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$Si/Si_{1-x}Ge_x$ Selective Epitaxial Growth by Ultra High Vacuum Chemical Vapor Deposition Using Si_2H_6, GeH_4

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Ultra high vacuum chemical vapor deposition (UHV-CVD) using Si_2H_6, SiH_4, or SiH_2Cl_2 has many advantages such as low temperature processing, SiGe alloy growth [1] and selective epitaxial growth (SEG).[2] In these advantages, SEG has become an important technology for fabricating structure of ultra large scale integrated circuits (ULSI's). Successful achievement of SEG has been reported for SiH_2Cl_2 system.[3] However, the growth rate with this SiH_2Cl_2 system was very low. Si_2H_6 or SiH_4 UHV-CVD systems have better growth rate but controlled SEG has yet to be achieved. We report here that the SEG using Si_2H_6 UHV-CVD system could be controled by the amount of supplied gas.[4] We also obtain precise growth control of $Si/Si_{1-x}Ge_x$ layers and B doping profiles in Si using fast gas flow switching.

Our new UHV-CVD has stainless steel growth chamber with base pressure $6x10^{-10}$ **Torr**, water cooling jacket, and nozzles for Si_2H_6, GeH_4 and doping gases. As shown in Figure 1, Growth chamber has **1000l/sec** turbo molecular pump and last gas valves very near the chamber to obtain fast gas flow switching. Source gases were pure Si_2H_6, GeH_4 and **1%** B_2H_6 diluted by H_2. The pressure during growth was about 10^{-4} **Torr.** A 6-inch (100) Si wafer covered with 2000Å SiO_2 patterns can be loaded in the growth chamber. SEG condition was observed by reflection high energy electron diffraction (RHEED).

In our cold-wall type UHV-CVD system, poly-Si nucleation on SiO_2 surface did not begin immediately. There was initial short period during which SEG was achieved. This short period was inversely proportional to Si_2H_6 flow rate , which means the amount of Si_2H_6 supplied in this initial period is constant. There was a critical amount of supplied Si_2H_6 beyond which SEG will break down and its selectivity. Figure 2 shows temperature dependence of a critical gas amount. So far as Si_2H_6 was supplied under the critical gas amount in Figure 2, perfect SEG Si could obtain at various flow rate and growth rate.

Figure 3 of a cross sectional transmission electron micrograph image shows a part of 30 periods 120Å Si and 69Å $Si_{0.83}Ge_{0.17}$ strained layer superlattice. This film was made by the way of periodic GeH_4 supply of **4sccm** under fixed Si_2H_6 flow rate of **4sccm.** Thin layers, of the order of 70Å, can be readily grown by gas supply control. In addition, the superlattice has good crystal quality without dislocation.

Figure 4 shows a Secondary Ion Mass Spectrometry (SIMS) profile of periodically B doping in Si epitaxial layer. B_2H_6 was supplied periodically and changed from 0.03 to 9.9 **sccm** round by round under fixed Si_2H_6 flow rate of 20 **sccm.** The SIMS profile shows that steeply controlled B concentration can be obtained by B_2H_6 flow switching. Further, B concentration was lineally increased with B_2H_6 flow rate at fixed Si_2H_6 flow rate.

We have demonstrated the SEG, the profile control of

$Si/Si_{1-x}Ge_x$ and B-doping in Si by the gas supply control using the newly designed UHV-CVD system. As shown in these results, the SEG and the profile control could be controled by the amount of supply gas and gas flow switching respectively.

References

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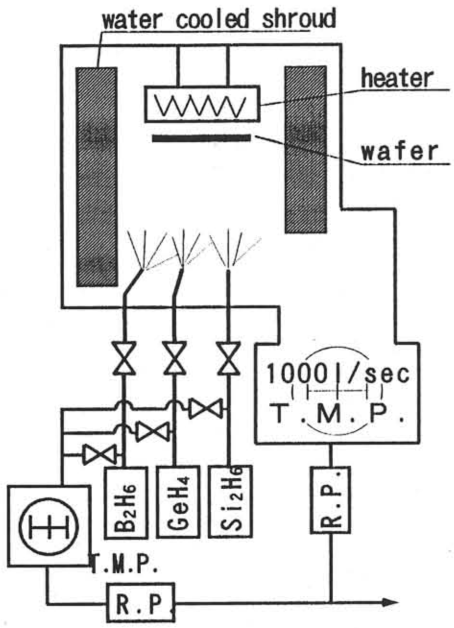

Fig.1 Schematic diagram of UHV-CVD.

