ABSTRACT

The motivation for choosing research topics undertaken in the dissertation was the widespread desire of both manufacturers and users to raise the operating temperature of infrared detectors. These studies concerned the technology of advanced devices, which are interband cascade infrared photodetectors with superlattice absorbers.

Interband cascade structures are an attractive alternative to the conventional single-stage devices. In the interband cascade device, electrons must be excited and collected several times before reaching the contact. Although counterintuitive, this transport feature can be beneficial for both energy-conversion and infrared detection technology. In particular, the interband cascade architecture is useful for improving the performance of narrow-bandgap optoelectronic devices operating at high temperature. Due to the high speed these detectors may be a new path of development of telecommunication devices based on quantum systems. The aim of this dissertation is theoretical and experimental analysis of the impact of technology and the architecture of interband cascade detectors on their high-temperature detection performance.

The paper shows how standard bulk semiconductor transport equations can be extended to the case of multiple-stage devices. The theory is then applied in order to improve the detection parameters that can be obtained by using a multiple-stage cascade structure. In the dissertation, two cascade detector architectures were analyzed: with identical cascade stages and with absorbers with variable thickness, selected to ensure equal quantum efficiency in each cascade stage. By optimizing the number of stages in cascade, depending on the absorption coefficient and the absorber thickness is shown that those detectors can achieve high sensitivities for applications requiring a very fast temporal response. The multiple-stage architecture is also useful for improving the sensitivity of high operating temperature detectors, especially, if a short diffusion length limits the quantum efficiency. Theoretically obtained parameters of the analyzed cascade devices were verified with literature data.

The experimental part presents the structure details and measurement results of optical and electrical parameters of interband cascade detectors made of epitaxial layers fabricated in the Center for High Technology Materials in Albuquerque and School of Electrical and Computer Engineering in Norman. These detectors utilized absorbers composed of InAs/GaSb type-II superlattices. Detectors with cascades of equal and variable thickness of absorbers in subsequent stages were analyzed.

The cut-off wavelengths of these detectors were in the mid-wave and long-wave infrared region, respectively. Mechanisms limiting the performance of the examined devices have been identified. All examined detectors had dark currents limited by surface leakage effects. The sensitivity and detectivity of the multiple-stage devices exceed that of the single-stage ones at room temperature. For the set of devices studied, it is shown that multiple-stage detectors using short absorbers in comparison to single-stage diodes are able to achieve higher values of R_0A in long-wave infrared range and have a photoresponse that is less sensitive to temperature, which allows maintaining the required detection parameters in the temperature range from 230 K to 380 K. This provides direct evidence of the utility of these devices for high-temperature detector operation.

The identified parameters limitations of the interband cascade detectors are non-fundamental and can be eliminated by improving the technology of structure growth and *processing*.