layer on a SiO_2/Si(100) substrate. A SiO_2 confined mask structure is then formed, and subsequent lateral selective area growth of GaN by MOCVD using AlN as a seed, produced site-selected placement of GaN and eliminated the in-plane misalignment. The design of growth process guided by these considerations enable the ability to form single crystal GaN integrated onto amorphous substrates under the ES-growth concept [1,2].

Shifting gear to SAD and SAE, we will briefly discuss the potential of vertical GaN transistors for next-generation high-power applications. However, the lack of SAD technique in GaN greatly limits the design flexibility and device performance. Implant or diffusion of dopants into GaN are currently being pursued. Additionally, attempts of SAE by reactive-ion etching (RIE) followed by regrowth doping have been reported by many groups; most of them reported defective electronic interfaces with very leakage characteristics. It was determined that the presence of highly energy ions, reactive chlorine species, and ultraviolet photons in RIE tend to generate both surface and sub-surface damages. Here, we report an alternative method of SAE to overcome this barrier. Tertiarybutylchloride (TBCl) is employed as an *in-situ* chemical etchant of GaN in MOCVD to create smooth trenches, and to remove plasma etching-generated damages on the surface [3, 4]. Regrowth is performed right after the TBCl etching without breaking the vacuum. Several key issues that will be discussed include 1) the exploration of etching parameter space, 2) comparisons among continuous, RIE-etched, and TBCl-etched regrown PN diodes, and 3) selective area etching and doping.

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Presenting author Email address: jung.han@yale.edu