Germanium-on-Insulator Fabrication by Hydrogen-Induced Layer Transfer

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Germanium is considered a promising material for high performance CMOS devices because it possesses higher bulk electron and hole mobility than Si. Similarly, the on-insulator structure is also a good candidate for improved device performance due to the electrostatic benefits it holds over bulk technologies. This project is meant to combine both advantages in the fabrication of Germanium-on-Insulator (GeOI) substrates.

The initial goal of this work is to develop a process to transfer a high quality Ge layer to a less expensive and more readily available Si handle wafer. This goal is accomplished by first implanting a bulk Ge transfer wafer with a high dose of hydrogen, and then direct-bonding the Ge wafer to an oxidized Si handle wafer. As the bonded wafer pair is annealed, the activation of the implanted hydrogen leads to the formation of micro-cracks near the peak of the implant and the eventual exfoliation of a thin Ge layer from the transfer wafer (Figure 1). By incorporating an epitaxial etch-stop layer in the transfer wafer, the implant-damaged Ge can be selectively removed by wet etching. This technique also allows for arbitrarily thin GeOI because the device layer is defined epitaxially and not by a polishing or etching step.

The most challenging aspect of this approach is the mismatch of the thermal coefficients of expansion between Ge and Si. A typical hydrogen activation anneal is performed at 300-400°C for Si applications. At this temperature, the Ge/Si bonded pair will break due to the great increase in thermal stress. For the fabrication of GeOI, it is necessary to reduce the temperature at which layer transfer will occur. One approach being investigated is the use of a second SiGe epitaxial layer as a gettering layer for the implanted hydrogen (Figure 2). This gettering layer is seen to reduce the time required for layer exfoliation at a given annealing temperature. Future work on this project will include device fabrication and analysis on partially depleted and fully depleted GeOI substrates.

Figure 1: Cross-sectional TEM of GeOI structure immediately after layer transfer.
Figure 2: SIMS analysis of a hydrogen-implanted transfer wafer with a double etch-stop structure.