Tuning of optical gap in layered gallium selenide

N.R. Arutyunyan[1], E.A. Obraztsova[2], D.V.Rybkovsky[3,1], E.D. Obraztsova[1]
[1] *A.M. Prokhorov General Physics Iinstitute RAS, Vavoliva st. 38, Moscow 119991, Russia*
[2] *M.M. Shemyakin and Yu.A. Ovchinnikov Institute of Bioorganic Chemistry RAS, Miklukho Maklaya st. 16/10, Moscow 117997, Russia*
[3] *Skolkovo Institute of Science and Technology (Skoltech), Nobelya Ulitsa 3, Moscow 121205, Russia*
Corresponding author: natalia.arutyunyan @gmail.com

Due to the unusual sombrero-like shape of the top of the valence band [1], few-layered gallium selenide (GaSe) is of great interest for the applications in optoelectronics, as photodetectors or non-lonear optical elements. Depending on the thickness of the layer, the shape of the valence band and the value of bandgap changes [1-4]. For the bulk material valence band has a maximum at Γ point. If the crystal has only few layers, the parabolic-like shape of the top of the valence band transforms into sombrero-like, when there is a local minimum at Γ point, surrounded by ring-shape maximum. The optical bandgap for the bulk material is about 2 eV. When the thickness of the crystal becomes smaller, the optical bandgap should increase up to 3.2 eV for single tetralayer [5].

Here, the Raman and photoluminescence spectra of few-layered GaSe crystals, produced on the $Si:SiO_2$ wafers by micro-mechanical exfoliation (Fig.1), are presented. The shift of the luminescence band (Fig.2) as well as the evolution of the Raman bands is shown. The degradation of the GaSe flakes due to the oxidation and appearance of the amorphous Se under the laser beam is discussed.

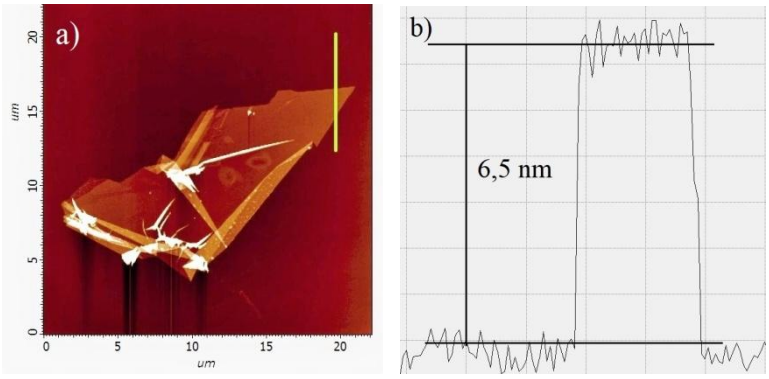

Fig.1. a) Few-layered flake of GaSe on $Si:SiO_2$ b) The profile of the height of the flake, which corresponds to 7 tetralayers.

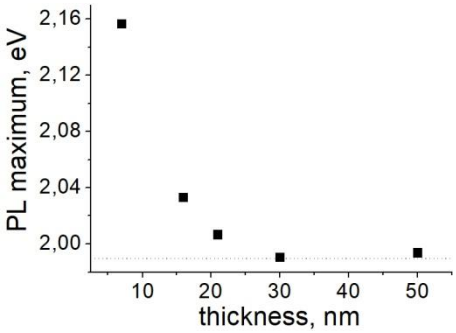

Fig.2. Positions of photoluminescence bands for flakes of various thickness (from 6 nm to bulk material).

[1] D.V. Rybkovskiy, A. V. Osadchy, and E. D. Obraztsova, PRB **90**, 235302 (2014).
[2] D. V. Rybkovskiy, N. R. Arutyunyan, A. S. Orekhov, I. A. Gromchenko, I. V. Vorobiev, A. V. Osadchy, E. Yu. Salaev, T. K. Baykara, K. R. Allakhverdiev, and E. D. Obraztsova, PRB **84**, 085314 (2011).
[3] D. Andres-Penares, A. Cros, J.P. Martínez-Pastor and J. F. Sánchez-Royo , Nanotechnology **28** 175701 (2017).
[4] Z. Ben Aziza, D. Pierucci, H. Henck, M. G. Silly, C. David, M. Yoon, F. Sirotti, K. Xiao, M. Eddrief, J.-C. Girard, and A. Ouerghi, PRB **96**, 035407 (2017).
[5] Gabriel Antonius, Diana Y. Qiu, and Steven G. Louie, Nano Letters **18**, 1925 (2018).