Nano Secondary Ion Mass Spectrometry : A New Approach to the Analysis of Nano Materials

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1. Introduction

Many of the complex materials developed today derive their unique properties from the presence of multiple phases or from local variations in elemental concentration. Simply performing analysis of the bulk materials is not sufficient to achieve a true understanding of their physical and chemical natures. In the last few years, there have seen a tremendous outburst of interest in surface studies [1].

Secondary ion mass spectrometer (SIMS) has met with a great deal of success in materials characterization. The basis of SIMS is the use of a focused ion beam to erode sample atoms from the selected region. The atoms undergo a charge exchange with their local environment, resulting in their conversion to positive and negative secondary ions. The mass spectrometric analysis of these secondary ions results in a method capable of elemental specificity from hydrogen to uranium with detectabilities in the parts per million (ppm) or parts per billion (ppb) atomic range. Extreme sensitivity and excellent depth resolution of SIMS make it ideally suitable for examining dopant profiles in semiconductors [2]. Nano secondary ion mass spectrometer (nano-SIMS, Cameca nano-SIMS 50) equipped with the reactive ion such as a cesium gun and duoplasmatron gun has a spatial resolution of 50 nm which is much smaller than other dynamic SIMS [3]. Therefore, nano-SIMS is used to analyze the spatial distribution of elements on the surface of various materials. Based on the above fact, the present study has developed a new method for the depth profiling of phosphorus implanted silicon by using the nano-SIMS in small area less than 10 μm x 10 μm.

2. Experiment

The samples used for depth profiling were Czochralskigrown (001) silicon (Si) wafers implanted with phosphorus at an energy of 80keV and a dose of 5x 10^{13}atoms/cm^2. The Si wafers were chemically cleaned before implantation to remove native oxide and organic contaminants. Nano-SIMS analysis was done with sample mounted in the ring with wood metal. Nano-SIMS has a distinctive feature of normal incident primary ions on the sample surface. Due to the co-axial configuration of primary and secondary ion paths, the working distance of the probe forming lens and extraction is short than other conventional SIMS.

It allows the nano-SIMS to have smaller spot size for a given current: lateral resolution down to 50 nm for Cs+ primary ions. It also increases secondary ion collection efficiency.

The experiments were carried with a nano-SIMS : the cesium primary ion beam of diameter 100 nm, impact energy of 16.0 keV, and primary ion beam current of 1 pA with high mass resolution technique. Two electron multipliers were used for the parallel detection of ^{30}Si and ^{31}P. The mass resolving power was set to be ~5000.

3. Result and Discussion

A depth profiling of the nano-SIMS is compared with that of IMS 6f SIMS. In order to clarify the

comparison, we selected the analysis conditions of IMS 6f SIMS that used to remove the sidewall effect perfectly and to get a good detection sensitivity. The depth resolution of the profile taken with IMS6f is similar to that taken by using the nano-SIMS. Detection sensitivity decreases as the analytical area and the rate of volume sampling are reduced. However, the depth resolution and detection limit of nano-SIMS are superior and efficient enough even though small area is used for depth profiling. The improved signal-to-noise ratio and detection sensitivity of nano-SIMS having high collection efficiency makes it well suited to small area depth profiling applications.

4. Conclusion

The performance on a small area depth profiling of nano-SIMS has been demonstrated on phosphorus implanted silicon wafers. Phosphorus implant characterization for total dose generally requires a high mass resolution which is a key feature of magnetic sector mass spectrometers such as nano-SIMS. Superior depth resolution and detection limits in comparison with IMS6f SIMS are observed on small areas as small as 10μm on a side. We expect that the established method of depth profiling involving nano-SIMS in this work will provide novel technique in evaluating the dopant distributions on the small pattern sample.

5. References

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