［様式－学 5］

Abstract of Doctoral Thesis

Title:

Study on high-speed and high-sensitivity InAlAs-system superlattice avalanche photodiodes with Mote Carlo analysis of impact ionization rates

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Theoretical and experimental study on InAlAs-system superlattice avalanche photodiodes (APDs) for high-speed optical communication is described in this thesis. The concept of superlattice APD, in which the impact ionization rates can be controlled artificially by using GaAs superlattice multiplication layers, was proposed in early 1980's. In this study, impact ionization multiplication characteristics were theoretically analyzed, and fundamental properties were experimentally confirmed in order to achieve long-wavelength InAlAs/InAl(Ga)As superlattice APDs. A new device structure for high-reliability was proposed and its experimental evaluations were also performed.

At first, theoretical analysis on impact ionization phenomena in superlattice was performed by Monte-Carlo simulation. To obtain simulation parameters, impact ionization rates in bulk InAlAs were experimentally determined for the first time. This Monte Carlo analysis elucidated hot carrier behavior, and electric field and structure dependences of impact ionization rates in InAlAs-system superlattice. As results, we found impact ionization rate ratio was enhanced mainly due to the hole ionization rate reduction in superlattice, of which well layer thickness was as thin as approximately 20 nm. The difference of impact ionization rate ratio between square barrier superlattice and graded barrier superlattice, sawtooth-type superlattice, was also indicated.

Next, to decrease dark current in conventional InGaAs ternary well superlattice APDs, this study proposed an InAlGaAs quaternary well superlattice APD. The device simulation indicated its hetero electric filed and layer structure dependence of high-frequency response. The experimental characterization of mesa structure APDs elucidated fundamental properties of InAlGaAs quaternary well superlattice APDs for high-speed and high-sensitivity device design,, such as, structure dependence of dark current and gain-bandwidth (GB) products. GB products over 100 GHz, small temperature dependence of breakdown voltage and GB product, and 2 dB higher sensitivity characteristics in 10 Gbps than conventional InP-APDs, were confirmed for the first time.

Lastly, to realize high reliability and high-speed response at the same time for practical use, a new planar structure APD was proposed, designed, and investigated for the first time. This planar structure has an advantage for controlling pn-junction position/multiplication layer thickness and electric field profile by using not a conventional diffused pn-junction, but a grown pn-junction, as well as obtaining stable surface leakage current. As results, receiver sensitivity of -28.0 dBm at 10 Gbps, and device lifetime over 10^6 hours were confirmed by the proposed planar InAlAs-system superlattice APD.