Pis'ma v ZhETF, vol. 115, iss. 10, pp. 611 – 612

Enhancement of the basal-plane stacking fault emission in GaN planar nanowire microcavity

E. I. Girshova[+1)], *G. Pozina*[*], *A. V. Belonovskii*[+], *M. I. Mitrofanov*[×∘], *I. V. Levitskii*[×∘], *G. V. Voznyuk*[+], *V. P. Evtikhiev*[*], *S. N. Rodin*[×∘], *M. A. Kaliteevski*[+]

[+] *ITMO University, 197101 St. Petersburg, Russia*

[*] *Department of Physics, Chemistry and Biology (IFM), Linköping University, S-581 83 Linköping, Sweden*

[×] *Submicron Heterostructures for Microelectronics, Research and Engineering Center, Russian Academy of Sciences, 194021 St. Petersburg, Russia*

[∘] *Ioffe Institute, 194021 St. Petersburg, Russia*

Submitted 5 April 2022
Resubmitted 12 April 2022
Accepted 13 April 2022

DOI: 10.31857/S1234567822100032, EDN: dyimlt

Optical microcavities based on semiconductor planar nanostructures attract significant interest due to a relative simplicity of growth [1–4].

We have studied microcavities based on GaN nanostructures grown using a "bottom-up" approach [5, 6]. Near the perfect shape of structures grown by selective area metal-organic vapor phase epitaxy (MOVPE) on sapphire (0 0 0 1) allowed the formation of cavity modes and the enhancement of the spontaneous emission intensity [7, 8]. In such microcavities, the exciton is considered as "bulk", (not confined in the active layer in difference from the microcavities with DBR). Exciton-cavity modes coupling conditions are different for these resonators.

We compare microcavities formed by GaN nanowires with structural defects (basal-plane stacking faults (SFs)) and without them and observe different behavior of the PL intensity and PL decay time with increasing excitation power for the exciton localized at SFs compared to the bulk exciton.

Figure 1a shows the end of a uniform flat GaN nanowire. The structures may have structural defects such as SFs. The low-temperature CL spectra shown in Figs. 1b were taken at different points of the nanowire along the line as shown in Fig. 1a. Panchromatic CL shows non-uniformity in the contrast at the edge of the NW, which indicates a presence of structural defect likely SFs. While CL spectra in points 1–3 in Fig. 1b shows near band gap emission with one dominant peak at ~ 3.48 eV, which is typical donor bound exciton (DBE) emission in GaN, the CL spectrum in point 4 demonstrates additional broader emissions at ~ 3.43 and ~ 3.35 eV. Similar signatures at ~ 3.42 eV and ~ 3.35 eV in GaN are associated with the emissions related to the basal plane SFs of type I1 and I2 [9, 10].

An increase in the excitation power P leads to a super-linear growth of the integrated intensity $I \sim P^{1.9}$ for the SF1 emission compared to the SF2 line, for which the dependence of the integrated PL intensity shows nearly linear growth on pumping $I \sim P^{1.1}$ (Fig. 1c).

Studies of time-resolved PL have revealed that the SF1 and SF2 emissions have opposite temporal behavior with the variation of the excitation power. The estimated PL decay time is plotted as a function of the pumping power in Fig. 1d for the PL lines SF1 and SF2 by solid triangles and circles, respectively. Clearly, the recombination time is shorter for the SF1 emission compared to the SF2 line. As the excitation power increases, τ increases for the SF1 line from ~ 30 to ~ 100 ps while, in contrast, τ decreases from $\sim$1100 to ~ 500 ps for the SF2 emission.

Interaction of exciton and cavity modes can occur in microcavities of various types; the resonator size should be significantly smaller than the wavelength to provide a large energy interval between the microcavity modes [10]. The studied planar GaN NWs have width and length of ~ 7 and $\sim 110\,\mu$m, respectively, and, thus, possess properties of so-called meso-cavity when the size of the resonator corresponds to tens of wavelengths [11, 12]. The field distribution for the cavity modes was calculated. It is shown that light is well localized at the ends of nanowires.

In conclusion, a different behavior of the PL intensity and the PL decay time with increasing excitation power for an exciton localized on a SF as compared to a bulk exciton is demonstrated. Calculations show good localization of the field at the boundary of the structure in the region of the exciton energy.

The work has been supported by the Russian Science Foundation # 21-12-00304. The work is financially supported by Priority 2030 program.

