The Influence of Annealing Sequence on Electrically Activated Boron Distribution in Silicon Wafers

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Low energy boron implantation combined with rapid thermal annealing (RTA) is necessary to obtain required proper ultrashallow P+ junctions for ultra large-scale integrated circuits. Because boron transient enhanced diffusion (TED) may significantly limit the formation of ultrashallow junctions, the born diffusion behavior during post implantation annealing has been extensively studied by secondary ion mass spectroscopy (SIMS) [1, 2]. TED and electrical activation of boron atoms determine the carrier concentration profile and greatly depend on the process history of post implantation annealing. In this work, we employ scanning capacitance microscopy (SCM) and spreading resistance techniques to investigate the influence of annealing sequence on the distribution of electrically active boron atoms in low energy BF2+ implanted silicon wafers.

After the low energy implantation, samples were then treated either by one-step or two-step annealing processes to study the annealing sequence effect on the carrier distribution of each sample. One-step RTA and one- step furnace annealing (FA) processes were performed at 850 J for 30 seconds and at 550 J for 3 hours in N2 ambient, respectively. Two-step annealing processes were carried out by RTA treatment followed by FA (RTA+FA), or vice versa (FA+RTA). The width and pitch of the designed grating pattern are 0.8 and 2 mm, respectively. Before annealing, the lateral distribution of implanted boron atoms is uniform. The plane-view SCM images and the corresponding dC/dV profiles reveal that, unlike samples treated by FA+RTA and one-step annealing, samples treated by RTA+FA processes exhibit uniform dC/dV intensity in the implanted region. Comparing the dC/dV profiles across the implantation pattern of samples treated under different annealing conditions, one can find that there are less electrically active boron atoms near the pattern edge than at the center region. The cross-sectional SCM images indicate that the RTA+FA treatment results in a centralized carrier distribution in vertical and lateral directions. The corresponding dC/dV profiles also indicate that that the RTA+FA process may give a better junction interface. In addition, samples annealed by the RTA+FA process exhibit a lower sheet resistance than samples annealed by the FA+RTA process, suggesting that the RTA+FA treatment leads to a higher density of electrically active boron atoms. This indicates that the RTA+FA process can remove defects in the sample more effectively.

According to this study, the distribution of electrically activated boron atoms strongly depends on the annealing sequence of the annealing processes. For the BF2+ implanted samples, the annealing sequence of RTA+FA post-implantation anneal treatment can produce the formation of ultrashallow junctions of better quality.

References:

1. E. Napolitani, A. Carnera, E. Schroer, V. Privitera, F. Priolo, and S. Moffatt, Appl. Phys. Lett., 75, 1869 (1999).

2. L. Shao, J. R. Liu, P. E. Thompson, X. M. Wang, I. Rusakova, H. Chen, and W. K. Chu, Electrochem. Solid-State Lett., 5, G93 (2002).