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9-я Международная научно-практическая конференция

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Theoretical and experimental comparison of multilayer Ge/Si photodetectors with quantum dots

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The work discusses multilayer infrared photodetectors with quantum dots of germanium on silicon. It compares the theoretical calculations results of the dark current density of multilayer photodetector with Ge/Si quantum dots with the experimental results from previous research.

The success of quantum well structures for infrared detection applications has urged the development of quantum dot infrared photodetectors. In the past decades, the QDIPs have become a topic of extensive research not only for the fundamental understanding of fascinating physics that exists in zero-dimensional systems but also for their application in infrared optoelectronics [1]. At present, nearly defect-free quantum dot devices can be fabricated reliably and reproducibly [2].

In the presented work the theoretical model described in [2] is developed in order to take into account the presence of multiple quantum dot layers in photodetectors. To verify our model, we compared the theoretical values of the dark current with the experimental results obtained in other researchers works [3-4].

In [3], the mid-infrared photodetectors were vertical p+–p–p+ diodes with Ge QD layers, separated by Si or SiGe intervals and enclosed between two highly doped p-type contact layers, operating in the mode of restriction by generation-recombination noise are investigated. The experimental dark current-voltage characteristics of a multilayer photodetector with germanium quantum dots on silicon from [3] were compared with the theoretical results we achieved in our calculations and the theoretical obtained values of the parameter $E_{0,n}$ and the parameter $E_{0,m}$ best match the experimental data when selecting the model parameter values as in table 1.

Table.1: Values of the model parameters used for the calculations of dark current-voltage characteristics:

Temperature, K	Parameter $E_{0,m}$, meV	Parameter $E_{0,n}$, meV
90	44	263
110	57	311
120	71	330
140	71	364

In [4], mid–infrared photodetectors based on silicon p–i–p structures doped with boron and containing 20 layers with germanium quantum dots in their intrinsic region are described, and a strong dependence of the dark current value on the doping level is observed. The experimental and calculated results of the dark current of the described structures for two different concentrations of the dopant: $6 * 10^{18}$ cm^{-3} (sample A) and $0.6 \cdot 10^{18}$ cm^{-3} (sample B) are presented. To get the best match we chose the parameters values listed in table 2.

Table.2: Values of the model parameters used for the calculations of dark current-voltage characteristics:

	Sample A	Sample B
Dopant concentration, cm^{-3}	$0.6 \cdot 10^{18}$	$6 \cdot 10^{18}$
Temperature, K	77	77
Parameter $E_{0,m}$, meV	84	59
Parameter $E_{0,n}$, meV	180	247
F_0, kV/cm	2.4	2.4
α, meV*cm/kV	1	1

Thus, such theoretical calculations can serve as an alternative method for estimating the position of the main energy levels in a quantum dot.

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