Diffusion and Activation of Arsenic in Silicon Germanium Alloys

Personnel

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Sponsorship

Hitachi Ltd., DARPA, and collaboration with IBM

We are studying arsenic (As) diffusion and electronic properties as a n-type dopant in Silicon Germanium (SiGe), to enable the fabrication of a wide range of devices. With the recent success of the strained Si MOSFET, new markets are expected to be developed based upon strained Si/relaxed SiGe CMOS circuits. An understanding of n-type dopant diffusion in SiGe, specifically the formation of the source/drain regions in the NMOS and the n-body region in the PMOS, is essential for the success of this technology. In addition, n-type SiGe fabrication technology is expected to be important for the development of other devices such as thermoelectric generators, novel MOSFET structures that utilize SiGe source/drain contacts, and the pnp HBT.

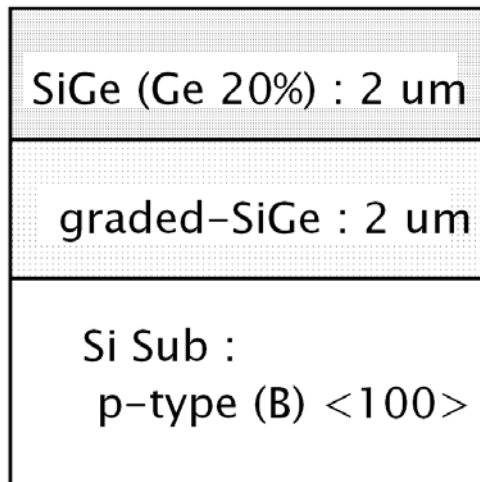


Fig. 1: Structure of SiGe samples.

As a first step, we compare the diffusivity of ion implanted As and Phosphorus (P) in SiGe and Si under equilibrium conditions. The relaxed SiGe epitaxial wafers are provided by Chris Leitz (E. A. Fitzgerald, Materials Science and Engineering). Figure 1 shows the structure of the samples. Sample wafers were ion implanted As (30KeV 4E14) or P (30KeV 8E14). The samples were then furnace annealed at from 950C to 1050C for 30 minutes in an Ar ambient. The oxide layers were stripped and samples were analyzed by Secondary Ion Mass Spectrometry (SIMS) at Charles Evans and Associates. The SIMS data was compared with TSURPREM-4 simulations. For comparison, Si control pieces were processed and analyzed at the same time as the SiGe samples.

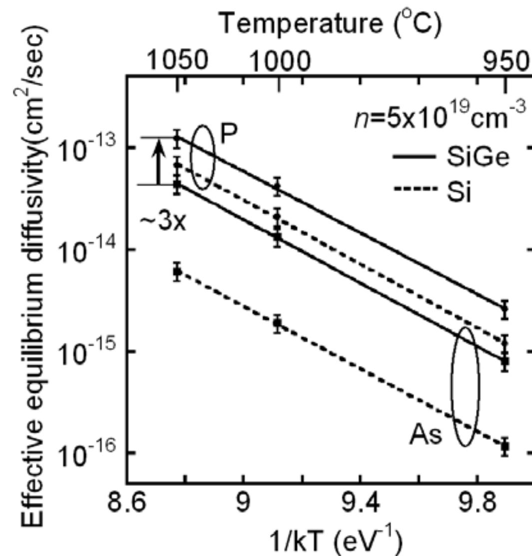
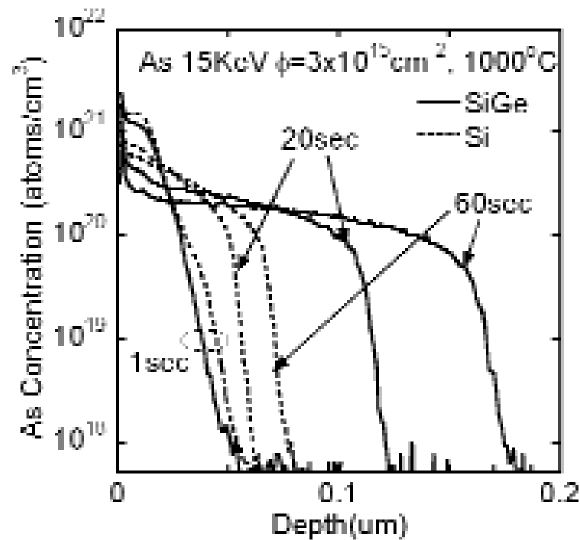


Fig. 2: Comparison of As and P effective diffusivities in Si and SiGe under equilibrium conditions.

Figure 2 shows the comparison of As an P effective diffusivity in the temperature range from 950C to 1050C under equilibrium conditions. As the results, the diffusivities of n-type dopant are observed to be enhanced in SiGe compared to Si, in contrast to the diffusion of B, which is known to be retarded in SiGe relative to B diffusion in Si. The expression for the concentration-dependent diffusivity of P in Si must be multiplied by a factor of roughly two, in order to match the P in SiGe profile. And the effective arsenic diffusivity enhancement factor is roughly 7 for diffusion in SiGe compared

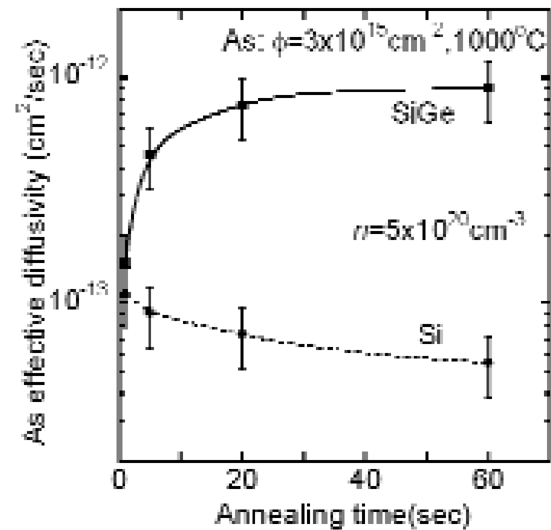
to diffusion in Si. The absolute value of As effective diffusivity is still 3 times lower than that of phosphorus. These results suggest that As is better choice for shal-



low source/drain than P.

Fig. 3: Comparison of As profiles in Si and SiGe under transient diffusion conditions.

As diffusion behavior under transient diffusion conditions has also been studied. Fig. 3 shows the comparison of As profiles in Si and SiGe after short time annealing (1000°C 1, 20, 60 sec). Fig. 4 shows the time dependence of As effective diffusivities in Si and SiGe. TRD (Transient Retarded Diffusion) is observed for As diffusion in SiGe, while TED (Transient Enhanced Diffusion) is observed at As diffusion in Si. This TRD shows the possibility of forming As ion implanted source/ drains in SiGe as shallow as those in Si by optimizing the annealing conditions. The mechanism of As



TRD in SiGe is now being investigated.

Fig. 4: Time dependence of As effectives diffusivities in Si and SiGe under transient diffusion