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Ge And GeB Infusion Doping & Deposition For USJ And Blanket Or Localized SiGe Formation On Cz And SOI Wafers

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Rather than using SiGe epitaxial growth or high dose Ge ion implantation, we report on our studies using Ge and GeB infusion doping to form localized or blanket SiGe and SiGeB structures. Epion’s GCIB (gas cluster ion beam) system was used in this study using 200mm and 300mm wafers. By using the infusion doping/deposition method, precise dose controlled processing and lower manufacturing costs can be realized. This technique can eliminate the graded and relaxed SiGe epitaxial layer process and post polishing step for blanket SiGe formation for bulk CMOS applications. For PD/SOI CMOS applications this technique can be used with either SIMOX or bonded SOI wafers in forming SGOI and significantly reduce the processing steps by as much as 75%. Because the infusion process is at room temperature, photoresist masking material can be used to achieve patterned localized Ge infusion and the formation of localized SiGe structures.

Infusion doping of Ge at low GCIB doses (<E14/cm2) resulted in shallow Ge profiles of <30nm as shown in Fig. 1. At higher GCIB doses of Ge (>E15/cm2) dose controlled monolayer deposition was realized as also illustrated in Fig. 1 for a 100nm and 180nm thick Ge layer. The calculated deposition rate on 300mm wafers is 5nm/min and >1,000 Ge atoms were contained in each cluster ion.

Adding B2H6 gas resulted in co-doping of GeB as illustrated in Fig.2. This resulted in a GeB infusion process of Si (<10%) Ge (<55%) B (<35%) determined by XPS analysis. The presence of Ge in the GCIB resulted in a self-amorphization boron doping process as illustrated by the X-TEM anaylsis in Fig.3. Complete single crystal regrowth of the 12nm deep self-amorphous SiGeB structure was achieved with either a 550°C or 950°C 1 hour furnace anneal as shown in Fig.3 without any evidence of residual end-of-range (EOR) damage usually seen with implantation Ge-PAI processing. High magnification X-TEM is shown in Fig. 4. The boron solid solubility (Bss) level in this SiGeB structure was about 3x higher than in 100% Si for the 950°C anneal case as determined by SIMS analysis (9E19/cm^3 versus 3E19/cm^3). Increasing the infusion dose resulted in 90nm GeB amorphous deposition as shown in Fig.5. Complete recrystalization of the amorphous layer after the 950°C 1 hour furnace anneal with threading dislocations can be seen. Unlike CVD of SiGe or Ge, the infusion deposition process is not sensitive to surface native oxide since there is no post deposition interfacical layer can be detected that would affect the amorphous layer SPE recrystallization process.

Depending on the deposition thickness and annealing conditions various levels on SiGe strain and strain relaxation can be achieved from 0.03% to 1.95% as determined by Raman analysis.

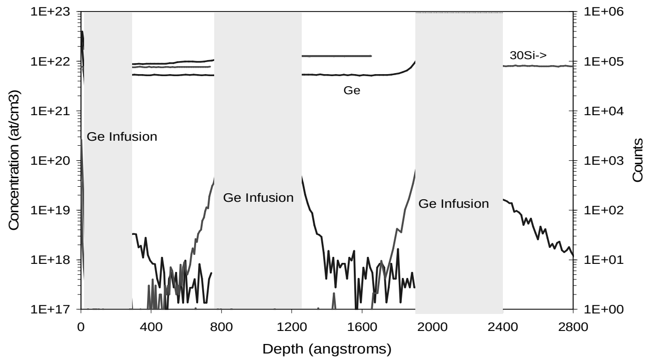

Fig. 1: Ge infusion doping and deposition comparison.

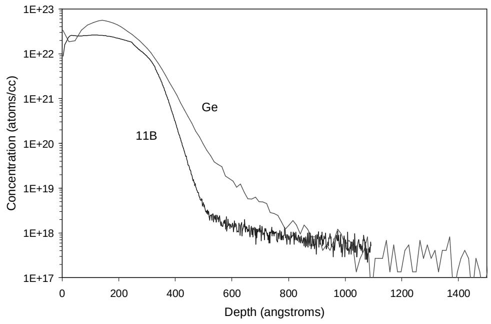

Fig.2: GeB infusion doping resulting in $Si_{0.1}$ $Ge_{0.55}$ $B_{0.35}$.

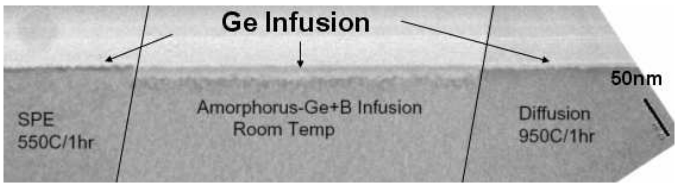

Fig. 3: X-TEM of Ge+B infusion doping process with <12nm amorphous SiGeB top surface structure.

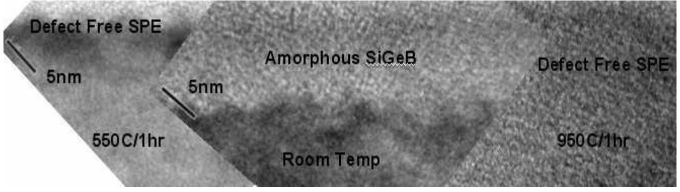

Fig. 4: Higher magnification X-TEM.

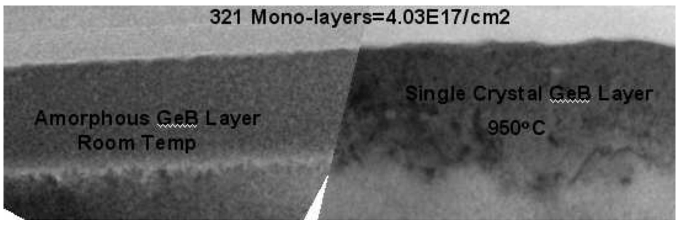

Fig. 5: X-TEM of GeB infusion deposition process with >90nm amorphous deposit