Reviews on Advanced Materials and Technologies, 2025, vol. 7, no. 3, pp. 198–202
DOI: 10.17586/2687-0568-2025-7-3-198-202

Laser Processing of Gallium Oxide Crystals in the Preparation of Samples for Microelectronics

D.I. Panov [1], V.A. Spiridonov [1], O.S. Vasilev [2], P.A. Bogdanov [1], D.A. Bauman [1], A.E. Romanov [1,3]

[1] ITMO University, Kronverkskiy pr., 49, lit. A, St. Petersburg, 197101, Russia
[2] LLC Laser Center, Marshala Tukhachevskogo str., 22, «Sova» business-center, office 228-231, St. Petersburg, 195067, Russia
[3] Changchun University of Science and Technology, Weixing Rd.7089, Changchun, 130022, China

Received: September 11, 2025 Corresponding author: P.A. Bogdanov

Abstract. The paper presents the results of a study on an approach for sample preparation from bulk gallium oxide crystals using ablation laser cutting. The study was carried out using a «MicroSet» setup based on a fiber laser source with a wavelength of 1.064 μm and a power of 30 W. The possibility of processing material using a laser beam has been shown, the optimal trochoid width and pulse duration were selected, as well as the energy characteristics of the laser source and focusing optical system. The fundamental possibility of cutting gallium oxide crystals in different directions, regardless of the internal structure, the orientation of atoms and their bonds in the crystal lattice, has been shown.

Acknowledgements. This research was supported by the Russian Science Foundation (grant № 24-12-00229). A.E. Romanov was supported by Foreign Experts Key Support Project (Northeast Special Project), Grant No. D20240015 for his work in China on theoretical analysis of cracking induced by thermal stresses.

