EXPERIMENTAL INVESTIGATION AND MODELING OF THE EFFECTS OF HIGH-DOSE ION IMPLANTATION DAMAGE ON BORON DIFFUSION IN SILICON

A DISSERTATION

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DOCTOR OF PHILOSOPHY

By

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I certify that I have read this dissertation and that in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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Abstract

As device dimensions shrink, it becomes imperative to have a predictive capability for the impurity redistribution in high-dose source/drain implanted regions during subsequent thermal anneals. The final doping profile depends on the interaction between high concentration diffusion, implant damage, dopant solubility, amorphous layer regrowth, extended defect formation, and dopant segregation. The purpose of this work is to experimentally characterize the effects of high-dose implantation damage on boron diffusion and to implement physically-based models for these effects into SUPREM-IV.

Epitaxial silicon is used to grow a boron buried marker layer so that the effect of implant damage alone on dopant diffusion can be carefully studied. Silicon implants are used to generate surface damage and the motion of the boron layer is monitored during furnace annealing in inert or oxidizing ambients. For anneals in inert ambients, the diffusion of the marker layer is enhanced as compared to equilibrium conditions due to the point defects generated by the implant. The enhanced diffusion is characterized as a function of implant dose, implant energy, anneal time, and anneal temperature. For short-time, low-temperature anneals, the enhanced diffusion is independent of the silicon implant dose, even above the amorphization level. For long times, the enhanced diffusion of the marker layer is less for implant doses above the amorphization level. Extended defects form anytime an amorphous layer is generated and are most likely responsible for the smaller enhancements observed for long times. This hypothesis is confirmed by the anneals in oxidizing ambients. Oxidation-enhanced diffusion of the boron layer is significantly reduced in regions containing extended defects as compared to regions without them. Some of the interstitials injected during the oxidation which normally enhance the diffusion of the boron layer are absorbed by the extended defects. Transmission electron microscopy shows the growth of extended defects during the thermal oxidations.

A new equilibrium pair diffusion model has been implemented into SUPREM-IV as the new full.cpl model. In addition, a simple one-dimensional model for extended defect

growth has been implemented into SUPREM-IV. This model for extended defects has been extended to account for the dissolution of interstitial-type clusters. Simulation results using these new models are compared to the experimental data.

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