The Study of Boron Diffusion from Selective Epitaxial Grown $Si_{1-x}Ge_x$ into Silicon after RTA

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Boron-doped strained $Si_{1-x}Ge_x$ epitaxial layers were grown selectively in the exposed Si regions with oxide as the isolation material by ultra high vacuum chemical molecular epitaxy (UHVCME) method. Rapid thermal annealing was used to study the boron diffusion characteristics in the $Si_{1-x}Ge_x$/Si layers. The results show that the boron diffusion depth from the selective epitaxial growth (SEG) $Si_{1-x}Ge_x$ region into the silicon substrate depends on the boron concentration, the Ge profile in the SEG area, and the size of the SEG area. Higher boron concentration in the SEG $Si_{1-x}Ge_x$ film increases the boron diffusion depth into the silicon. Besides, it was found that the samples with graded Ge profile in the SEG $Si_{1-x}Ge_x$ material have higher diffusion depth than those with uniform Ge profile in the SEG $Si_{1-x}Ge_x$ layers. In addition, the boron diffusion depth increases with the increase in the size of the SEG $Si_{1-x}Ge_x$ area. The strains in the SEG $Si_{1-x}Ge_x$ films, the chemical forces and the electrical field induced by the Ge distributions in the SEG $Si_{1-x}Ge_x$ film and in the $Si_{1-x}Ge_x$/Si interface and the misfit dislocations induced in the SEG $Si_{1-x}Ge_x$ layers are the main reasons for the phenomena observed.

Fig. 1 shows the calculated diffusion depths of SEG $Si_{0.86}Ge_{0.14}$ structures. The boron concentrations in the $Si_{0.86}Ge_{0.14}$ films are $1.4\times10^{19}cm^{-3}$ and $7\times10^{18}cm^{-3}$. The diffusion depth depends on the boron concentration. This is caused by two reasons. One is that at high boron concentration, the concentration gradient at the transition region is higher, which provides higher driving force for diffusion. Another reason is caused by the strain factor.

Fig. 2 (a) shows the diffusion depth of boron of the graded Ge structure is larger than the uniform Ge composition. This is because the electrical field induced by the chemical potential gradient in the Ge graded structure helps with the diffusion of the boron ions which are positively charged. Hence, boron diffusivity in the graded structure is larger than that with uniform Ge composition. The calculated boron diffusion coefficient dependence on the annealing temperature is plotted in Fig.2 (b).

Fig. 3 shows the diffusion depth dependence on the size of the SEG diffusion source area. As previous research indicated [1], the dislocation is higher in large size SEG areas than in small areas. Since samples with large SEG area have higher dislocation density, the boron out-diffusion will be enhanced. Thus, less boron out-diffusion can be obtained by using small area SEG $Si_{1-x}Ge_x$ layer.

Reference

1. D. B. Noble, J. L. Hoyt, C. A. King, J. F. Gibbons, T. I. Kamins, M. P. Scoot, Appl. Phys. Lett. 56 (1), 1 January 1990.

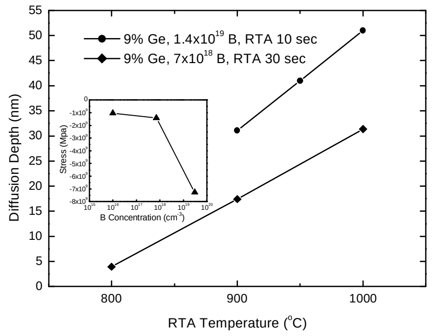
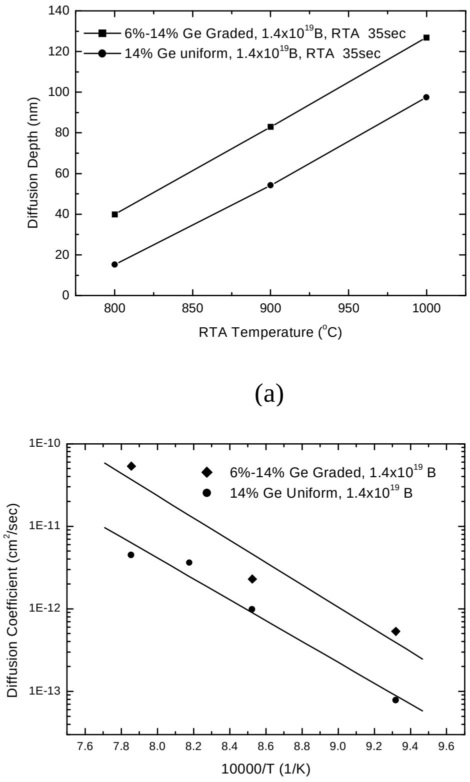


Fig. 1. Diffusion Depth as a function of annealing temperature for strained $Si_{0.91}$-$Ge_{0.09}$ layer on Si substrate. Insert figure shows the stress of the boron doped $Si_{1-x}Ge_x$ film.



(a)

(b)

Fig. 2. (a) Diffusion depth as a function of annealing temperatures for graded Ge and uniform Ge $Si_{1-x}Ge_x$ layers on Si substrate, annealing time was35 seconds (b) The calculated boron diffusion coefficient dependence on the annealing temperature

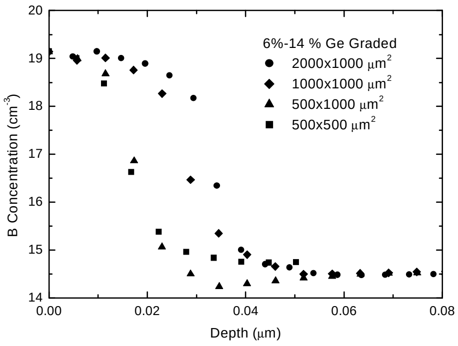


Fig. 3. Dependence of the diffusion depth in Si on boron concentration in the $Si_{1-x}Ge_x$ layer for different SEG $Si_{1-x}Ge_x$ diffusion source areas in the case of graded $Si_{1-x}Ge_x$ films