

Quantification of a SiGe Microelectronic Device using AES

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Introduction

As part of an investigation into the characterisation of next generation device grade silicon-germanium on insulator [1] carried out at the University of Southampton, the accurate quantification of the silicon and germanium concentrations throughout the structure of a tree-like, branched device was required (Figure 1).

Auger electron spectroscopy (AES) is ideally suited to the investigation of these small devices because of the small spot sizes possible (<20 nm). Accurate quantification in AES requires the use of calibration standards with known concentrations [2]. By plotting the intensities of the constituent elements against one another, a deviation from a linear intensity relationship reveal can reveal a matrix factor which can be used to provide an improvement in the accuracy of quantification.

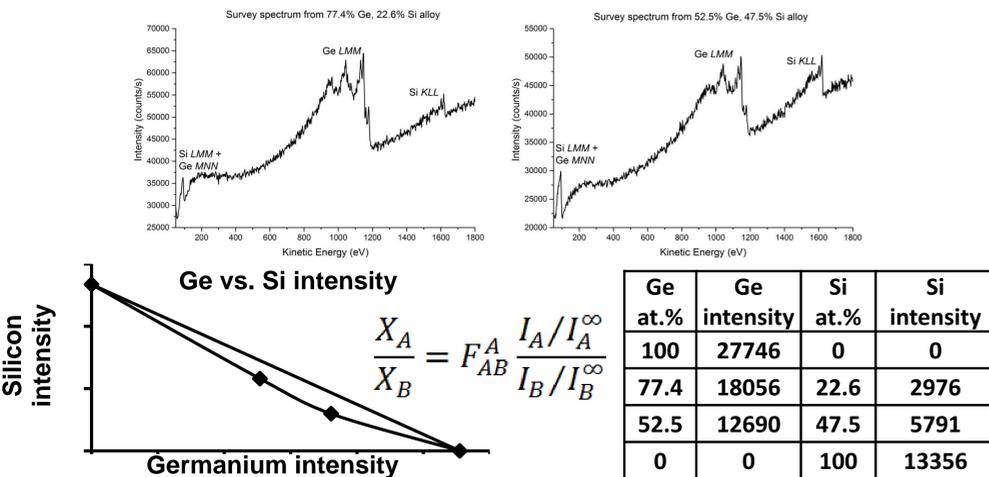
Experimental

AES was performed using a Thermo Scientific Microlab 350 scanning Auger microscope, with a spot size of 20 nm. High resolution Si *KLL* and Ge *LMM* spectra were collected from 1300-1650 and 650-1205 eV, respectively, with a step size of 2 eV, a retard ratio of 4 and a dwell time of 100 ms per channel. The air formed surface oxide and surface carbon contamination were removed with 20 seconds of argon ion sputtering using a 3 kV beam energy and 25 $\mu\text{A cm}^{-2}$ sample current density. A linear background subtraction was performed over the peak ranges 1300-1650 and 650-1205 eV for silicon and germanium respectively.

Quantification of SiGe

Four samples of mixed concentration SiGe alloys were used as standards for calibration purposes. These standards were provided with concentrations of 52.4, 77.5, and 100 at.% germanium, together with pure silicon. Their concentrations were confirmed by X-ray photoelectron spectroscopy.

The average intensity of the Si *KLL* and Ge *LMM* Auger transitions from eight points on each of the alloys is shown in the table below. By plotting their intensities a deviation from a linear relationship is observed, showing the presence of a matrix factor for silicon in germanium. This was calculated to be ~0.9, by using the equation shown below, where: X_A is the concentration of Si, X_B is the concentration of germanium, F is the matrix factor, I_A is the intensity of the Si peak, I_A^∞ is the intensity from pure Si, I_B is the intensity of the Ge peak and I_B^∞ is the intensity from pure Ge.



Results

The concentration of germanium along the central strip of the tree like structure was found to remain fairly constant at ~83 at.% along its length. The AES concentration results closely matched previously collected results from Raman analysis, performed at the University of Southampton. These are shown in Figure 2.

Discussion

The small difference between the AES and the Raman can be attributed to the difficulty in extracting the Si peak intensity from the high resolution spectra at high Ge compositions because the signal is close to the noise floor. This method of quantification using a matrix factor is typically assigned a error of between 5-15% [3].

Because AES and Raman have slightly different depths of analysis, <10 nm and ~100 nm respectively, the top 200 nm of SiGe was removed to analyse the middle region of the device. There was no distribution in composition with depth, as expected since the epitaxial growth front propagates laterally and not vertically [1].

Conclusions

The results obtained from this work illustrate the accurate quantification of the silicon and germanium concentrations within a microelectronic device using AES. Commercially available standards were studied in order to determine a matrix factor to improve the accuracy of the quantification.