1) e-mail: ilinishna@gmail.com

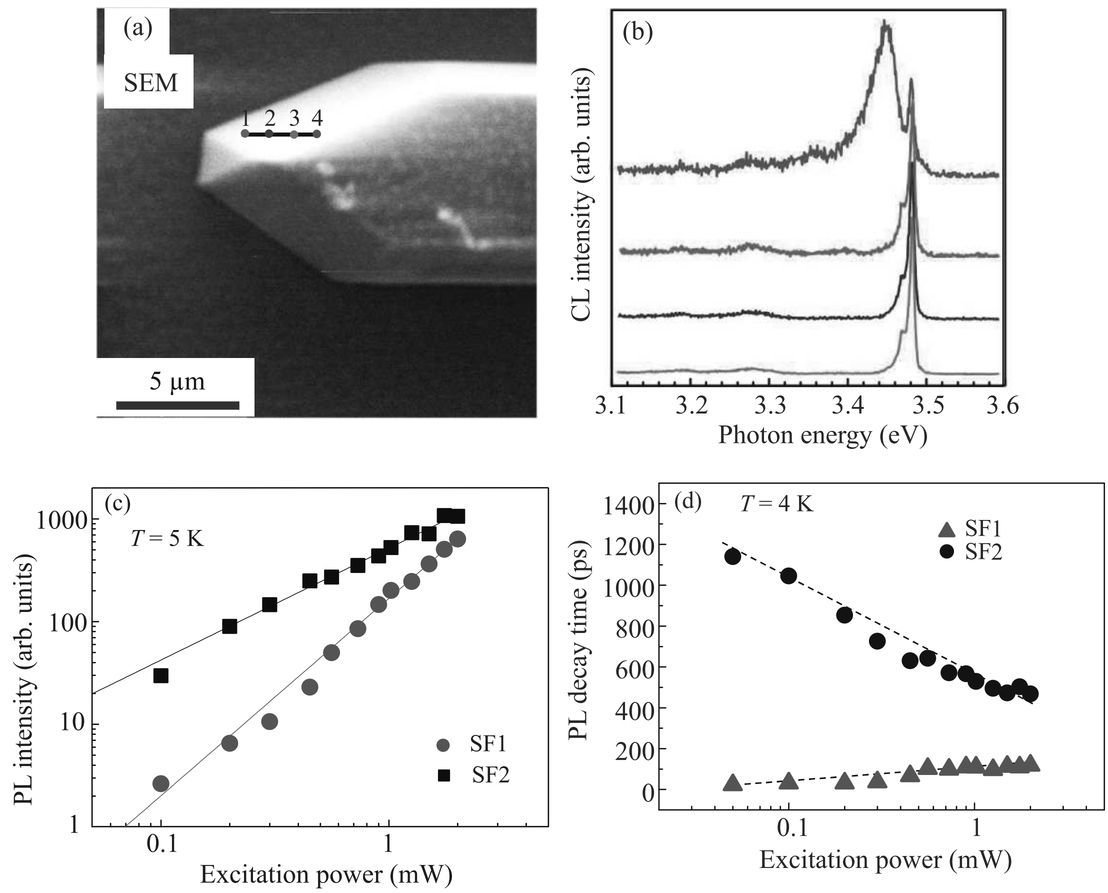

Fig. 1. (Color online) (a) – Bird-view SEM image showing end of the nanowire measured simultaneously by SEM. (b) – Normalized CL spectra taken at 5 K at different points along the line shown in (a) and labeled by corresponding numbers. Spectra are shifted vertically for clarity. (c) – Dependence of the integrated PL intensity for the SF1 and SF2 emissions on the excitation power. (d) – PL decay time extracted from the PL decay curves shown as a function of the excitation power for the SF1 and SF2 peak emissions by closed triangles and circles, respectively

This is an excerpt of the article "Enhancement of the basal-plane stacking fault emission in GaN planar nanowire microcavity". Full text of the paper is published in JETP Letters journal. DOI: 10.1134/S0021364022100605

1. A. C. Tamboli, E. D. Haberer, R. Sharma, K. H. Lee, S. Nakamura, and E. L. Hu, Nature Photon. **1**, 61 (2007).
2. T. Takeuchi, S. Kamiyama, M. Iwaya, and I. Akasaki, Rep. Prog. Phys. **82**, 012502 (2019).
3. M. S. Kang, C.-H. Lee, J. B. Park, H. Yoo, and G. C. Yi, Nano Energy **1**, 391 (2012).
4. C. Berger, A. Dadgar, J. Bläsing, A. Franke, T. Hempel, R. Goldhahn, J. Christen, and A. Krost, Phys. Status Solidi C **9**(5), 1253 (2012).
5. G. Pozina, A. R. Gubaydullin, M. I. Mitrofanov, M. A. Kaliteevski, I. V. Levitskii, G. V. Voznyuk, E. E. Tatarinov, V. P. Evtikhiev, S. N. Rodin, V. N. Kaliteevskiy, and L. S. Chechurin, Sci. Rep. **8**, 7218 (2018).
6. G. Pozina, C. Hemmingsson, A. V. Belonovskii, I. V. Levitskii, M. I. Mitrofanov, E. I. Girshova, K. A. Ivanov, S. N. Rodin, K. M. Morozov, V. P. Evtikhiev, and M. A. Kaliteevski, Status Solidi A **217**, 1900894 (2020).
7. G. Pozina, K. A. Ivanov, M. I. Mitrofanov, M. A. Kaliteevski, K. M. Morozov, I. V. Levitskii, G. V. Voznyuk, V. P. Evtikhiev, and S. N. Rodin, Status Solidi B **256**, 1800631 (2019).
8. P. P. Paskova, R. Schifano, T. Paskova, T. Malinauskas, J. P. Bergman, B. Monemar, S. Figge, and D. Hommel, Physica B **376/377**, 473 (2006).
9. J. Lahnemann, O. Brandt, U. Jahn, C. Pfüller, C. Roder, P. Dogan, F. Grosse, A. Belabbes, F. Bechstedt, A. Trampert, and L. Geelhaar, Phys. Rev. B **86**, 081302(R) (2012).
10. C. Weisbuch, M. Nishioka, A. Ishikava, and Y. Arakawa, Phys. Rev. Lett. **69**(23), 3314 (1992).
11. A. V. Belonovski, I. V. Levitskii, K. M. Morozov, G. Pozina, and M. A. Kaliteevski, Opt. Express **28**(9), 12688 (2020).
12. A. V. Belonovski, K. M. Morozov, E. I. Girshova, G. Pozina, and M. A. Kaliteevski, Opt. Express **29**(13), 20724 (2021).