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Modification of β-Ga_2O_3 epilayer properties by direct laser micro-machining

Justinas Jorudas[1], Simonas Indrišiūnas[1], Maxim Moscotin[1], Giedrius Stalnionis[1], Ilja Ignatjev[1], Tomas Daugalas[1], Paulius Gečys[1], Ray-Hua Horng[2] and Irmantas Kašalynas[1]

[1]*Optoelectronics department, Center for Physical Sciences and Technology (FTMC), Lithuania.*
[2] *Institute of Electronics, National Yang Ming Chiao Tung University (NYCU), Taiwan.*
Email: justinas.jorudas@ftmc.lt

Direct laser micro-machining (DLM) is widely studied technique in material processing, due to its contactless nature, sub-micron precision, and high speed. In the case of compound semiconductors, DLM has been used for laser lift-off of the epitaxial layers [1], laser vertical interconnect accesses (VIAs) drilling [2], and laser dye dicing [3], [4]. However up to date – very little research has been reported on the usage of DLM for processing steps used in the semiconductor device formation such as mesa isolation formation or recessing for ohmic and Schottky contacts.

We investigated the structural and electrical properties of β-Ga_2O_3 epilayers modified via DLM with aim to realize the shallow recesses suitable for novel production of high-voltage semiconductor devices. Utilizing a 342 nm wavelength femtosecond laser and precisely controlling parameters of focused beam fluence and overlap, we developed the processes of forming the recesses on large semiconductor surface with the depth ranging from 200 nm down to 20 nm. The scanning electron microscopy, and Raman spectroscopy methods were also employed to reveal the morphology and perform structural analysis of the DLM-recessed areas and as-grown β-Ga_2O_3. By forming the DLM recesses shallower than 70 nm, we enable wide-range control of sheet resistance up to 100 MΩ/sq. while maintaining ohmic behavior. For depths exceeding 70 nm, recess resistance surpasses 10^{10} Ω, providing effective and maskless way for formation of intra-device isolation. Proof of principle DLM gate-recessed β-Ga_2O_3 MOSFET was fabricated also to prove versatility of DLM fabrication technique.

These findings highlight DLM as a viable, green and mask-less technique for high-precision mesa isolation and recess formation on the wide-bandgap semiconductor layers.

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