Citation: Rev. Adv. Mater. Technol., 2025, vol. 7, no. 3, pp. 198–202

View online: https://doi.org/10.17586/2687-0568-2025-7-3-198-202

View Table of Contents: https://reviewsamt.com/issues

REFERENCES

1. A.Bhattacharyya, P. Ranga, S.Roy, C. Peterson, F. Alema, G. Seryogin, A. Osinsky, S. Krishnamoorthy, Multi-kV class β-Ga_2O_3 MESFETs with a lateral figure of merit up to 355 MW/cm², *IEEE Electron Device Letters*, 2021, vol. 42, no. 9, pp. 1272–1275.
2. Y. Zhang, S. Luan, Design of lateral β-Ga_2O_3 MOSFET with PFOM of 769.42 MW cm^{-2}, *Engineering Research Express*, 2024, vol. 6, no. 1, art. no. 015060.
3. P. Kachhawa, Sk. Masiul Islam, N. Chaturvedi, Gallium Oxide-Based Field Effect Transistors, *Physica Status Solidi A*, 2025, vol. 221, no. 16, art. no. 2400400.
4. S. Zhang, Z. Liu, Y. Liu, Y. Zhi, P. Li, Z. Wu, W. Tang, Electrical Characterizations of Planar Ga_2O_3 Schottky Barrier Diodes, *Micromachines*, 2021, vol. 12, no. 3, art. no. 259.
5. S.I. Stepanov, V.I. Nikolaev, V.E. Bougrov, A.E. Romanov, Gallium oxide: Properties and applications - a review, *Reviews on Advanced Materials Science*, 2016, vol. 44, no.1, pp. 63–86.
6. S.J. Pearton, J. Yang, P.H. Cary, F. Ren, J. Kim, M.J. Tadjer, M.A. Mastro, A review of Ga_2O_3 materials, processing, and devices, *Applied Physics Review*, 2018, vol.5, no. 1, art. no. 011301.
7. D.I. Panov, V.A. Spiridonov, D.A. Zakgeim, A.V. Kremleva, D.A. Bauman, A.E. Romanov, V.E. Bougrov, Growth technology and characterization of bulk crystalline gallium oxide, *Journal of Physics: Conference Series*, 2020, vol. 1695, no. 1, art. no. 012024.
8. Z. Galazka, β-Ga_2O_3 for wide-bandgap electronics and optoelectronics, *Semiconductor Science and Technology*, 2018, vol. 33, no. 11, art. no. 113001.
9. D.A. Zakgeim, D.I. Panov, V.A. Spiridonov, A.V. Kremleva, A.M. Smirnov, D.A. Bauman, A.E. Romanov, M.A. Odnoblyudov, V.E. Bougrov, Volume Gallium Oxide Crystals Grown from Melt by the Czochralski Method in an Oxygen-Containing Atmosphere, *Technical Physics Letters*, 2020, vol. 46, no. 11, pp. 1144–1146.
10. S. Lee, K. Kaneko, S. Fujita, Homoepitaxial growth of beta gallium oxide films by mist chemical vapor deposition, *Japanese Journal of Applied Physics*, 2016, vol. 55, no. 12, art. no. 1202B8.
11. S. Geller, Crystal Structure of β-Ga_2O_3, *The Journal of Chemical Physics*, 1960, vol. 33, no. 3, pp. 676–684.
12. E.G. Víllora, K.Shimamura, Y. Yoshikawa, K. Aoki, N. Ichinose, Large-size β-Ga_2O_3 single crystals and wafers, *Journal of Crystal Growth*, 2004, vol. 270, no. 3, pp. 420–426.
13. J.D. Blevins, K. Stevens, A. Lindsey, G. Foundos, L. Sande, Development of Large Diameter Semi-Insulating Gallium Oxide (Ga_2O_3) Substrates, *IEEE Transactions on Semiconductor Manufacturing*, 2019, vol. 32, no. 4, pp. 466–472.
14. G.G. Gladush, I.Y. Smurov, *Fizicheskiye osnovy lazernoy obrabotki materialov (Physical Fundamentals of Laser Processing of Materials)*, Fizmatlit, Moscow, 2017 (in Russian).
15. F. Ullmann, U. Loeschner, L. Hartwig, D. Szczepanski, J. Schille, S. Gronau, T. Knebel, J. Drechsel, R. Ebert, H. Exner, High-speed laser ablation cutting of metal, *Proceedings of SPIE 8603, High-Power Laser Materials Processing: Lasers, Beam Delivery, Diagnostics, and Applications II*, 2013, art. no. 860311.
16. M.G. Berhe, H.G. Oh, S. Park, D. Lee, Laser cutting of silicon anode for lithium-ion batteries, *Journal of Materials Research and Technology*, 2022, vol. 16, pp. 322–334.
17. T. Sakai, A. Fujisaki, K. Kashiwagi, T. Kayahara, T. Shigematsu, High quality and high speed cutting of Al_2O_3 substrate with single mode fiber laser, *Proceedings of the ICALEO 2012: 31st International Congress on Laser Materials Processing, Laser Microprocessing and Nanomanufacturing*, ASME, 2012, pp. 1277–1280.
18. O.S. Medvedev, O. Khait, S.Yu. Kurin, A.S. Usikov, B.P. Papchenko, H. Helava, Yu.N. Makarov, Laser cutting of GaN/Al_2O_3 structures, *Journal of Physics Conference Series*, 2015, vol. 643, art. no. 012129.
19. K. Leitz, B. Redlingshöfer, Y. Reg, A. Otto, M. Schmidt, Metal Ablation with Short and Ultrashort Laser Pulses, *Physics Procedia*, 2011, vol. 12, pp. 230–238.
20. B. Neuenschwander, B. Jaeggi, M. Schmid, From fs to Sub-ns: Dependence of the Material Removal Rate on the Pulse Duration for Metals, *Physics Procedia*, 2013, vol. 41, pp. 794–801.
21. L.K. Wlodarczyk, M. Ardron, J.A. Waddie, A. Dunn, D.M. Kidd, J.N. Weston, P.D. Hand, Laser microsculpting for the generation of robust diffractive security markings on the surface of metals, *Journal of Materials Processing Technology*, 2015, vol. 222, pp. 206–218.

22. K. Zhang, Z. Xu, H. Wang, S. Zhang, B. Dong, Patterning the surface structure of transparent hard-brittle material β-Ga_2O_3 by ultrashort pulse laser, *Ceramics International*, 2022, vol. 48, no. 19, pp. 27650–27657.
23. M. Ahn, A. Sarracino, A. Ansari, B. Torralva, S. Yalisove, J. Phillips, Unique material modifications of Ga_2O_3 enabled by ultrafast laser irradiation, *Proc. SPIE 11281, Oxide-based Materials and Devices XI*, 2020, art. no. 112810O.
24. K. Zhang, Z. Xu, B. Dong, S. Zhang, Process exploration of β-Ga_2O_3 blind hole processing by water-assisted femtosecond laser technology, *Journal of Alloys and Compounds*, 2023, vol. 939, art. no. 168769.
25. D.A. Bauman, D.Iu. Panov, V.A. Spiridonov, A.V. Kremleva, A.E. Romanov, On the successful growth of bulk gallium oxide crystals by the EFG (Stepanov) method, *Functional Materials Letters*, 2023, vol. 16, no. 07, art. no. 2340026.
26. D.A. Bauman, D.I. Panov, V.A. Spiridonov, A.V. Kremleva, A.V. Asach, E.V. Tambulatova, A.V. Sakharov, A.E. Romanov, High quality β-Ga_2O_3 bulk crystals, grown by edge-defined film-fed growth method: Growth features, structural, and thermal properties, *Journal of Vacuum Science & Technology A*, 2023, vol. 41, no. 5, art. no. 053203.
27. Laser Center is a leading Russian manufacturer of laser equipment for cutting, engraving, marking, welding and microprocessing. Technology development, laser integration, *Electronic Resource*, URL: https://newlaser.ru/en/ (last access: 10.09.2025).