Quantification of Ge and B in SiGe using Secondary Ion Mass Spectrometry

H.-Ulrich Ehrke, Hans Maul

FEI Company, Bruckmannring 40, Oberschleissheim, Munich, D-85764, Germany
Phone: +49 (0) 89 3158 91-33 e-mail: uehrke@de.feico.com

1. Introduction

This paper reports on routine SIMS applications in SiGe EPI process control. Subjects, among others, are quantitative Ge and B co-dopant depth profiles because of their correlation to the bipolar performance figures such as Ft (cut-off frequency), F_{max} (maximum oscillation frequency at unity gain) and BVceo (collector-emitter break down voltage) [1].

2. SIMS analysis of SiGe with low energy normal incidence oxygen beam

The quantitative Ge and B depth profiling can be done best with a beam of low energy oxygen primary ions at normal incidence. [2]. These conditions are superior for high depth resolution profiling of the B co-doping. Easy quantification of boron is supported, because the RSF (Relative Sensitivity Factor) is independent of the Ge concentration. In addition, under these conditions the Ge concentration is directly proportional to the Ge secondary ion intensity over the entire concentration range of interest. No Ge concentration dependent calibration factors need to be applied to convert the measured Ge intensity to Ge fraction %, as is required when using Cs primary ions. According to the above it is sufficient for the concentration calibration to determine the amount of Ge at a single point of the depth profile. This is usually done at the top of the profile (Ge-plateau). Typically a RSF generated from a single concentration Ge standard by ratioing the Ge signal to the bulk Si signal for concentration calibration is used.

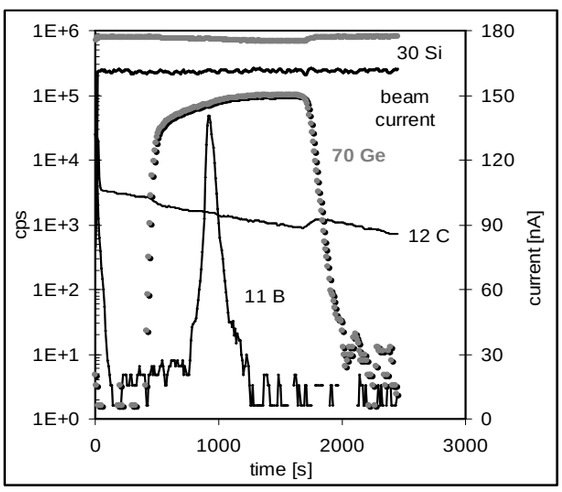

Fig. 2 The primary ion beam current on the sample was monitored simultaneously during depth profiling. It's stability proves excellent charge compensation.

3. Application in routine measurements

Process control data of both blank and patterned B doped SiGe wafers are presented in table I. LP-CVD (low pressure chemical vapour deposition) has been used to grow the SiGe EPI on Si substrates. The layer structure consists of a near 12% SiGe layer deposited on the Si substrate, followed by a B doped, graded SiGe layer topped by a B doped Si cap. The wafers were analysed using an FEI - Atomika SIMS 4500, installed at TSMC using a 1keV oxygen beam at normal incidence.

The results in table I show that in this process control application the Ge concentration is measured with a precision of better than 0.5% atom. The repeatability of the B peak concentration is better than 5%. The B peak depth position precision is 0.2 nm.

It is fair to conclude that SIMS, especially SIMS with normal incidence oxygen low energy primary ion beam in combination with OCE can reliably monitor an important step in the SiGe production process.

Table I shows the process stability of Ge plateau concentration, B peak concentration and B peak depth position, respectively. Note: RSD includes RSD of sample composition and RSD of measurement.

same day relative Ge concentration		day to day relative Ge conc.	day to day relative B conc.	day to day B-peak position
test 1	test 2	(plateau)	(peak)	[arbu]
96.65%	97.03%	95.5%	105.2%	14.31
101.35%		95.5%	102.4%	14.07
101.35%		91.0%	102.4%	14.17
101.35%		96.6%	95.8%	14.17
101.35%	97.03%	102.1%	102.4%	14.17
101.35%		102.1%	102.4%	14.17
101.35%		102.1%	102.4%	14.17
102.57%		102.1%	102.4%	14.17
102.57%	102.97%	108.8%	99.1%	14.17
101.35%		102.1%	89.6%	14.17
96.65%		102.1%	95.8%	14.17
101.35%				
101.35%	102.97%			
101.35%				
94.78%				
94.78%				
RSD 2.75%		RSD 4.87%	RSD 4.55%	RSD 0.38%

Summary

SiGe quantification is a routine task for SIMS analysis. Normal incidence sputtering with Oxygen offers in combination with OCE a reliable, stable and precise protocol for the measurement of absolute Ge and B concentration in ultra thin layers of strained silicon.

Main advantages in contrast to Cs primary ions are better depth resolution and Ge-concentration independent RSF`s for B and Ge, which allows quantification for a wide range of Ge-concentration from a single reference standard.

Acknowledgements

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References

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[2] M.Dowsett et al., Proceed. SIMS XIII, Applied Surface Science 203-204 (2003) 500

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