The results from this work have contributed to the publication "Next Generation Device Grade Silicon-Germanium on Insulator" in *Scientific Reports*, currently in press. The calibration spectra from this work have also been submitted to the archival journal *Surface Science Spectra*.

Acknowledgments

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References

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- [2] D. Briggs, M. P. Seah, *Practical Surface Analysis*, 2nd ed., vol. 1, John Wiley and Sons, Chichester 1990, p. 201-255.
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Analysis of the device

By combining the matrix factor with the intensities measured from the standard alloys and the intensity from each point along the device, a concentration of silicon and germanium was calculated. These concentrations are shown in the table inset on Figure 1. Si *KLL* and Ge *LMM* Auger transitions from point 1 and point 8 of the device are shown below to highlight the spectral consistency in the results.

Figure 1 Next generation device grade silicon-germanium on insulator

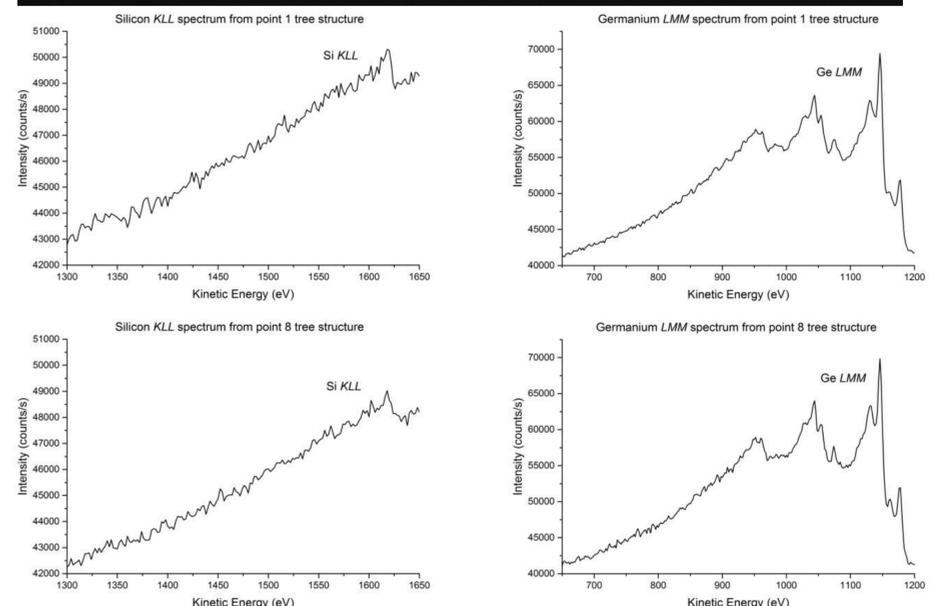
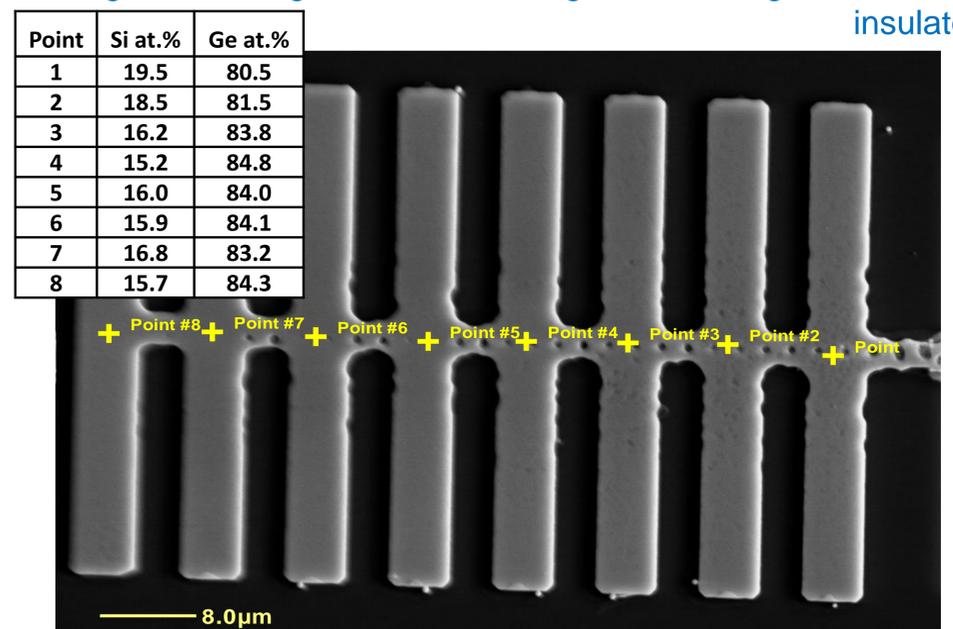


Figure 2 Relationship between AES and Raman results

