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Interface Electron Traps as a Source of Anomalous Capacitance in AlGaN/GaN Heterostructures

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We studied by modeling and simulation how deep traps at the AlGaN/GaN heterostructure interface influence the shape of capacitance–voltage (*C*–*V*) curves of the heterostructure. Assuming donor and acceptor type of traps, we found differences in the *C*–*V* curves for sharp energy interface states or continuously distributed states with the same total concentration for the acceptor-type interface states. The background doping concentration of GaN had only a marginal influence on the shape of the *C*–*V* curves. We observed that an anomalous capacitance peak occurred for the continuous distribution of traps in the bandgap; a similar peak had been observed in experiment. We also saw that the capacitance curves shifted slightly to the right or to the left depending on the GaN doping concentration. A remarkable difference was found between the capacitance curves for the structures with the sharp acceptor trap level and continuous distribution of traps. For donor-type interface states, we found practically no influence on *C*–*V* curves since they remain populated and charge neutral during the measurement.

Key words: III–V heterostructures, heterostructure capacitance, interface traps, deep levels, semiconductor traps

INTRODUCTION

Transistors based on AlGaN/GaN heterostructures have been in the focus of semiconductor device research in recent years. They work at very high frequencies, high temperatures, and high power. Their physics and technology have been worked out to great sophistication. However, there are still questions and problems waiting to be answered and solved.

One such problem is the role that electron traps and surface states play in the heterostructure electrical properties. The surface states are on the AlGaN layer surface, and the traps are in the bulk of semiconductor. Surface states located at the top of the AlGaN layer were studied by Brannick et al.[1] The states localized at the interface between the AlGaN and GaN layers are called interface states. It has been found, e.g., that the current collapse in AlGaN/GaN high-electron-mobility transistors (HEMT) is more pronounced when there are deep acceptors present in the buffer layer. It was shown by deep-level transient spectroscopy (DLTS) measurements that the traps are mostly located near the AlGaN/GaN interface.[2,3] Two deep levels located at the AlGaN/GaN interface were observed by deep-level optical spectroscopy also by Nakano et al.[4] Interface states between GaN and AlInN were identified also by a photocurrent method[5] and by analyzing the frequency dispersion in the capacitance and conductance of AlGaN/GaN structures.[6] It is also assumed that the interface states and the charge accumulated in these states may be the main reason for the capacitance hysteresis observed in AlGaN/GaN heterostructures.[7] Hole-like traps at the interface were observed by Fang et al.[8] The authors found a continuous distribution of interface states from 56 meV to 110 meV below the conduction band of GaN and argued that those states are responsible for the gate leakage current. They

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