Surface Morphology and Thermal Cleavages of Ultrafast Laser Irradiated β-Ga_2O_3 (AGSR_48)

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The intrinsic properties of gallium oxide (Ga_2O_3) are highly favorable for transforming applications in power electronics, UV solar blind detection, and gas sensing. Ultrafast (femtosecond pulse) laser irradiation provides a unique means of material modification. In this work, ultrafast laser irradiation of single crystal (010) β-Ga_2O_3 (Sn-doped and unintentionally doped) will be presented. The β-Ga_2O_3 substrate was irradiated by a Ti:sapphire ultrafast laser (780 nm, 150 fs pulse width) with varying fluence and number of shots in air ambient. Single exposure irradiation above ablation threshold results in concentric modified regions with differing optical contrast, possibly indicating melting or a phase transition of the material. Threshold fluence for these regions were evaluated by plotting effective radius and laser fluence. Noticeably, a number of parallel features resembling cleavages are observed in single irradiation experiments. These features are aligned with a particular crystallographic direction in the β-Ga_2O_3 substrate and are independent of laser polarization. These features exhibit a second, less dominant, feature similar to a cleavage at roughly 90 degrees to this crystallographic direction. The more dominant features have a width of ~60 nm as measured by AFM while the less dominant features are smaller, measuring ~30 nm. These features are not commonly observed in ultrafast laser irradiated materials. Measurements of crystallinity of this surface region are presented. Several characterization techniques proved that there was no phase transition of ultrafast laser irradiated β-Ga_2O_3. Laser induced thermal stress is suggested as the origin of these features. Furthermore, for the fluence regime below ablation threshold, laser induced periodic surface structures (LIPSS) were observed by laser rastering and multi-shot irradiation of Ga_2O_3. The surface morphologies of these materials will be presented, characterized by laser confocal microscopy, scanning electron microscopy, and atomic force microscopy. Crystallographic information will be reported based on analysis by Raman spectroscopy, electron backscattering diffraction. These results will provide a preliminary understanding of ultrafast laser interaction with Ga_2O_3, and may offer a unique means for morphological and electronic modification of Ga_2O_3 relevant for device applications.

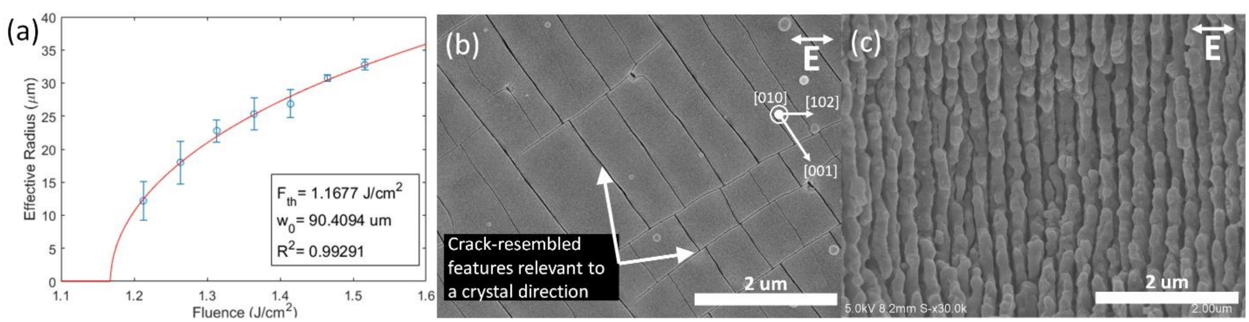

Figure. (a) Curve fitting of ablation threshold fluence of Ga2O3. (b) SEM image of cleavage features where the alignment is related to a crystal direction. (c) SEM image exhibiting high spatial frequency LIPSS (HSFL).