Optical and Electronic Transport Properties of Si Nanostructures

A. K. Sharma

Air Force Research Laboratory, Electronics Foundations Group

Abstract—A detailed investigation focused upon evaluating the effects dimensional nanoscaling of silicon features on the optical and electronic properties is presented. The feature dimensions in this study ranged from \( \approx 200\)nm down to \( \approx 10\)nm. This range represents the transition region from material bulk properties towards the onset of quantization. These structures were fabricated on silicon-on-insulator using interferometric lithography, reactive-ion-etching and thermal oxidation methods. In order to investigate the optical and electronic properties, the nanostructures were configured in a two terminal metal-semiconductor-metal test device arrangement. The metal-semiconductor-metal configuration was chosen for this study due to its practicality in photonic and electronic parameter characterization and the ease of device fabrication. Characterization methods included steady-state DC measurements and transient time response measurements using a modified version of the Haynes-Shockley experiment for evaluating the carrier mobility as a function of feature size. Results show that the total carrier drift-diffusion dependent conduction for same biasing conditions increased as the feature dimension was reduced from \( \approx 200\)nm to \( \approx 10\)nm. The transient time response measurements show that the low field electron mobility can be increased in the best case at room temperature from \( \approx 1000\) cm\(^2\)/V-s to \( \approx 4000\) cm\(^2\)/V-s as the cross-sectional area becomes narrower due to confinement effects. Theoretical models for optical coupling and electronic transport properties are provided to give physical insight at these small scales.

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