ATHERMAL, PHOTONIC EFFECTS ON BORON DIFFUSION AND ACTIVATION IN SILICON DURING MICROWAVE RAPID THERMAL ANNEALING

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Fabrication of sub-micron silicon integrated circuits (IC's) requires ultra-shallow, high-dose ion implantation of dopant atoms, e.g., boron, followed by a rapid, high-temperature anneal. Since the implantation process damages the crystal lattice structure, the anneal is expected to repair this damage and react the implanted B atoms into Si lattice sites while minimizing inward diffusion of the dopant atoms. Under optimized process conditions, rapid thermal annealing (RTA) by optical flashlamp [1] or microwave [2] or RF radiation [3] sources satisfies the manufacturing objectives for IC transistors with gate lengths as small as 45 nm [1] [2] [3].

In recent comparative studies, intriguing differences were observed between specimens subjected to lamp-based (optical radiation) RTA versus microwave RTA. For example, greater B diffusion near the surface of the implanted sample is observed after microwave RTA as compared to a lamp-based RTA under the same conditions.

In order to further study these differences, a microwave reactor was modified to accommodate a 672 nm wavelength, 250 mW laser [3]. The laser was configured such that half of the sample was exposed to optical radiation while the microwave radiation rapidly heated the sample. The intensity of the laser was sufficient to induce photon-affected defect chemistry but not intense enough to perturb significantly the temperature set by the intense microwave fields. The samples were examined for both diffusion and reaction, or "activation" of the B after experiencing three different heating protocols: a rapid, ~1000 °C "spike" anneal; a 10 second, ~1000 °C "soak"; and a 30 minute, ~550 °C soak. The high-temperature experiments illustrate the effect of optical photon illumination on both diffusion and activation. The low-temperature soak experiments were designed to limit diffusion, isolating the effects of optical photon illumination on the activation reaction. Additionally, it has been shown that B diffusion is affected by the ambient oxygen concentration [2] and the co-implantation of F, so samples were heated in both atmospheric (21% O_2) and low (100 ppm O_2) concentrations, with and without co-implanted F.

In general, the amount of B diffusion differed between the illuminated and non-illuminated samples, with an average difference in junction depth of about 10 nm. It was observed that the local concentration of F and O affect not only the total diffusional behavior of B but also the relative difference in B diffusion between the illuminated and non-illuminated samples. Finally, after a low temperature anneal designed to limit diffusion, no difference in sheet resistance existed between the illuminated and non-illuminated samples.

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