Quantum-dot photodetectors: 
In search of optimal design for room-temperature operation

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Quantum-dot structures provide possibilities to control photoelectron kinetics and in this way to improve the photodetector performance (photoconductive gain, responsivity, and operating temperature). The performance of current room-temperature photodetectors is limited by extremely fast photoelectron relaxation/capture. In order to increase the photoconductive gain and to improve responsivity and detectivity of quantum-dot infrared photodetectors (QDIPs), the processes of photoelectron capture should be suppressed. This can be done by means of potential barriers, which separate the conducting electron states in the matrix from the localized states in quantum dots. A potential barrier around each dot can be formed by doping of the interdot space. The electrons from the dopants populate quantum dots and create the depletion regions around the dots. The potential barriers are produced by the electrons trapped in quantum dots and by the ionized dopants in the depletion regions. The potential profile depends on the size of the dots, on the doping, and on the distance between the dots.

We analyze photodetectors with three substantially different structural arrangements of dots. 1) In the single dot structures the potential barriers of the dots are practically independent due to a substantial distance between the dots. 2) Collective barriers can be easily created in quantum-dot structures with lateral photoelectron transport. In these structures, the collective potential barriers are created by negatively charged planes of quantum dots and positively charged planes of dopants. 3) Substantial potential barriers can be formed by vertically correlated dot clusters (VCDC) in the photodetectors with vertical transport.

In this talk, we present results of our simulations and modeling, which show strong suppression of capture processes by the potential barriers. Monte Carlo simulation demonstrates that compared with ordinary quantum dot structures, where the photoelectron lifetime at room temperatures is of the order of 1-10 ps, the VCDC structures allow for increasing the lifetime up to three orders of magnitude. Fabrication of photodetectors with VCDC structures is shortly discussed.

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Vladimir Mitin, SUNY Distinguished Professor at the Department of Electrical Engineering at the University at Buffalo, The State University of New York, was the Chair of that Department for two terms: 2003-2006 and 2006-2009. During 1993-2003 he was a Professor in the Department of Electrical and Computer Engineering at Wayne State University in Detroit, Michigan. His fields of specialization are nanoelectronic, microelectronic and optoelectronic devices and materials. Currently he is working in the following areas: design and simulation of devices; heat dissipation in nano-structure and nano-devices; light absorption and emission in inhomogeneous materials, heterostructures, and nanostructures. Special emphasis in his research now is in simulation and modelling of nanosensors, and quantum dot infrared photodetectors. He has more than 400 publications including ten patents, four monographs and four textbooks.

He obtained his Doctor of Science degree in 1987 from the Institute of Semiconductors of Ukrainian Academy of Sciences in Kiev, Ukraine.