Materials Science & Engineering Thesis Defense

MOCVD Based In-Situ Etching of β-Ga_2O_3 using Triethylgallium (TEGa)

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Abstract

Over the past decade, gallium oxide has drawn significant attention from the research community due to its exceptional properties. With a high theoretical breakdown field of 8MV/cm, a wide band gap of 4.7eV, and an impressive Baliga's figure of merit (BFOM) that is 3444 times that of Si, gallium oxide demonstrates great promise for application in high-frequency and high efficiency power electronics. Moreover, gallium oxide stands out as the preferred ultra-wide bandgap semiconductor for power device manufacturing, thanks to the availability of bulk substrates through cost-effective melt growth techniques and high-quality epitaxial layers with low defect density. This paves the way for the commercialization of Ga_2O_3 based power electronics, positioning it to compete against established SiC and GaN technologies, particularly in the multi kilo-volt class medium and high voltage device segment.

This thesis presents the investigation of a novel in-situ etching technique for β-which can be carried out within a Metal Organic Chemical Vapor Deposition reactor (MOCVD) using triethylgallium (TEGa) as the etching agent. The experiments were performed in an Agnitron Agilis 100 oxide MOCVD reactor and the TEGa is fed via the showerhead along with nitrogen carrier gas. Due to higher chamber temperature, TEGa undergoes pyrolysis leading to formation of Ga and hydrocarbon species. Hydrocarbons are subsequently removed through the exhaust and Ga adatoms deposit on the sample surface and react with the gallium oxide resulting in formation of volatile gallium suboxide (Ga_2O). Since the substrate is kept at high temperature, the suboxide desorbs from surface resulting in etching. Impact of MOCVD chamber parameters like chamber pressure, TEGa flow rate and substrate temperature on etch characteristics like etch rate and surface morphology is studied in detail and a model for etch rate is developed. Wide range of etch rates from 0.3 µm/hr to 8.5µm/hr is demonstrated by controlling the TEGa molar flow rate. Smooth surface morphology on the etched surface is also demonstrated on (010) and (001) β-Ga_2O_3 substrate orientations. Furthermore, patterned etching of β-Ga_2O_3 is also studied with vertical and smooth sidewalls demonstrated along few in plane directions. To conclude, a precise control etching technique is demonstrated based on MOCVD using triethylgallium as etchant.

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