Native Point Defect Measurement, Processing, and Identification Near Ga_2O_3 Surfaces

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Ga_2O_3 research has expanded rapidly due to its wide band gap enabling very high breakdown fields and n-type doping ranging from intrinsic to degenerate, both features which lead to numerous solid state electronics applications. However, it is not yet known what defects form to compensate free carriers, reduce their mobilities, and limit their densities. We used a combination of depth - resolved cathodoluminescence spectroscopy (DRCLS), surface photovoltage spectroscopy (SPS), and remote oxygen plasma (ROP) processing to measure and begin to identify native point defects within the outer tens of nanometers of Ga_2O_3 grown by pulsed laser deposition (PLD), organometallic chemical vapor deposition (MOCVD), and edge-defined film- fed growth (EFG). All three growth methods exhibit common optical features corresponding to transitions into and out of multiple deep level defect states within the Ga_2O_3 band gap. (Fig.1.) DRCLS permits measurements of defect states from the free semiconductor surface into the bulk with depth resolution of tens of nanometers or less [1]. (Fig.2.) This capability permits us to measure how near-surface chemical processing changes DRCLS features, initially, how ROP filling of oxygen vacancies (V_O) reduces specific V_O-related deep level features, as found for other oxide semiconductors [2,3]. ROP processing produces clear reductions in specific defect features corresponding to V_O-related features, largest near the surface and extending more than 40 nm below. (Fig. 3) SPS features determine deep level energies corresponding to DRCLS transitions. (Fig. 4.) These SPS energies complement DRCLS transition energies and correlate with defect energies predicted theoretically for V_O in different lattice configurations (VDW) [4] and with energy levels extracted experimentally from deep level transient and optical spectroscopies DLTS and DLOS (SAR), respectively [5]. (Fig.5.)

These results indicate that oxygen vacancies in Ga_2O_3 form multiple defect levels in the range of 2.5 – 3.5 eV above the valence band maximum (E_V). Additional near-surface processing methods and characterization techniques are available to probe the defect nature of other deep level features now observed. In turn, the combination of near-surface detection and processing of Ga_2O_3 opens a new avenue for identifying and controlling native point defects in this and other semiconductors. Supported by NSF Grant No. DMR-1305193 with thanks to Tamura Corp.

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Supplemental Information

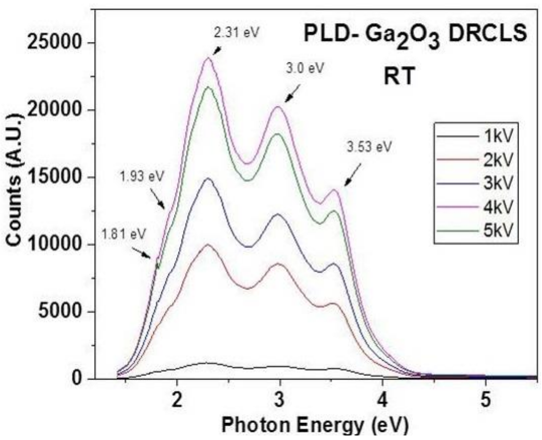

Fig. 1. PLD Ga_2O_3 DRCL spectra showing multiple peaks and emission changes vs. depth.

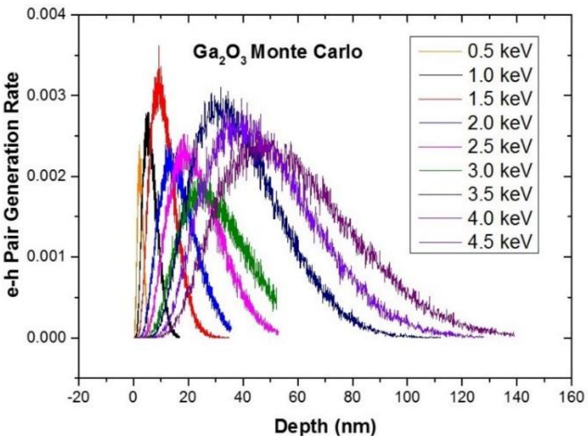

Fig. 2. Ga_2O_3 Monte Carlo e-h pair creation rates vs. depth.

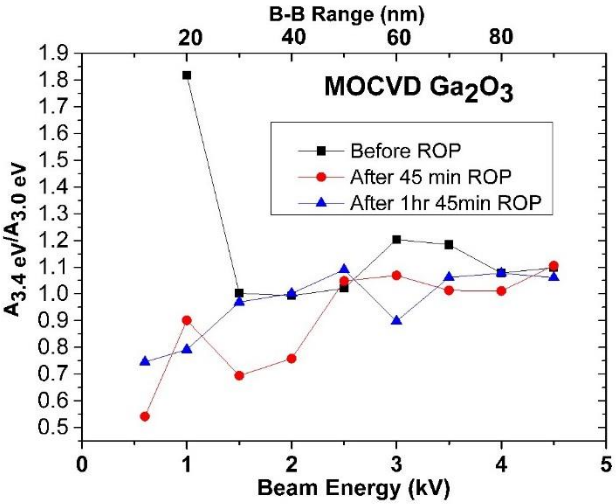

Fig. 3. MOCVD Ga_2O_3 DRCL defect ratios vs. depth with remote oxygen plasma (ROP) treatment.

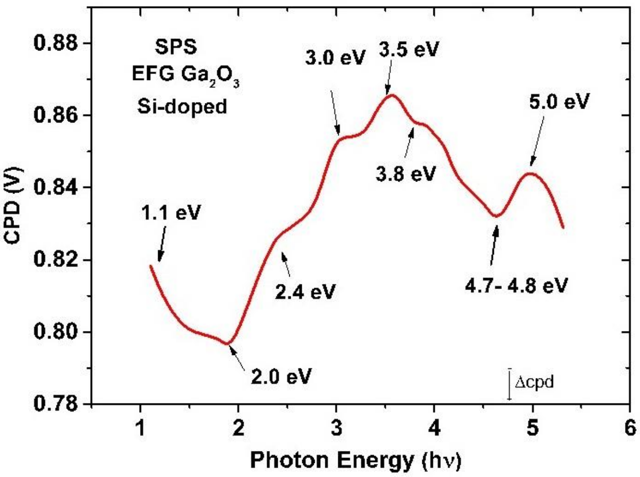

Fig. 4. EFG Ga_2O_3 SPS spectra. CPD features correspond to optical threshold energies.

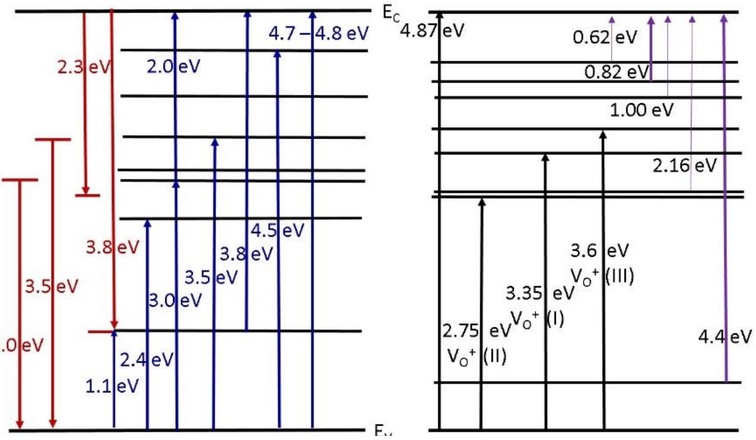

Fig. 5. Ga_2O_3 defect states (left) measured by CLS and SPS vs. (right) predicted by theory[4] and measured by DLTS/DLOS.[5]