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Collective effects in Si-based quantum dot nanomaterials to tune the functionality of nano electronic and nanophotonic components

Anatoly Dvurechenskii, Andrew Yakimov, Aigul Zinovieva, Vladimir Zinovyev, Aleksei Bloshkin, Aleksei Nenashev, Viktor Kirienko

Rzhanov Institute of Semiconductor Physics, Russia

The approaches to obtaining high-performance infrared photodetectors and luminescent structures based on Ge/Si QDs silicon Nano heterostructures coupled with metal surfaces and photonic crystals are considered. It was shown that the composite Meta surface consisted of a two-dimensional regular array of silicon pillars and subwavelength holes array in a periodically perforated gold film on top of the detector active region displaying about 15 times peak responsivity enhancement at a wavelength of 4.4 μm relative to the bare detector. The planar Ge/Si QDs photodetector coupled with a plasmonic structure consisting of a two-dimensional regular array of Al nano disks can increase the photodetectors efficiency by about 40 times at λ=1,2 μm and by 15 times at λ= 1,55 μm with an appropriate choice of the array periodicity and the size of the Al nano disks. The other idea of the approach is to use photonic crystals in processes of optical absorption in thin layers of quantum dots embedded in photonic crystals. We found that the incorporation of Ge/Si quantum dot layers into a two-dimensional photonic crystal leads to multiple (up 34 times) enhancement of the photocurrent in the near-infrared range. The results are explained by the excitation of planar photonic crystal modes by the incident light wave propagating along with the Ge/Si layers and effectively interacting with interband transitions in quantum dots. The photoluminescence of the combined Ge/Si QDs heterostructures consisted of a combination of large (200–250 nm) GeSi nano disks and layered stacks of compact groups of smaller (30 nm) quantum dots were grown by site-controlled nucleation in the strain fields of nano disks show the multiple increases in the photoluminescence intensity. The main channels of radiative recombination correspond to spatially direct optical transitions.

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Recent Publications

1. A. V. Dvurechenskii, Andrew Yakimov, V. V. Kirienko, Aleksey Bloshkin- Near-infrared photoresponse in Ge/Si quantum dots enhanced by localized surface plasmons supported by aluminum nanodisks October 2020Journal of Applied Physics 128(14):143101, Doi/10.1063/5.0023249

2. A. V. Dvurechenskii, Andrew Yakimov, Aleksey Bloshkin- Plasmonic Field Enhancement by Metallic Sub wave Lattices on Silicon in the Near-Infrared Range September 2019JETP Letters 110(6):411-416- DOI:10.1134/S0021364019180115

3. A. V. Dvurechenskii, Andrew Yakimov, Aleksey Bloshkin- Plasmon Enhancement of the Electric Field in Mid-Infrared Ge/Si Quantum-Dot Photodetectors with Different Thicknesses of the Active Region February 2019Semiconductors 53(2):195-199 DOI:10.1134/S1063782619020039

dvurech@isp.nsc.ru

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