Origin of Surface Defects in Homoepitaxially Grown (010) β-Ga_2O_3 films

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The origin of surface defects is investigated in homoepitaxially grown (010) β-Ga_2O_3 films. Optical and atomic force microscopy revealed surface pitting distributed nonuniformly across the sample with regions of high and low density of surface defects in a 6 um thick film. The samples are grown via metalorganic chemical vapor deposition with a substrate temperature of 840 °C and 15 Torr pressure. The relationship between the epilayer and substrate defects is studied using x-ray topography and transmission electron microscopy. A recent study observed a threading dislocation at the epilayer-substrate interface that nucleates into the pits that are observed at the surface. This work identifies an alternate source of the surface defects and reports differences in the etch pit defect morphologies.

X-ray topography was used to generate wafer scale tilt maps using the (820) reflection to identify regions of local distortion in the epitaxial layer caused by defects. High defect dense regions in this sample result in highly misoriented domains (>200”) with respect to the surrounding material. Triple axis x-ray diffraction measurements that isolate these regions of low and high defect density show clear differences in the rocking curves with FWHM of 20” and 34” and FW0.001M of 380” and 640” for low defect and high defect dense regions respectively. The nonuniform distribution of defects is further investigated with scanning electron microscopy, which reveals an aggregation of surface pitting that forms a surface morphology similar to a mountain range.

Cross sectional transmission electron microscopy was taken across a single defect as well as within the high defect dense region along the $[10\underline{2}]$ zone axis. The cross section taken across the single pit revealed a V-shaped defect with misoriented twinned grains that create a 68° angle, which corresponds to the angle with (830) and $(\underline{8}30)$ twinned planes. Additionally, selected area electron diffraction measurements showed that the region between the V-shape twinned grains was oriented the same as the bulk material, suggesting a directional growth to the misoriented defect. In the defect dense region, polycrystalline material was observed with elongated grains in the out of plane direction, reminiscent of polycrystalline diamond growth. The epilayer-substrate interface in this region had a roughness of ~18 nm and showed no evidence of a high quantity of threading dislocations originating from the substrate. In addition, the backside of the sample was polished and etched to reveal substrate defects formed during bulk growth. The density of etch pits on the backside was on the order of 5×10^4 cm^{-2} compared to a etch pit density exceeding 2×10^6 cm^{-2} (lower bound due to pitting overlap) in the high defect region on the epilayer surface. This further supports the idea that the high defect density in epitaxial layer does not correspond to a high defect density in the substrates. This suggests that the defects can originate from surface damage (i.e. surface cleaning or polishing) and are not only associated with threading dislocations formed during bulk growth.