ABSTRACT

OPTICAL AND STRUCTURAL CHARACTERIZATION OF SEMICONDUCTORS FOR MID-WAVE INFRARED APPLICATIONS

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This study evaluates advanced semiconductor materials for mid-wave infrared applications. The first part investigates the rapid thermal oxidation of Ge(Sn) on Si by examining their optical and structural changes. Group-IV oxides, particularly GeO_2, are promising piezoelectric materials suitable at high-temperature environments. As-received samples, prepared by chemical vapor deposition, underwent ultrasonic cleaning before oxidation. The samples were rapidly thermally oxidized at a pressure of 2.7 atm with an oxygen flow rate of $\approx$ 0.2 L/min. Spectroscopic ellipsometry measurements revealed that oxide thickness increased with both annealing temperature and time. Depolarization and surface discoloration indicated non-uniformity within the oxide, which was incorporated into their optical modeling. X-ray diffraction confirmed formation of α-quartz GeO_2. Reciprocal space maps were used to determine the strain state of the Ge epilayer and the relaxation/Sn content for the GeSn epilayer. The Deal-Grove model described Ge oxidation on Si, resulting in an activation energy of 4 ± 2 eV for oxygen diffusion in Ge. The oxidation consumption rates for Ge and GeSn epilayers were determined to be 0.56-0.57 and 0.54, respectively.

The second part characterizes various III-V materials (GaInAsSbBi on GaSb, strain-balanced InAs/InAsSb on GaSb, and InGaAs/InAsSb superlattice on GaSb) using time-resolved photoluminescence over temperatures ranging from 5 to 300 K. The samples undergo low-excitation conditions where the resulting time-resolved photoluminescence yields a single exponential decay rate, providing an evaluation of the minority carrier lifetime. The temperature-dependent lifetime is analyzed using a recombination rate model to determine the temperature-dependent Shockley-Read-Hall, radiative, and Auger recombination rates. These recombination rates effectively model the lifetime data above 100 K in all samples and provide the defect energy level, capture cross section defect concentration product, carrier concentration, and Bloch overlap parameters in each sample. Below 100 K, the lifetime's temperature dependence is complicated by additional factors that increase the lifetime at lower temperatures, which is believed to be carrier localization. A trap-delayed recombination model is introduced providing insight in how localization influences the minority carrier lifetime.