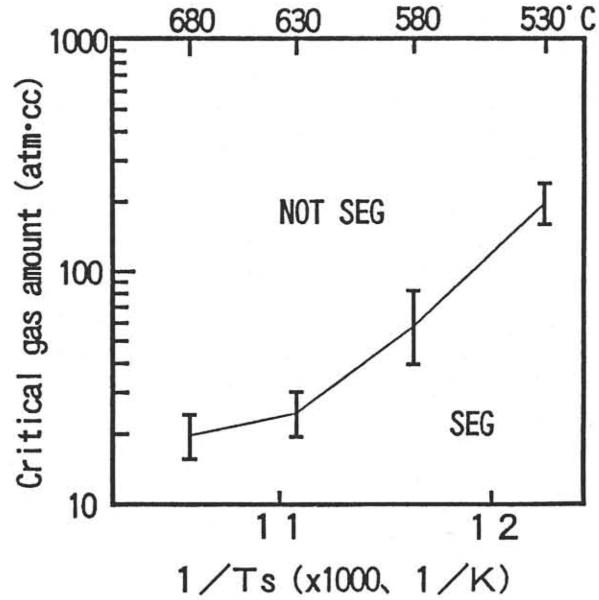

Fig.2 Temperature dependence of critical gas amount. When Si_2H_6 gas was supplied over critical gas amount at various flow, polycrystalline Si nucleation started on SiO_2.

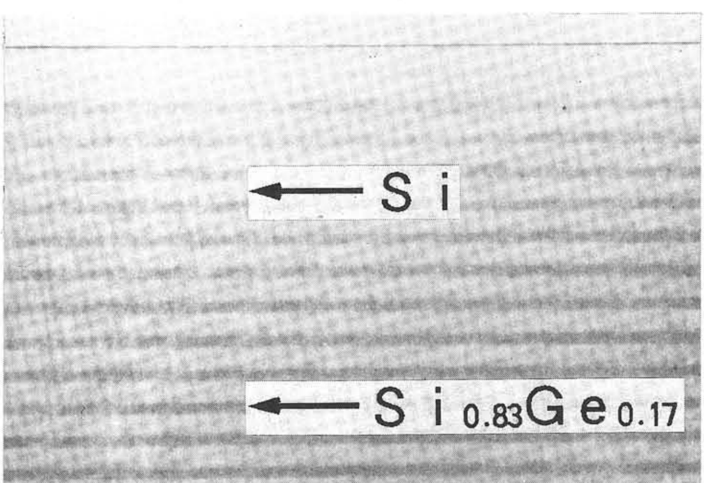

Fig.3 Cross sectional TEM image of Si and SiGe superlattice. Thickness of Si is 120Å and that of SiGe is 69Å. Substrate temperature is 587°C.

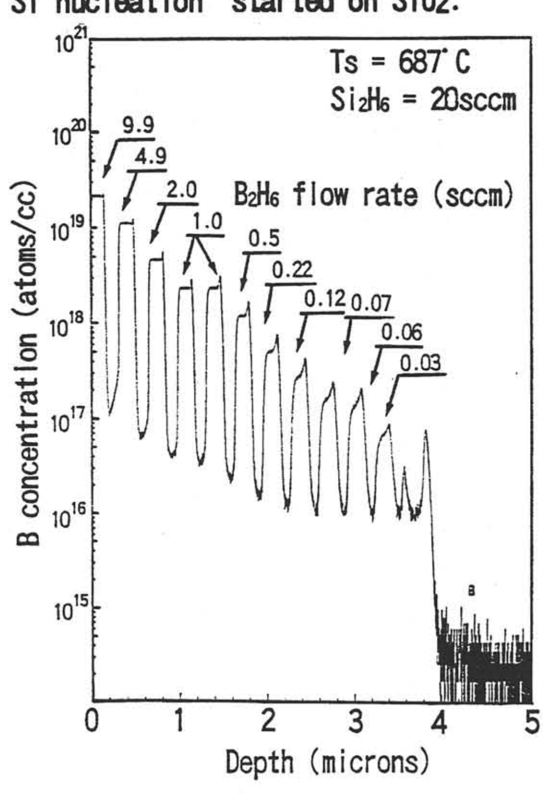

Fig.4 SIMS profile of periodic B doping in Si epitaxial layer.