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A-3-3 Some Applications of Ion Microprobe Analysis to Problems in Semiconductor Devices

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There are some analytical problems which have persisted in semiconductor device manufacture, i.e. detection and identification of impurities and measurement of diffusion conditions. Although ion microprobe analysis has several advantages in analyzing solids, these problems require still higher performances. This work was carried out to determinate analytical conditions needed to improve detection sensitivity and accuracy as well as to develop stable and accurate in-depth analysis for semiconductor wafers and devices.

Oxygen gas is introduced into the sample chamber to improve secondary particle ionization efficiency. Figure 1 shows the intensities of principal secondary ions from silicon wafers as a function of oxygen pressure. The current of secondary Si^+, B^+, P^+, As^+ and Sb^+ ions increase with oxygen pressure in the range of 10^{-7}-10^{-5} Torr, but reach plateaus at 10^{-5}-10^{-4} Torr whose values are 5-50 times greater than at 10^{-7} Torr. When O_2^+ is used as the primary ion in place of Ar^+, intensity variations of the secondary ion under oxygen pressure in the sample chamber are almost the same as in Fig.1. The introduction of various organic and inorganic gases in place of oxygen were also tried. The result was that the mass spectra became more complicated because of the superposition of spectra from the sample with those from the introduced vapors.

Several other attemps were made to sensitivity and accuracy. The experiments proved that increasing the extracting voltage of secondary ions and setting the impinging angle of the primary ion to the sample surface at 30°-60° were very useful in increasing secondary ion intensity. Consequently, the sensitivity of the ion microprobe analyzer became 10^2-10^4 times greater than usual.

In addition, adopting an electrostatic sector to remove scattered particles decreases the background noise and appropriate selection of the energy of secondary ions increases reproducibility. Furthermore, the improvement of the high speed ion beam scanning method by combining a mask method permitted more accurate in-depth analysis and a reduction in measurement time.

Figure 2 shows in-depth profile of impurities in silicon. The dopant is As of 2.7×10^{17} atoms/cm^3 in the epitaxial layer and 2.2×10^{19} in the substrate. The As^+ ion current is constant through both regions. The ratio of the As^+ ion current in the substrate to that in the epitaxial layer is about 90. This closely agrees with the atomic concentration ratio. Though impurities Ni, Na, K and Cu

are observed near the surface, they are not detected at the interface.

Figure 3 shows calibration curves of impurities Sb, As, P and B doped silicon. These impurities can be mass-analyzed quantitatively and the species of the impurities have different sensitivities because of the difference in secondary ion yields and in background ions. The boron calibration curve shows 50-100 times higher sensitivity than that given by Croset[1] and Colby[2].

In the semiconductor field microanalysis in micron order is essential. Figure 4 shows minimum detectable concentrations of the impurities versus the beam diameter squared. In the case of the 10 μm diameter it is 2 x 10^{16} atoms/cm^3 which should prove useful in semiconductor field.

References
1) M. Croset, Revue Thomson-CSF 3 (1971) 19
2) J. W. Colby, Proc. 8th Natl. Conf. Microprobe Analy., California (1973) 6A

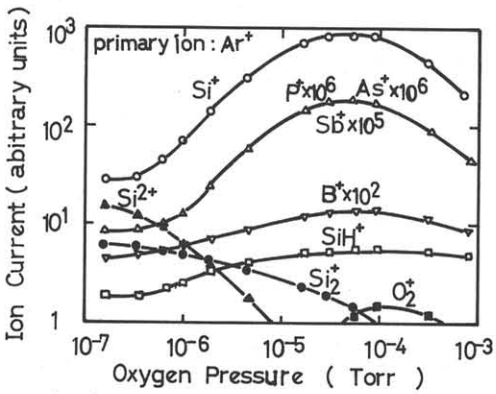

Fig.1 Secondary ion currents as a function of oxygen pressure

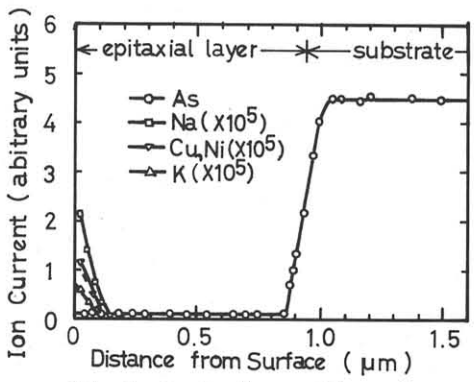

Fig.2 In-depth profiles of impurities in silicon

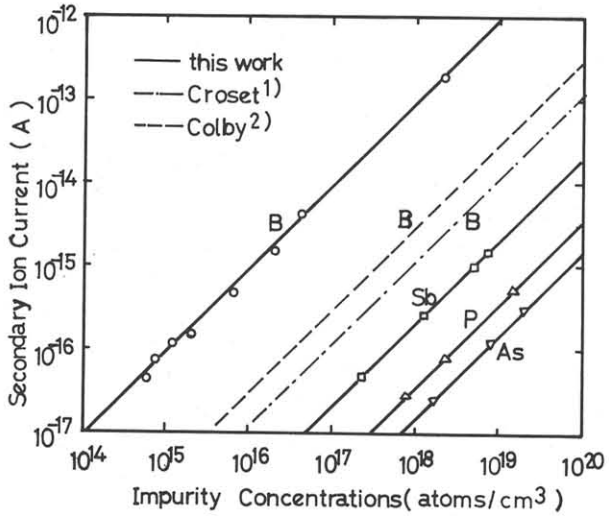

Fig.3 Calibration curves of impurities in silicon

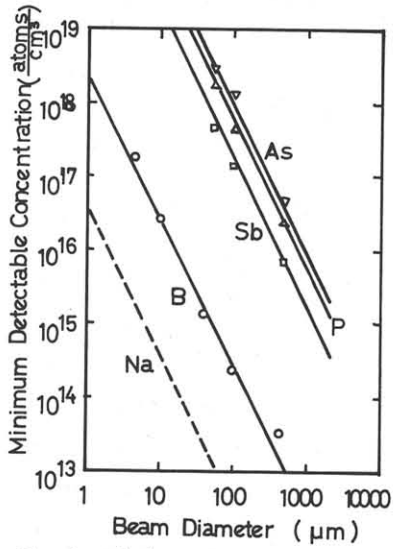

Fig.4 Minimum detectable concentrations versus ion beam diameter