

BCl₃-based plasma etching of (010) β -Ga₂O₃ substrates

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A. Introduction

Monoclinic β -Ga₂O₃ present excellent properties: wide band gap (4.8 eV), high breakdown electric field (8 MV/cm) and thermal and chemical stability^[1]. It is intended to be used for both power (rectifiers, MOSFETs) and optoelectronic (VLEDs, MSA-LED) devices^[2]. For these applications, wafers of β -Ga₂O₃ can be directly used as templates. Substrates are obtained by dicing β -Ga₂O₃ ingots grown either by Czochralski (CZ), edge-defined film-fed (EFG) or floating zone (FZ) methods^[3]. β -Ga₂O₃ substrates are then cleaned by Chemical Mechanical Polishing (CMP) followed by a wet etching process. These three steps introduce dislocations and surface defects, such as polishing scratches and etch pits. In order to overcome these limitations and improve surface flatness, we propose to replace the wet etching step by a dry etching step. This work aims to remove defects by utilizing both the chemical (radicals) and physical (ionic sputtering) phases of a plasma in an Inductively Coupled Plasma (ICP) etcher.

B. Experiments

Monocrystalline (010) β -Ga₂O₃ substrates were obtained from dicing ingots grown by FZ and then polished by CMP at AIST. Pressure has been set to 0.65 Pa, etching time to 5 min and source power (W_s) to 400W. BCl₃ is used as the main etchant gas. The effect of bias power (W_b) has been studied and varied from 0 to 100 W. Additionally, Optical Emission Spectroscopy (OES) was used to monitor BCl₃ decomposition in the plasma. Surface morphology of polished and unpolished β -Ga₂O₃ substrates were determined before and after plasma exposure, using AFM and SEM.

C. Results and discussion

Un-treated β -Ga₂O₃ substrates present high density of irregular steps and scratches, for diced only and diced and polished samples, respectively

(see Fig.1). In the case of samples exposed to BCl₃ plasma with no biasing (0 W_b), grains are observed at the surface on SEM images, accompanied with a sharp increase of the RMS roughness measured by AFM. These observations indicate a rearrangement of the crystalline structure from monocrystalline to amorphous, due to isotropic reactions between radicals (originating from BCl₃ decomposition) and O atoms at the β -Ga₂O₃ surface. The decomposition of the boron trichloride is monitored by OES. The peak noticed at 272 nm and the continuum observed between 420 and 740 nm can be attributed to BCl and BCl₂ radicals respectively^[4]. OES spectra display similar peaks and intensities indicating that the introduction of bias does not modify the plasma decomposition. For similar plasma conditions, the introduction of bias (W_b = 100 W) leads to a decrease of RMS roughness. Biasing introduces ionic sputtering assistance from Cl ions. We speculate that sputtered Ga and O atoms react with BCl₃ based radicals in the plasma to form volatile by-products, limiting the diffusion of these radicals to the surface, therefore limiting isotropic reactions and modification of the surface morphology.

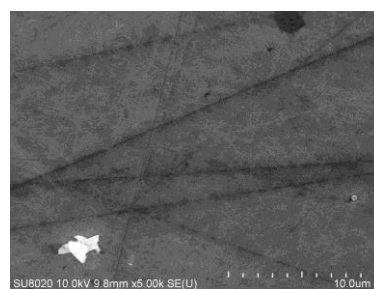


Figure 1: SEM image of (010) β -Ga₂O₃ substrates after CMP process and before any plasma treatment.

References:

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