Pereinamųjų metalų oksidų ALD sluoksnių tyrimai GaN optoelektronikos taikymams

Investigation of ALD transition metal oxide films for GaN optoelectronic‘s applications

Roland Tomašiūnas[1], Ignas Reklaitis[1], Tadas Malinauskas[1], Sandra Stanionytė[2], Riina Ritasalo[3], Martin Mandl[4], Sebastian Taeger[4], Martin Strassburg[4]

[1] Institute of Photonics and Nanotechnology, Vilnius University, Saulėtekio al. 3, 10257 Vilnius, Lithuania
[2] State Research Institute Center for Physical Sciences and Technology, Sauletekio ave. 3, LT-10257 Vilnius, Lithuania
[3] Picosun Oy, Tietotie 3, 02150 Espoo, Finland
[4] OSRAM Opto Semiconductors GmbH, Leibnizstr. 4, 93055 Regensburg, Germany
rolandas.tomasiunas@ff.vu.lt

Anticipation for the oxide barrier layers to fulfill simultaneously a complex of requirements for current spreading, passivation, light extraction, encapsulation, or chemical stability within the process flow of optoelectronic device manufacturing is high. Besides that, the electrical characteristics for the device operation are essential, meaning the stable flat-band, the low leakage current, the high breakdown strength, etc. That’s why the efforts of the oxides community pay off with the appearance of new oxides, new bilayer, or even multilayer combinations featuring better, more persistent, qualities.

The atomic layer deposition (ALD) is among the most popular oxide deposition techniques, providing uniform deposition of conformal ultra-thin films with controllable thickness, even on complex three-dimensional surfaces. Not a surprise that the GaN optoelectronic industry has this technique more and more integrated into their production lines of LED, LD, MOS, and other devices.

In this work, we present a study about a series of transition metal oxides, HfO_2, ZrO_2, Ta_2O_5, TiO_2, Nb_2O_5, and Y_2O_3 but also SiO_2 and Al_2O_3 as a reference, ALD deposited on silicon or GaN substrates. The key issue was to focus on thermal and electrical stability. We correlate the oxide layer surface morphology with the post-annealing phase transformation while showing selective crystallization kinetics for the ALD oxide on silicon and GaN, in the view of deposition temperature, and oxidant [1]. A high breakdown field beneficial for insulation layers, we demonstrate for the oxides deposited at a lower temperature of ≤125°C, in particular HfO_2, ZrO_2, Ta_2O_5/H_2O (oxide/oxidant), and Al_2O_3. For the oxide-GaN interface at zero gate voltage and under unstressed condition, we have observed a qualitative feature demonstrating different dependence of the net fixed charge in the oxide or/and at the interface with the deposition temperature, namely, an increase of positive charge for oxidant water and an increase of negative charge for oxidant ozone. Best interface quality, least charge, and only slightly influenced by the deposition temperature, we have observed for the ZrO_2/H_2O. Instead, the highest temperature dependence – observed for the Al_2O_3/H_2O [2]. Comparatively, we discuss the C-V hysteresis resulting from the variation of interface trapping state concentration and their changes in the course of the crystallization. Worth mentioning that the comparative study on a variety of oxides deposited and investigated was performed on the same trial.

This research was executed within a project FLINGO under the M-ERA.NET scheme and was funded by the Research Council of Lithuania (grant No.M-ERA.NET-2/2016), German Federal Ministry of Education and Research (BMBF), and Finnish national funding agency.

Keywords: ALD, oxide, film, GaN, silicon, annealing, electrical breakdown, interface.

Literatūra

[1] I. Reklaitis, E. Radiunas, T. Malinauskas, S. Stanionytė, G. Juška, R. Ritasalo, T. Pilvi, S. Taeger, M. Strassburg, and R. Tomašiūnas., Surf. Coat. Technol. **399**, 126123 (2020).
[2] R. Tomašiūnas, I. Reklaitis, E. Radiunas, G. Juška, R. Ritasalo, T. Pilvi, M. Mandl, S. Taeger, and M. Strassburg. 21st Int. Conf. on Transparent Optical Networks, ICTON '19, 2019, Anger, France. IEEE Proc., We.E4.5, 2019 (ISBN: 978-1-7281-2779-8/19).