Chapter 1 - Introduction

1.1 Demands of the technology.

Secondary Ion Mass Spectrometry is a highly sensitive technique for the surface compositional analysis of many materials. Thanks to recent instrumentation developments, ultra low primary beam energies can now be routinely used to analyse materials with sharp features in the matrix. However, modern semiconductors often have high analyte concentrations in the top few nms of the surface. Even for beams with primary energies as low as 250eV (125eV per O^+), a transient region exists in the top 1 nm at the start of the SIMS profile. Ion yields and erosion rates have not yet stabilised in this region, and this means that quantification in the top few nms of a SIMS profile is incredibly difficult, if not impossible. In addition, non-dilute concentrations also cause changes in the erosion rates and ion yields, meaning that the depth eroded is not proportional to time or ion dose. As high concentrations are often present in modern semiconducting materials, the effects due to this will also need to be considered.

Furthermore, at the ultra low primary beam energies used in this work, the collision cascade and the processes leading to the emission of secondary ions may well be different to that of the medium to high primary ion beam energies (> 5 keV) with consequences both for analysis and instrumental design.

1.2 Thesis overview.

The thesis begins with an overview of current and past research into the lattice defects resulting from ion implantation, and their effect on the final distribution of the dopants within the material. Knowledge of the internal structure of implanted

material can be obtained by modelling the lattice and through experimental surface analytical techniques.

These techniques are reviewed in Chapter 2 and their comparative strengths and weaknesses are discussed. Chapter 3 focuses on the main technique used in this thesis; Secondary Ion Mass Spectrometry (SIMS). The instrumentation is described and the processes leading to the emission of sputtered particles are detailed. Recent advances in the field are discussed, for example, the use of ultra low energy primary beams.

Profiling with ultra low energy primary ion beams will result in less energy being available for atomic mixing processes and therefore, also reduce the energy available for the emitted secondary ions. This may have implications both for the analysis of materials, and instrument design. Furthermore, as the number of collisions which result in the emission of a secondary ion is lowered, the energy spectrum may exhibit sample composition related structure as the energy of each momentum transfer would contribute a component. This is investigated in Chapter 4.

The analysis of ultra shallow high dose arsenic implants is detailed chapter 5. When measuring arsenic implanted into a silicon matrix, the single isotope of arsenic at mass 75 suffers a mass interference from Si_2O. When profiling with O_2^+ or in the presence of a surface oxide, the molecular ion is detected and contributes to the mass 75 response. This can reduce the dynamic range or possibly distort the depth profile. With a primary beam of Cs^+, there are several masses which can be monitored to track the arsenic distribution; the mass corresponding to the atomic ion, ^{75}As or molecular ions, for example, $^{103}AsSi$, and ^{91}AsO. The choice of a molecular ion

would depend on the matrix composition. A difference in the near surface shape of the atomic and molecular response is observed, the cause of this is investigated in Chapter 5. Comments are also made about the distribution of dopants.

Similarly, chapter 6 analyses ultra shallow high dose boron implants. In addition to discussing various diffusion mechanisms and investigating the presence of clustering to explain the boron distribution, this chapter also identifies the sources of inaccuracies in the SIMS depth profile arising from the chemistry of the analyte.

The work in chapter 7 continues from chapter 6, and describes techniques used to locate and quantify the thin high concentration sharp boron distribution near the surface of processed high dose boron implants. An implant with an apparent near surface concentration of > 50 % B was capped and the wafer was used to investigate the transient and self-induced matrix effects on the ion yields and erosion rates. It was found that boron enhances its own ionisation probability when present at very high concentrations. XPS and MEIS were used to complement the SIMS data, and identify the relative positions of the boron high concentration spike and the surface impurities. These data enabled the location of the boron spike to be identified with greater accuracy.