Temperature-dependent Photomodulated Reflectance of InAs/InGaAs Dots-in-a-Well Quantum Structures

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In recent years, an advanced InAs/InGaAs dots-in-a-well (DWELL) quantum heterostructure was used in quantum dot infrared photodetectors (QDIPs). This novel QDIP concept is based on intraband optical transitions between the bound-states of quantum dot (QD) and quantum well (QW), and allows a control of the operating wavelength through adjusting QD/QW parameters and/or applying a bias voltage [1]. However, better understanding of electronic structure and optical properties in a wide temperature range is essential for optimization and further development of these photodetectors.

In this work, temperature-dependent (3–300 K) photoreflectance (PR) spectroscopy was used to explore InAs QD- and InAs/InGaAs QW-related optical interband transitions within InAs/InGaAs/GaAs/AlAs photodetector heterostructure (see Fig. 1). Also, room temperature contactless electroreflectance (CER), phototransmittance (PT), and high-excitation photo-luminescence (PL) were measured for comparison. Photomodulated signal intensity (energy) variation with temperature was analyzed using Arrhernius (Varshni) expression. Moreover, numerical calculations were performed to interpret the observed optical transitions.

For the first time, the evidence for the influence of back-surface reflection effects on the PR spectra of DWELL structures is provided. The interband optical transition energies of ground-state and four excited-states were established in 3–300 K temperature, indicating a high uniformity of QD ensemble. It was found that PR lineshape is influenced by variation of photomodulation mechanism with temperature. In particular, at high temperatures, lineshape is governed by the quantum-confined Stark effect, whereas, at low temperatures, PR lineshape indicates state-filling effects [2]. Moreover, optical transition energy in QDs follows the Varshni relation with intermediate parameters between that of a bulk GaAs and InAs [3]. This suggests that QD composition is partially changed due to Ga/In interdiffusion. The obtained activation energy (~320 meV) at high temperatures suggests that signal intensity quenching is governed by exciton emission from dot-to-well bound-states.

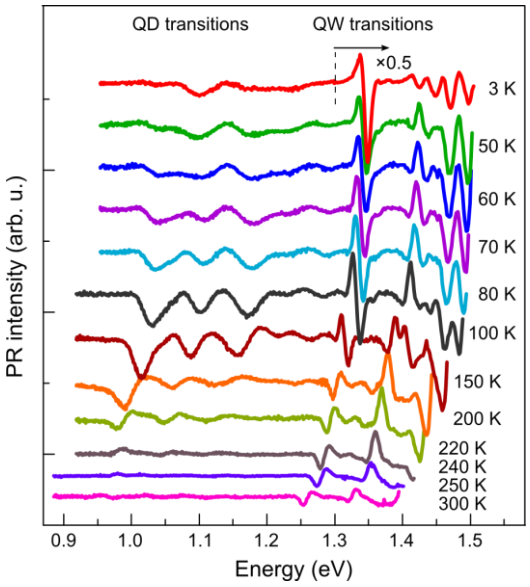

Fig. 1. PR spectra of DWELL structure in a temperature range 3–300 K.

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