High Quality SiGe:B of high Ge Layer for 14nm and Beyond FINFET Processes

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FinFET based device structures are quickly becoming default scaling methodology for sub-14nm and beyond technologies - primarily due to ultra-thin bodies which suppress short channel effect[1-2]. Additionally, the P-FinFET performance is boosted with the use of high mobility channels with Source/Drain (S/D) stressors of Boron-doped SiGe[3-4]. SiGe deposited in S/D has a compressive strain which generates strain in Si channel region and enhances the hole mobility. On the other hand, high Boron concentration is a crucial for reducing S/D parasitic resistances. In this study, a high quality SiGe with high Ge% of >50% is demonstrated in 14nm FinFET structure. We have also investigated the B out-diffusion behaviors in high Ge% S/D region.

Selective SiGe:B epitaxial deposition on the S/D areas of FINFET structures was prepared in a 300mm single-wafer CVD reactor with the use of SiH_4-based process. The Ge content and strain relaxations were analyzed by High Resolution X-Ray Diffraction meter (HRXRD). The Epi film morphology was analyzed by transmission electron microscope (TEM). Scanning electron microscope (SEM) was used for surface inspection. In-Situ doping Boron concentration was analyzed by Secondary Ion Mass Spectroscopy (SIMS).

The high [Ge] concentration SiGe film was grown and analyzed by TEM. Figure 1(a) shows bad Epi film quality with the use of Epi growth temperature > 600°C. The abnormal Epi and dislocations can be observed by TEM. The high quality Epi morphology is shown in Fig 1 (b) by the use of lower temperature (<600°C) during the Epitaxial growth. The diamond shape, dislocation free Epi film can be observed.

High quality SiGe Epi with high [Ge] concentration was analyzed by XRD measurement on the specific 50x50μm square test pattern. Figure 2(a) shows the flat Epi surface on the square test pad by SEM. The full strain Epi film can be analyzed by XRD as figure 2(b). The Ge of >50% can be obtained by the XRD measurement. Figure 2(c) shows Boron profile by SIMS analysis. The in-situ [B] doping is >2E20 atom/cm^3 with abruptness of 3nm/decade.

The in-situ doped Boron out-diffusion behavior in high Ge of SiGe was also studied. Figure 3(a) shows the process flow for the [B] out-diffusion study. After epitaxial deposition of SiGe, S/D implant anneal were implemented to check [B] out-diffusion by SIMS. Figure 3(b) shows that there is significant [B] out diffusion for the post S/D implant and anneal split compared to as deposited (Epitaxial SiGe) only. The tail abruptness increased from 3nm/decade to 4nm/decade after S/D imp and anneal. The [B] out-diffusion can be well controlled by the high Ge and high quality SiGe Epi.

In summary, the selective Epi of high quality with the high Ge of >50% has been demonstrated. The high quality Epi morphology can be obtained by modulating the Epi temperature to < 600°C. The diamond shape Epi film with dislocation free can be observed by TEM. The flat Epi surface and the full strain Epi film can be analyzed by XRD. The Boron out-diffusion behavior in SiGe of high Ge study shows the tail abruptness was from 3nm/decade to 4nm/decade after S/D imp and anneal. The Boron out-diffusion can be well controlled by the high Ge and high quality SiGe Epi.

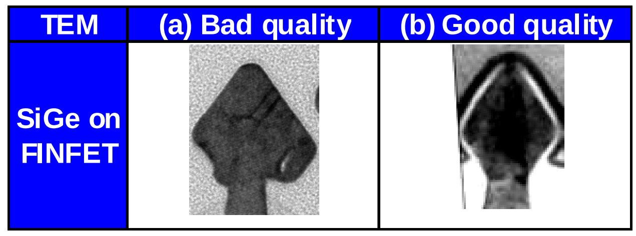

Figure 1. TEM shows (a) Bad quality (b) Good quality Epi film growth on FinFET struture by different growth temperatures.

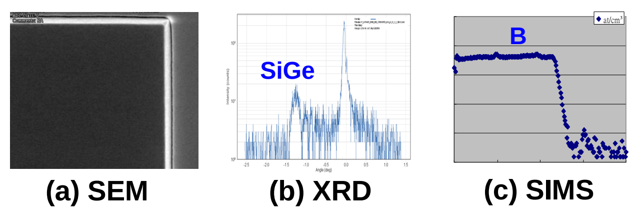

Figure 2. High Ge Epi inspection (a) Flat Epi surface on the square test pad by SEM. (b) Full strain Epi film and SiGe of Ge>50% measured by XRD. (c) Boron SIMS profile check of doping > 2E20 atom/cm^3.

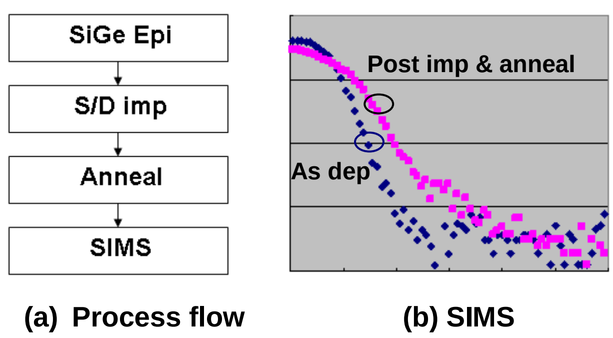

Figure 3. The in-situ doped Boron out-diffusion behavior study (a) Experimental process flow (b) Enlarged SIMS tailing profile. The tail abruptness was from 3nm/decade to 4nm/decade after S/D imp and anneal.

References

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