Si/Si$_{1-x}$Ge$_x$ Selective Epitaxial Growth by Ultra High Vacuum Chemical Vapor Deposition Using Si$_2$H$_6$, GeH$_4$

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Ultra high vacuum chemical vapor deposition (UHV-CVD) using Si$_2$H$_6$, SiH$_4$, or SiH$_2$Cl$_2$ 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$_2$Cl$_2$ system.$^3$ However, the growth rate with this SiH$_2$Cl$_2$ system was very low. Si$_2$H$_6$ 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$_2$H$_6$ UHV-CVD system could be controlled 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 $6 \times 10^{-10}$ Torr, water cooling jacket, and nozzles for Si$_2$H$_6$, GeH$_4$ and doping gases. As shown in Figure 1, Growth chamber has 10001/sec turbo molecular pump and last gas valves very near the chamber to obtain fast gas flow switching. Source gases were pure Si$_2$H$_6$, GeH$_4$ and 1% B$_2$H$_6$ 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$_2$H$_6$ flow rate, which means the amount of Si$_2$H$_6$ supplied in this initial period is constant. There was a critical amount of supplied Si$_2$H$_6$ beyond which SEG will break down and its selectivity. Figure 2 shows temperature dependence of a critical gas amount. So far as Si$_2$H$_6$ 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$_{83}$Ge$_{17}$ strained layer superlattice. This film was made by the way of periodic GeH$_4$ supply of 4sccm under fixed Si$_2$H$_6$ 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$_2$H$_6$ was supplied periodically and changed from 0.03 to 9.9 sccm round by round under fixed Si$_2$H$_6$ flow rate of 20 sccm. The SIMS profile shows that steeply controlled B concentration can be obtained by B$_2$H$_6$ flow switching. Further, B concentration was linearly increased with B$_2$H$_6$ flow rate at fixed Si$_2$H$_6$ 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 controlled by the amount of supply gas and gas flow switching respectively.

References