Boson peak related to Ga-nanoclusters in AlGaN layers grown by plasma-assisted molecular beam epitaxy at Ga-rich conditions

© V.Yu. Davydov[1], V.N. Jmerik[1], E.M. Roginskii[1], Yu.E. Kitaev[1], Y.M. Beltukov[1], M.B. Smirnov[2], D.V. Nechaev[1], A.N. Smirnov[1], I.A. Eliseyev[1], P.N. Brunkov[1], S.V. Ivanov[1]

[1] Ioffe Institute,
194021 St. Petersburg, Russia
[2] Saint-Petersburg State University,
199034 St. Petersburg, Russia

E-mail: valery.davydov@mail.ioffe.ru; jmerik@pls.ioffe.ru; e.roginskii@mail.ioffe.ru; yu.kitaev@mail.ru; ybeltukov@gmail.com; smirnomb@rambler.ru; nechayev@mail.ioffe.ru; alex.smirnov@mail.ioffe.ru; zoid95@yandex.ru; brunkov@mail.ioffe.ru; ivanovsv@mail.ioffe.ru

Received July 8, 2019
Revised July 16, 2019
Accepted July 16, 2019

We report the results of systematic Raman spectroscopy studies of $Al_xGa_{1-x}N$ ($x \sim 0.75$) layers grown using plasma-assisted molecular beam epitaxy at various stoichiometric conditions and growth fluxes. The high-intensity asymmetric low-frequency peak obeying Bose statistics is discovered in Raman spectra of the layers grown by temperature-modulated epitaxy at strongly Ga-enriched conditions. Theoretical model is developed to explain the origin and the high intensity of the observed low-frequency peak, which is attributed to the presence of excessive metallic gallium in AlGaN layers and can be explained by vibrations of gallium clusters with a diameter of ~ 1 nm. The nature of the low-frequency peak is similar to that of the boson peak in glasses, which occupies the same frequency range in Raman spectra. We demonstrate the capabilities of Raman spectroscopy as an express and non-destructive technique for optimization of growth conditions of AlGaN layers to achieve simultaneously the atomically-smooth droplet-free surface morphology and the high structural quality.

Keywords: AlGaN alloys, plasma-assisted molecular beam epitaxy, Raman spectroscopy, nanoclusters, boson peak.

Full text of the paper will appear in journal SEMICONDUCTORS.