Accurate depth profiling of oxidized SiGe (intrinsic or doped) thin films by extended Full Spectrum ToF-SIMS

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Precise depth profiling of the various elements present in Si/SiGe heterostructures is crucial in order to optimize the electrical properties of devices. The condensation technique allows the Ge enrichment of low Ge content SiGe layers by a selective oxidation of Si compared to Ge [1]. It can be used to obtain Ge nanowires for the elaboration of high performance devices [2]. Saracco et al. proposed in [3] a new top-down method based on the Silicon-On-Insulator (SOI) technology to fabricate 3D suspended Ge-rich nanowires by Ge condensation, which is completely CMOS compatible. An in-depth knowledge of the behaviour of such layers during the high temperature oxidation step (such as Ge and impurities diffusion and/or condensation pattern, oxidation rate etc) would in that respect be most useful for process optimization.

In this work, we thus report on the accurate characterization, using Time of Flight Secondary Ion Mass Spectrometry (ToF-SIMS), of the structural properties of intrinsic or doped SiGe layers enriched with the Ge condensation technique. SIMS (and ToF-SIMS) characterization of SiGe layers often suffers from matrix effects due to non linear variation of ionization yields with Ge content. Moreover, the presence of oxide in these layers definitely increases the difficulty of obtaining quantitative profiles by SIMS. This is particularly the case in enriched hetero-structures, which successively feature a silicon dioxide (SiO$_2$) layer, a Ge-rich SiGe layer, and a Ge-poor SiGe layer followed by the substrate (Si or SOI). Such quick changes in matrix material undoubtedly lead to hampered SIMS quantification of the different elements of interest (Ge and impurities if present), especially at the interfaces between those materials. To overcome those matrix effects, we resorted to the extended Full Spectrum (Ext. FS) protocol proposed in [4]. This protocol was shown to be particularly useful for the study of annealed intrinsic or doped (with B, P or C) SiGe/Si superlattices [5]. It was also found by Ferrari et al. [6] to help reduce matrix effects through oxides. It indeed allows a simultaneous quantification of matrix elements, as shown by the profile displayed in Figure 1.

We will discuss here its accuracy for the quantitative depth profiling of matrix elements in dry or wet oxidized, intrinsic or doped SiGe layers by confronting its results with those obtained using more established protocols. The profiles provided by the extended Full Spectrum protocol were indeed found to be more accurate than the others, notably around interfaces. Specific features of the dry oxidation of SiGeC layers or the wet oxidation of SiGe, SiGeC, SiGeB and SiGeP layers that were evidenced thanks to those ToF-SIMS profiles will otherwise be presented.

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**Reference**