

Differential Hall characterisation of shallow strained SiGe layers

R. Daubriac¹ (rdaubria@laas.fr), M. Abou Daher¹, E. Scheid¹,
S. Joblot², D. Barge² and F. Cristiano¹

¹ LAAS, CNRS and Univ. of Toulouse, 7 av. Du Col. Roche, 31400 Toulouse, France

² STMicroelectronics, 850 rue Jean Monnet, 38926 Crolles, France

During the last decade, a considerable diversification of the possible MOS device architectures for future nodes has occurred. They range from planar Fully-Depleted (FD)-SOI transistors, to 3D multigate FinFETs or gate-all-around nanowire (NW)-FETs. Within this context, the reduction of the source/drain contact resistance (R_C) is a particularly critical challenge. R_C strongly depends on the active dopant concentration at the semiconductor/silicide interface. It is therefore essential that electrical activation and mobility at different depths within a device are reliably determined.

Hall Effect is an effective method to measure the active dose, together with the sheet resistance and the carrier mobility. However, the measured values are averaged over the entire active layer thickness. In contrast, the Differential Hall Effect method (DHE) can solve this problem, as it can provide an accurate profile of the previous three physical parameters as a function of depth with nm resolution. This technique relies on the iteration of oxidation/etch cycles based either on anodic or native oxidation processes. DHE has been successfully demonstrated for both Si and Ge materials; however its application to SiGe alloys is far more challenging due to the different oxidation rates of these two species. Considering the technological interest for SiGe, which is today the material of choice for p-MOS source/drain regions, it is therefore important to develop a reliable DHE method for this material.

In this work, we have developed a SiGe chemical etching process based on the $\text{NH}_4\text{OH}:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ solution (SC1). The SC1 removes the issue of silicon selectivity over germanium during SiGe oxidation as it reacts simultaneously with both semiconductors. In particular, our study is focused on boron-doped strained $\text{Si}_{1-x}\text{Ge}_x$ shallow layers ($0.2 < x < 0.3$). On the basis of XRD, ellipsometry, AFM and TEM analysis, the optimisation of this technique is first achieved in terms of etch rate ($\sim 1\text{\AA}/\text{min}$), surface roughness, strain and stoichiometry stability during etch (cf. Fig. 1). A dedicated o-ring cell has then been designed to etch only the central area of a square Van der Pauw structure while protecting the peripheral metal contacts. Finally, SiGe DHE results will be presented from dedicated *in-situ* doped test samples (cf Fig. 2), allowing the calibration of the Hall scattering factor, as well as from technology relevant p-type doped SiGe thin layers obtained using advanced fabrication techniques, including low temperature solid phase epitaxy or non-melt laser annealing.

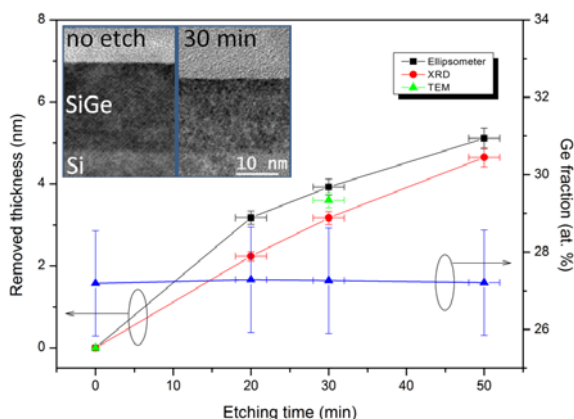


Figure 1: SiGe Etch rate calibration: removed SiGe thickness measured by different methods (left scale) and Ge fraction measured by XRD (right scale) as a function of etching time. Inset: TEM cross-section micrographs from reference and 30-min etched sample.

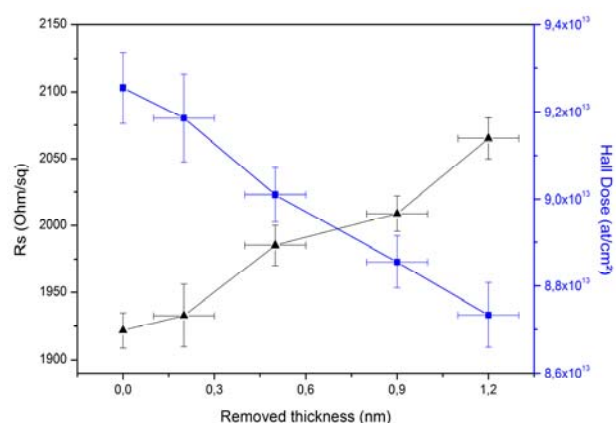


Figure 2: DHE measurements from an *in situ* doped 20 nm-thick $\text{Si}_{1-x}\text{Ge}_x$ sample ($x=0.23$, B concentration: $1 \times 10^{19} \text{ cm}^{-3}$): Sheet resistance (left scale) and Hall dose (right scale) as a function of the removed SiGe thickness.

