Terahertz Emission from Silicon Nanostructures Heavily Doped with Boron

Nikolay T. Bagraev*, Andrey .K. Kaveev†, Leonid E. Klyachkin*, Anna M. Malyarenko*, Vladimir A. Mashkov*, Dmitrii I. Tsypishka†, and Ilya A. Vinerov†

[*] *Ioffe Physical Technical Institute, St. Petersburg, Russia*
Email: impurity dipole@mail.ioffe.ru
[†] *TYDEX, LLC., Domostroitelnaya str. 16, 194292 St. Petersburg, Russia*
Email: andreykaveev@tydex.ru

The THz emission from the microcavities embedded in silicon nanostructures appears to be revealed by measuring with the Bruker-Physik VERTEX 70 FT-IR spectrometer.

The device has been prepared on the n-type Si (100) surface within frameworks silicon planar technology. Making a mask and performing photolithography after preliminary oxidation, the short time diffusion of boron was used to obtain the ultra-shallow p+-n junctions [1]. The cyclotron resonance measurements as well as the infrared and local tunneling spectroscopy data have shown that the p+-boron diffusion profile represent the ultra-narrow p-type silicon quantum well (Si-QW), 2 nm, confined by the δ-barriers, 3 nm, heavily doped with boron, $N(B)=5\cdot10^{21}cm^{-3}$on the n-type Si (100) surface. The SIMS and STM studies have shown that the δ-barriers represent really alternating arrays of silicon empty and doped dots, with dimensions restricted to 2 nm. This extremely high concentration of boron seems to indicate that each doped dot located between empty dots contains two impurity atoms of boron. The EPR studies show that these boron pairs are the trigonal dipole centers, B(+) - B(-), that contain the pairs of holes, which result from the negative-U reconstruction of the shallow boron acceptors, 2B(0) => B(+) + B(-).

This device appears to allow the THz emission of the dipole boron centers inside the δ-barriers which is caused by the stabilized drain-source current along the Si-QW plane. The corresponding series of the electroluminescence (EL) spectral lines are in an agreement with the values of the negative-U energy gap, 0.044 eV, and the excited states of trigonal boron dipole centers [1]. This THz emission lines, 1.35, 2.9, 3.4, 5.3 and 10.6 THz, are found to be enhanced by inserting the corresponding planar cavities, 4, 8 and 16 microns.

Besides, the 0093 THz and 0.129 THz emission spectral lines caused by also the radiation of the dipole boron centers are revealed by measuring the Shapiro and Fiske steps, which are identified also as the modulation frequency of the black body radiation of the device [2]. These findings seem to be due to the oscillations of the heat capacity that are induced by the THz emission of the dipole boron centers inside the δ-barriers confining the Si-QW. Finally, by varying the values of the drain-source current and the lateral voltage applied in the Si-QW plane, the phase shifts of the THz modulation of the black body radiation appear to be observed as a result of the negative-U properties of the dipole boron centers.

References

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