Fabrication of exceptionally stable $Si_{0.5}Ge_{0.5}$ by oxidation of SiGe

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1. INTRODUCTION

Ultra-thin SiGe on silicon on insulator (SiGe on SOI) is fabricated using a Ge enrichment process [1]. The oxidation/condensation step is done at low temperature, which allows us to obtain high Ge rich layer (GRL) and abrupt interfaces between the GRL and the silicon. We study the SiGe oxidation process, and highlight a particular role played by the SiGe with a 50 % Ge concentration. We show that this concentration is stabilised whatever the strain level, nominal concentration and oxidation time are. Scanning Transmission Electron Microscopy (STEM) and Energy Dispersive Spectroscopy (EDS) show SiGe GRL perfectly planar and monocrystalline despite the high Ge concentration (≥ 50 %).

2. RESULTATS

The Ge condensation process [1] is a great tool for fabrication of GRL structures with a controlled thickness and composition. The germanium condensation (or enrichment) process is a dry oxidation of SiGe (here with 20 % Ge) which consumes (oxidize) Si atoms and forms a SiO_2 layer on top of the SiGe. The Ge atoms (which remain non-oxidized) thus pile up at this new SiGe/SiO_2 interface, forming a GRL.

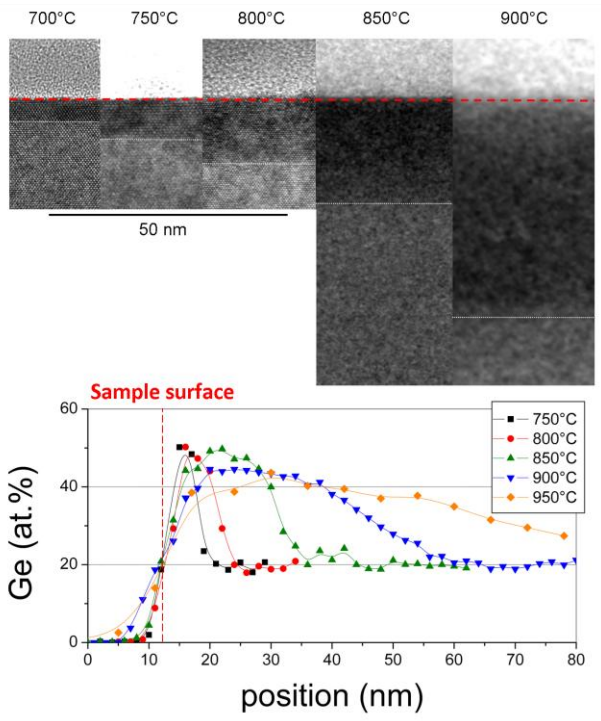

Figure 1. Influence of the temperature on the oxidation of relaxed $Si_{0.8}Ge_{0.2}$.

Figure 1 shows five HRTEM cross-section images of the GRL obtained at various oxidation temperatures (between 700 and 950°C) on a same scale (top) and the corresponding germanium concentration profiles measured by STEM-EDS analysis on cross sections of structures obtained at the same (bottom). For clarity purpose, the curve for the lowest temperature (700 °C) and the TEM image of highest one (950 C) are not shown. Taking into account all the curves corresponding to different oxidation temperatures and the HRTEM images, we can say that 1) the GRL thickness increases exponentially with the temperature, 2) the interface

between the GRL and the underlying $Si_{0.8}Ge_{0.2}$ broadens when the temperature exceeds 850°C, and 3) the GRL has a concentration around 50 % when the temperature is ≤900 C.

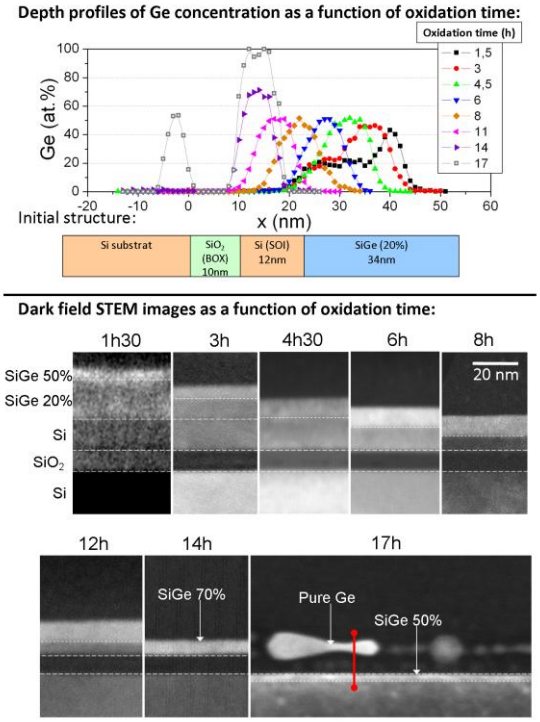

Figure 2. Top: evolution of the Ge concentration profile in the GRLs as a function of the oxidation time . Bottom: DF-STEM images of these GRLs.

In figure 2, the graph on top presents EDS measurements of the germanium concentration as a function of depth for different oxidation duration (at 750 C). The precise distance to the Si(sub.)/BOX interface is determined thanks to oxygen and silicon profiles recorded at the same time (not shown for clarity). A schematic representation of the initial structure is drawn under the graph for reference. At the bottom, dark-field STEM cross-section images corresponding to each oxidation duration are displayed on the same scale. During the first stage of the oxidation, the GRL thickness increases with time until 5-6 hours which corresponds to the transformation of the full $Si_{0.8}Ge_{0.2}$ layer into $Si_{0.5}Ge_{0.5}$. During a second stage of oxidation, the GRL thickness stays the same and only the underlying silicon from the SOI is slowly consumed until approximately 13h which corresponds to the consumption of all the silicon from the initial SOI. During all this oxidation period, the GRL concentration remains about 50%. In a third oxidation stage, the silicon from the $Si_{0.5}Ge_{0.5}$ GRL starts to be oxidised and the Ge concentration in this layer increases. In the last image after 17h of oxidation, all the silicon available above the BOX has been oxidized and the resulting pure Ge layer dewets from the oxide while a small amount of the Ge diffuses through the BOX and surprisingly forms a new $Si_{0.5}Ge_{0.5}$ thin layer at the BOX/substrate interface.

3. CONCLUSION

Using the Ge condensation process on $Si_{0.8}Ge_{0.2}$ in two different systems, we have fabricated a defect-free GRL containing 50 % of Ge. By keeping the temperature low, we have shown it is possible to obtain a very sharp interface between the GRL and the underlying silicon layer. The oxidation mechanism itself was investigated in details at low temperature. SiGe with 50 % Ge was shown to be very stable; and even when all the $Si_{0.8}Ge_{0.2}$ was consumed on SOI, Si atoms from the underlying silicon layer were oxidized instead of atoms from the top $Si_{0.5}Ge_{0.5}$ layer.

REFERENCES

[1] T. Tezuka, N. Sugiyama, T. Mizuno, M. Suzuki and S. ichi Takagi, *Japanese Journal of Applied Physics*, 2001, **40**, 2866–2874.